Peerapas Thongsawas

Carbon footprint and circular economy potential of furniture in a newly built neighborhood

Master's thesis in Industrial Ecology
Supervisor: Johan Berg Pettersen
Co-supervisor: Kamila Krych
June 2022

Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Engineering
Department of Energy and Process Engineering

NTNU
Norwegian University of Science and Technology

Peerapas Thongsawas

Carbon footprint and circular economy potential of furniture in a newly built neighborhood

Master's thesis in Industrial Ecology
Supervisor: Johan Berg Pettersen
Co-supervisor: Kamila Krych
June 2022

Norwegian University of Science and Technology
Faculty of Engineering
Department of Energy and Process Engineering

NTNU
Kunnskap for en bedre verden

Masteravtale/hovedoppgaveavtale

Sist oppdatert 11. november 2020

Fakultet	**Fakultet for ingeniørvitenskap**
Institutt	**Institutt for energi- og prosessteknikk**
Studieprogram	**MSINDECOL**
Emnekode	**TEP4930**

Studenten

Etternavn, fornavn	**Thongsawas, Peerapas**
Fødselsdato	**30.05.1990**
E-postadresse ved NTNU	**peerapat@stud.ntnu.no**

Tilknyttede ressurser

Veileder	**Johan Berg Pettersen**
Eventuelle medveiledere	**Kamila Krych**
Eventuelle medstudenter	

Oppgaven

Oppstartsdato	**10.01.2022**
Leveringsfrist	**10.06.2022**
Oppgavens arbeidstittel	**A scenario analysis of furniture in Trondheim**
Problembeskrivelse	**The master thesis is built on the fall project "Furniture consumption pattern of households in Trondheim", where a material flow analysis (MFA) was created to map the stocks and flows of furniture in Trondheim. Based on the MFA, an environmental impact assessment will be conducted for the current scenario. In addition, an alternative scenario which promotes circular economy will be selected and analyzed for an environmental impact. The two scenarios will be compared to illustrate the benefits and drawbacks of a circular-economy model of furniture.**

Risikovurdering og datahåndtering	
Skal det gjennomføres risikovurdering? **Dersom «ja», har det blitt gjennomført?**	**Nei** **Nei**
Skal det søkes om godkjenninger? (REK*, NSD)**	**Nei**
Skal det skrives en konfidensialitetsavtale i forbindelse med oppgaven? **Hvis «ja», har det blitt gjort?**	**Nei** **Nei**

* Regionale komiteer for medisinsk og helsefaglig forskningsetikk (https://rekportalen.no)

** Norsk senter for forskningsdata (https://nsd.no/)

Eventuelle emner som skal inngå i mastergraden

Retningslinjer - rettigheter og plikter

Formål

Avtale om veiledning av masteroppgaven/hovedoppgaven er en samarbeidsavtale mellom student, veileder og institutt. Avtalen regulerer veiledningsforholdet, omfang, art og ansvarsfordeling.

Studieprogrammet og arbeidet med oppgaven er regulert av Universitets- og høgskoleloven, NTNUs studieforskrift og gjeldende studieplan. Informasjon om emnet, som oppgaven inngår i, finner du i emnebeskrivelsen.

Veiledning

Studenten har ansvar for å

- Avtale veiledningstimer med veileder innenfor rammene master-/hovedoppgaveavtalen gir.
- Utarbeide framdriftsplan for arbeidet i samråd med veileder, inkludert veiledningsplan.
- Holde oversikt over antall brukte veiledningstimer sammen med veileder.
- Gi veileder nødvendig skriftlig materiale i rimelig tid før veiledning.
- Holde instituttet og veileder orientert om eventuelle forsinkelser.
- Inkludere eventuell(e) medstudent(er) i avtalen.

Veileder har ansvar for å

- Avklare forventninger om veiledningsforholdet.
- Sørge for at det søkes om eventuelle nødvendige godkjenninger (etikk, personvernhensyn).
- Gi råd om formulering og avgrensning av tema og problemstilling, slik at arbeidet er gjennomførbart innenfor normert eller avtalt studietid.
- Drøfte og vurdere hypoteser og metoder.
- Gi råd vedrørende faglitteratur, kildemateriale, datagrunnlag, dokumentasjon og eventuelt ressursbehov.
- Drøfte framstillingsform (eksempelvis disposisjon og språklig form).
- Drøfte resultater og tolkninger.
- Holde seg orientert om progresjonen i studentens arbeid i henhold til avtalt tids- og arbeidsplan, og følge opp studenten ved behov.
- Sammen med studenten holde oversikt over antall brukte veiledningstimer.

Instituttet har ansvar for å

- Sørge for at avtalen blir inngått.
- Finne og oppnevne veileder(e).
- Inngå avtale med annet institutt/ fakultet/institusjon dersom det er oppnevnt ekstern medveileder.
- I samarbeid med veileder holde oversikt over studentens framdrift, antall brukte veiledningstimer, og følge opp dersom studenten er forsinket i henhold til avtalen.
- Oppnevne ny veileder og sørge for inngåelse av ny avtale dersom:
  - Veileder blir fraværende på grunn av eksempelvis forskningstermin, sykdom, eller reiser.
  - Student eller veileder ber om å få avslutte avtalen fordi en av partene ikke følger den.
  - Andre forhold gjør at partene finner det hensiktsmessig med ny veileder.
- Gi studenten beskjed når veiledningsforholdet opphører.
- Informere veileder(e) om ansvaret for å ivareta forskningsetiske forhold, personvernhensyn og veiledningsetiske forhold.
- Ønsker student, eller veileder, å bli løst fra avtalen må det søkes til instituttet. Instituttet må i et slikt tilfelle oppnevne ny veileder.

Avtaleskjemaet skal godkjennes når retningslinjene er gjennomgått.

Godkjent av

Peerapas Thongsawas
Student

15.01.2022
Digitalt godkjent

Johan Berg Pettersen
Veileder

27.01.2022
Digitalt godkjent

Anita Yttersian
Institutt

01.02.2022
Digitalt godkjent

Master`s Agreement / Main Thesis Agreement

Faculty	Faculty of Engineering
Institute	Department of Energy and Process Engineering
Programme Code	MSINDECOL
Course Code	TEP4930

Personal Information

Surname, First Name	Thongsawas, Peerapas
Date of Birth	30.05.1990
Email	peerapat@stud.ntnu.no

Supervision and Co-authors

Supervisor	Johan Berg Pettersen
Co-supervisors (if applicable)	Kamila Krych
Co-authors (if applicable)	

The Master`s thesis

Starting Date	10.01.2022
Submission Deadline	10.06.2022
Thesis Working Title	A scenario analysis of furniture in Trondheim
Problem Description	The master thesis is built on the fall project "Furniture consumption pattern of households in Trondheim", where a material flow analysis (MFA) was created to map the stocks and flows of furniture in Trondheim. Based on the MFA, an environmental impact assessment will be conducted for the current scenario. In addition, an alternative scenario which promotes circular economy will be selected and analyzed for an environmental impact. The two scenarios will be compared to illustrate the benefits and drawbacks of a circular-economy model of furniture.

Risk Assessment and Data Management

Will you conduct a Risk Assessment? **If "Yes", Is the Risk Assessment Conducted?**	**No** **No**
Will you Apply for Data Management? **(REK*, NSD**)**	**No**
Will You Write a Confidentiality Agreement? **If "Yes", Is the Confidentiality Agreement Conducted?**	**No** **No**

*   REK -- https://rekportalen.no/

** Norwegian Centre for Research Data (https://nsd.no/nsd/english/index.html)

Topics to be included in the Master`s Degree (if applicable)

Guidelines – Rights and Obligations

Purpose

The Master's Agreement/ Main Thesis Agreement is an agreement between the student, supervisor, and department. The agreement regulates supervision conditions, scope, nature, and responsibilities concerning the thesis.

The study programme and the thesis are regulated by the Universities and University Colleges Act, NTNU's study regulations, and the current curriculum for the study programme.

Supervision

The student is responsible for

- Arranging the supervision within the framework provided by the agreement.
- Preparing a plan of progress in cooperation with the supervisor, including a supervision schedule.
- Keeping track of the counselling hours.
- Providing the supervisor with the necessary written material in a timely manner before the supervision.
- Keeping the institute and supervisor informed of any delays.
- Adding fellow student(s) to the agreement, if the thesis has more than one author.

The supervisor is responsible for

- Clarifying expectations and how the supervision should take place.
- Ensuring that any necessary approvals are acquired (REC, ethics, privacy).
- Advising on the demarcation of the topic and the thesis statement to ensure that the work is feasible within agreed upon time frame.
- Discussing and evaluating hypotheses and methods.
- Advising on literature, source material, data, documentation, and resource requirements.
- Discussing the layout of the thesis with the student (disposition, linguistic form, etcetera).
- Discussing the results and the interpretation of them.
- Staying informed about the work progress and assist the student if necessary.
- Together with the student, keeping track of supervision hours spent.

The institute is responsible for

- Ensuring that the agreement is entered into.
- Find and appoint supervisor(s).
- Enter into an agreement with another department / faculty / institution if there is an external co-supervisor.
- In cooperation with the supervisor, keep an overview of the student's progress, the number of supervision hours. spent, and assist if the student is delayed by appointment.
- Appoint a new supervisor and arrange for a new agreement if:
  - The supervisor will be absent due to research term, illness, travel, etcetera.
  - The student or supervisor requests to terminate the agreement due to lack of adherence from either party.
  - Other circumstances where it is appropriate with a new supervisor.
- Notify the student when the agreement terminates.
- Inform supervisors about the responsibility for safeguarding ethical issues, privacy and guidance ethics
- Should the cooperation between student and supervisor become problematic, either party may apply to the department to be freed from the agreement. In such occurrence, the department must appoint a new supervisor

This Master`s agreement must be signed when the guidelines have been reviewed.

Signatures

Peerapas Thongsawas
Student

15.01.2022
Digitally approved

Johan Berg Pettersen
Supervisor

27.01.2022
Digitally approved

Anita Yttersian
Department

01.02.2022
Digitally approved

Abstract

Material Flow Analysis (MFA) and Life Cycle Analysis (LCA) are used to study the flows of furniture and the associated carbon footprint in a neighborhood with 1,340 inhabitants. The neighborhood has a furniture stock of 961.68 tons, inflows of 52.13 tons, outflows of 47.21 tons, used furniture of 59.79 tons; and a carbon footprint of 217.18 tons CO_2-eq. Two scenarios are created to study the potential for the circular economy of furniture. In the Second-hand scenario, furniture inflows are reduced to 24.8 tons, outflows to 19.89 tons; used furniture is increased to 80.53 tons, and the carbon footprint is reduced to 134.22 tons. In the Lifetime Extension scenario, furniture inflows are reduced to 19 tons, outflows to 14.09 tons; used furniture is increased to 85.93 tons, and the carbon footprint is reduced to 115.11 tons. To maximize the potential of reducing the carbon footprint of furniture, it is recommended that furniture with high carbon density – chairs and tables – is reused, and furniture with low carbon density – beds, sofas, and storages – is repaired. When compared to other emissions in the neighborhood, furniture constitutes approximately 3% of the total emissions, or 7% when compared to construction materials. Thus, it is recommended that policymakers prioritize reducing the carbon footprint of construction materials, mobility, and energy before furniture.

Acknowledgment

I would like to thank Johan Berg Pettersen, an associate professor of Industrial Ecology at Norwegian University of Science and Technology (NTNU), for supervising this study. His guidance had helped shape the direction of the study and his feedback had helped improve the modeling work done. His supervision had been invaluable from the beginning of this study. I would also like to thank Kamila Krych, a Ph.D. candidate in the Industrial Ecology program at NTNU, for co-supervising the study. Her knowledge and expertise in the furniture and household durables had been crucial. Her guidance had played a central role in the study. I want to thank Kim Rainer Mattson for providing insight into the waste industry. His expertise had helped with mapping the end of life of furniture in Norway. Finally, I would like to express my gratitude to friends who had been encouraging and supporting me throughout my study. Without them, the study wouldn't have been completed.

With deep gratitude,

Peerapas Thongsawas

Table of Contents

List of Tables

List of Figures

Introduction

As a highly developed country, it is to be expected that Norway has a high level of consumption. Research has shown that there is a correlation between gross domestic product (GDP) and households' consumption level (Liu et al., 2020; Zhang et al., 2017; Zhang et al., 2018). Statistics Norway reported that Norway has the second-highest consumption per capita in Europe, which is 27% higher than the European average (SSB, 2020). Among categories of household consumption, furniture is ranked the 7th highest expenditure of households (SSB, 2018). In 2018, Norwegian households together spent a total of 83 billion kroner on furniture, which is equivalent to 15,700 kroner per person. This is a 55% increase compared to the year 2000 (SSB, 2018). Because of the high spending, it is not surprising that Norwegian households have a high carbon footprint. Steen-Olsen et al. (2016) found that an average Norwegian household has a carbon footprint of 22,170 kgCO_2-eq per year. Of which, 1,280 kgCO_2-eq is from furniture.

The latest data shows Norway has a total Green House Gas (GHG) emissions of 49 MtCO_2-eq in 2020 (Norske Utslipp, 2021). With current policies, the emissions are projected to be reduced to 44-45 MtCO_2-eq in 2030, which is equivalent to 13-15% below the 1990 emissions level (Climate Action Tracker, 2021). This is far from the pledge the Norwegian government made to the UN, to reduce GHG emissions by 55% by 2030 (Klima- og miljødepartementet, 2021a). At the current trajectory, it is expected that emissions from Norway will contribute to a 3°C world instead of the targeted 2°C world (Climate Action Tracker, 2021).

In terms of circular economy, The Circularity Gap Report found that Norway is 2.4% circular, meaning, each year, 235 million tons of materials flow through the economy without being reused or recycled (Circular Norway, 2020; Klima- og miljødepartementet, 2021b). In a global context, Norway's circularity level is lower than the 8.6% global average (CGRi, 2020). To keep the global temperature within 2°C, the report stated that the level of circularity needs to be increased to a minimum of 17% by 2030, which will lead to 22.8 billion tons or 39% of GHG emissions reduction (CGRi, 2020).

To meet the challenges of both climate change and circular economy, the Norwegian government had proposed two national strategies: Climate Plan for 2021-2030 and National Strategy for a Green Circular Economy (Klima- og miljødepartementet, 2021b; Regheringen, 2021). The Climate Plan layouts initiatives to reduce GHG emissions in several sectors, including the building and construction sector. The government plans to reduce GHG emissions in this sector by 20%, which is equivalent to 10 million tonCO_2-eq by 2030. This is planned to be achieved by reducing fossil fuels in construction processes, increasing the efficiency of material uses and transport, and reducing construction wastes. Furniture, despite being part of every building, is not considered in the plan. This is because the current GHG emissions calculation of buildings does not include non-fixed furniture in the scope of calculation (Standard Norge, 2011, 2018); thus, overlooking the potential to further reduce GHG emissions in buildings. In terms of circular economy, furniture is listed as one of the areas of transition (Regheringen, 2021). The government plans to increase the degree of furniture circularity by creating policies to reduce the purchase of new furniture, reduce the import of furniture, encourage reparation to increase furniture lifetime, and explore alternative business models such as furniture rental (SINTEF, 2020).

The goal of this thesis is to study how furniture can play a role in Norway's climate change mitigation and circular economy transition. Material flow analysis (MFA) and Lifecycle Analysis (LCA) are used as tools to carry out the study. MFA is used to calculate the amount of furniture flows while LCA is used to calculate the carbon footprint associated with the flows. This thesis is built upon the study done by Thongsawas (2021), where an MFA of furniture consumption of households in Trondheim was created based on a consumer survey. The scope of this thesis is set to a neighborhood level to fill the existing research gap. So far, Krych and Pettersen (2021b) had used dynamic MFA to create a consumption model of household durables – including furniture – at the national level; while Lauvland (2020) had used LCA to calculate the carbon footprint of furniture at a building level. To the author's knowledge, there is no study on furniture flows and the carbon footprint of furniture at a neighborhood level in Norway.

The following three research questions are asked in this study:

1. What are the material flows of furniture in a newly built neighborhood in 2021?
2. What is the carbon footprint of furniture in the neighborhood?
3. What are the potentials for circular economy in terms of material flows and carbon footprint?

To answer these research questions, a hypothetical neighborhood in Trondheim with the same characteristic as the Zero Village Bergen is used as a reference neighborhood. It is assumed that this neighborhood is newly built, and residents have just moved in. This assumption is made to accurately represent the characteristic of survey participants from Thongsawas (2021).

In this study, the first research question is answered by creating an MFA of furniture in a newly built neighborhood based on the municipal-level MFA and survey data from Thongsawas (2021). The second research question is answered by creating an LCA model based on the new furniture MFA. Finally, the third research question is answered by designing two circular economy scenarios and repeating the processes of creating MFA and LCA models for the new scenarios.

Literature Review

This section outlines the literature review conducted for this study. The literature can be divided into five categories, arranged in the same order as the work done in this study. The categories are as follows.

- Literature related to furniture
- Literature related to MFA of durables
- Literature related to LCA of furniture and neighborhood
- Literature that combines MFA with LCA
- Literature related to circular economy and household consumption

The literature review is presented in a table format with the following information: author, title of the study, scope of the study, methodology, and result and conclusion.

Summary of literature related to furniture

The literature presented in this section is, for the most part, related to furniture in Norway, both from production and consumption perspectives. However, there is also literature related to furniture from Sweden and UK, which are geographically closed to Norway; thus, share similar supply chain and consumer behavior characteristics. Literature from the production side is qualitative, while literature from the consumption side is quantitative.

Table 1 Summary of literature related to furniture

Author	Tittle	Scope	Methodology	Result and Conclusion
Carlsson Kanyama et al. (2021)	Shifting expenditure on food, holidays, and furnishings could lower greenhouse gas emissions by almost 40%	Calculation of GHG emissions of households in Sweden and potential GHG reduction behaviors.	Input-output analysis	An average person is found to have a consumption-based GHG of 6.9 tons per year, of which 56-59% are from food, holidays, and furniture. Adopting behaviors such as eating a plant-based diet, buying second-hand furniture, and traveling by train can reduce GHG emissions by 36-38%.
Qiu et al. (2017)	Competitiveness and connectivity in design innovation: a study of Norwegian furniture industry	A longitudinal analysis of design innovation in the Norwegian furniture industry.	Network analysis	Between 1976-2015, it was found that design was one of the main factors that drove innovation in the Norwegian furniture industry. However, it was also found that the industry has a 'lock-in' characteristic with little collaboration with other countries.
Steen-Olsen et al. (2016)	The Carbon Footprint of Norwegian Household Consumption 1999–2012	A calculation of the carbon footprint of Norwegian households between 1999-2012.	Input-output analysis	The study found that a Norwegian household has a carbon footprint of 22.3 tons in 2012, which is an increase of 26% compared to 1999. Transport, housing, and food were the main sources of emissions. Furniture accounted for 1.28 tons of CO_2-eq in 2012.
Høgevold (2011)	A corporate effort towards a sustainable business model. A case study from the Norwegian furniture industry	An exploration of a sustainable business model. HÅG, a Norwegian furniture company was used as a case study.	Interview	The study found that it is not only possible but also profitable for businesses to be more sustainable. The key to the transition is to have the support of the upper management. The study also stated that business can have a direct influence on transforming its supply chain. HÅG, as an example, was able to reduce its average emission of chairs to 36-55 $kgCO_2$-eq compared to the industry standard of 100-120 $kgCO_2$-eq.
Michelsen et al. (2006)	Eco-efficiency in extended supply chains: A case study of furniture	A methodology was developed to calculate eco-efficiency in a	Eco-efficiency; Cradle-to-grave, allocation cut-off	Eco-efficiency was used to measure the relative environmental and value performance in an extended supply chain of furniture in Norway.

	production	supply chain. A furniture supply chain in Norway was used as a case study.	LCA	The study concluded that eco-efficiency can be used as a supplementary indicator alongside LCA, especially for procurement purposes.
Leslie and Reimer (2003)	Fashioning Furniture: Restructuring the Furniture Commodity Chain	An exploration of how perception is changing in the furniture industry in the UK and Canada.	Interview	The perception of furniture has been changing from durable goods to fashion products. This is represented in magazines, by retailers, and manufacturers. As a result, the industry is required to restructure its methods of operating to remain competitive.

Summary of literature related to MFA of durables

Due to the limited number of literature related to MFA of furniture, the scope of MFA literature is expanded to include other durables. While the function of furniture is different from other household durables, the household consumption patterns are similar. Therefore, the same MFA methodology can be applied to both furniture and other durables. The studies consist of both dynamic MFA and static MFA, both top-down and bottom-up. The top-down MFA is created by using statistical data while the bottom-down MFA is created by field data such as a survey. Most of the studies were used as a basis to create a bottom-up MFA of furniture in Trondheim in Thongsawas (2021). However, since end-of-life data was missing in Thongsawas (2021), additional studies on the end of life are used as a guideline to combine the bottom-up MFA with top-down statistical data in this study.

Table 2 Summary of literature related to MFA of durables

Author	Tittle	Scope	Methodology	Results and Conclusion
Krych and Pettersen (2021a)	Lifetime of appliances and furniture in Norwegian households.	8 appliances and furniture in Norway between 1900-2100	Dynamic MFA	The amount of durable goods in Norway is expected to saturate around 2025 and remain constant toward 2100. Lifetimes of durable goods decreased by 40-55% between 1960-2000.
Thongsawas (2021)	Furniture consumption pattern of households in Trondheim	29 categories of furniture in Trondheim, Norway in 2021	Bottom-up static MFA	A survey was carried out to investigate furniture stock and flows of Trondheim residents. A static MFA was created based on the survey. The result showed that, in 2021, Trondheim has an in-use furniture stock of 118,175.2 tons; an inflow of 15,720.9 ton/year; and an outflow of 4,561.1 ton/year.
Liu et al. (2020)	Material flows and in-use stocks of durable goods in Chinese urban household sector	43 durable goods in Chinese urban households between 1985-2015	Dynamic MFA	Urban consumption increased 23 times during this period, with 147 tons per household in 2014. Durables had sharp increases followed by saturation in China; most had reached saturated levels.
Mora Sojo (2020)	Norwegian Consumption of Durables: A Model to Analyze Different Circular Economy Strategies	16 types of clothing categories in Norway in 2014	Top-down static MFA	A system definition of clothing in Norway was developed. In 2014, the inflow was 62,424 tons and the outflow was between 50,000-63,000 tons. The stock was between 270,000-1,178,000 tons.
Whetstone et al. (2020)	Informing Sustainable Consumption in Urban Districts: A Method for Transforming Household Expenditures into Physical Quantities	6 consumer product categories in Sweden in 2012	Conversion of monetary data to MFA and LCA data	Four steps were outlined as steps to convert monetary data to MFA and LCA data: data collection, data transformation, consumption pattern, and data outputs.
Ooghe et al. (2019)	WIM project: wood flow analysis in Heyvaert district	Wooden construction materials and furniture in Heyvaet district, Belgium in 2017	Bottom-up static MFA	In 2017, the district had a stock of wooden construction materials of more than 200 tons and an outflow of wooden furniture of more than 10 tons per year.
Schiller et al. (2017)	Mapping the anthropogenic stock in	Economy-wide anthropogenic stocks	Top-down and Bottom-up static	The top-down MFA had an inflow of 664 Mt and an outflow of 109 Mt. The bottom-up MFA

	Germany: Metabolic evidence for a circular economy	and flows of buildings and durable goods in Germany in 2010.	MFAs	had an inflow of 353 Mt and an outflow of 211.1 Mt. The study pointed out that flows are often underestimated in a bottom-up MFA.
Harder et al. (2014)	Quantification of Goods Purchases and Waste Generation at the Level of Individual Households	Household's purchased goods and waste generation in Sweden	Conversion of behavior into MFA data	The study outlined two methods of data collection to quantify households' purchases and waste. The first method is by analyzing purchase receipts and weighing waste. The second method was recordkeeping using a smartphone app.
Eckelman and Chertow (2009)	Using Material Flow Analysis to Illuminate Long-Term Waste Management Solutions in Oahu, Hawaii	9 categories of materials in Oahu, Hawaii in 2008.	Top-down static MFA	An MFA of Oahu was mapped by using data from imports, exports, resource extraction; military; private sector; and waste management in 2008. There is a potential for Oahu to be self-sufficient by using local materials, decreasing materials demand, and enhancing the cycling of materials.
Oguchi et al. (2008)	Product flow analysis of various consumer durables in Japan	94 consumer durables in Japan in 2003	Top-down static MFA	In 2003, Japan had consumer durables inflows of 1,667,000 tons and outflows of 1,691,000 tons. Of these, 11 items accounted for the majority of the flows.

Summary of literature related to LCA of furniture and neighborhood

Several LCA studies were carried out for furniture products, though most were for office furniture. This is because the public sector in several countries requires that purchased products must have an environmental declaration (Lauvland, 2021). The industry standard for documenting environmental impacts is Environmental Product Declaration (EPD). Most studies reviewed follows the EPD standard by using allocation cut-off LCA. However, since EPD is flexible when it comes to documenting environmental impacts at the end of life, many studies use cradle-to-gate LCA, and a few use cradle-to-grave LCA. In addition to the studies about LCA of furniture products, studies of LCA at a neighborhood level are also reviewed and used as a guideline for calculating carbon footprint at a neighborhood level in this study.

Table 3 Summary of literature related to LCA of furniture and neighborhood

Author	Tittle	Scope	Methodology	Result and Conclusion
Lausselet and Brattebø (2021)	Environmental co-benefits and trade-offs of climate mitigation strategies applied to net-zero-emission neighbourhoods	Development of an LCA methodology for climate mitigation strategies for the zero-emission neighborhood. Ydalir, a neighborhood in Elverum, Norway was used as a case study.	Cradle-to-grave, allocation cut-off LCA	Four mitigation strategies were explored: reduction of passenger cars, reduction of dwelling size, increase in the lifetime of cars and buildings, and a combination of strategies. Using one strategy, there was potential to reduce environmental impacts by 5-20%. Combining strategies allows the environmental impacts to be reduced further to 22-42%.
Lauvland (2021)	The Carbon Footprint of Furniture	LCA of office furniture in 6 buildings. Two scenarios were explored: reuse and prolonging lifetime.	Cradle-to-gate, allocation cut-off LCA	Furniture contributed to 4-13% of the total carbon emissions of buildings. Carbon footprint could be reduced by up to 59% by only using reused furniture and by 46% by prolonging the lifetime of all furniture.
Lausselet et al. (2019)	LCA modelling for Zero Emission Neighbourhoods in early stage planning	Development of an LCA methodology for the zero-emission neighborhood. Zero Village Bergen Noway was used as a case study.	Cradle-to-grave for buildings and cradle-to-gate for others, allocation cut-off LCA	Five areas were considered for LCA: buildings, mobility, open spaces, networks, and on-site energy infrastructure. The village had total GHG emissions of 117 kt CO_2-eq over 60 years. 52% of the emissions were from buildings, 40% were from mobility and 2.3% were from networks and open spaces.
Krystofik et al. (2018)	Adaptive remanufacturing for multiple lifecycles: A case	LCA comparison of manufacturing of office furniture using virgin	Cradle, allocation cut-off LCA	By using remanufactured instead of virgin materials, Davies Office could reduce its furniture's environmental impacts by half in

	study in office furniture	materials and remanufactured materials.		most categories and by 5 times in GWP.
Antov and Pancheva (2017)	Carbon footprint of furniture products	LCA of kitchen furniture and office chair in Bulgaria	Cradle-to-grave, ISO/TS 14067:2013, LCA	The result showed that kitchen furniture has carbon footprints between 24-43 kgCO_2-eq and office chairs have carbon footprints between 38-76 kgCO_2-eq. Most of the emissions are from materials, especially metal and wood.
Geyer et al. (2016)	Assessing the Greenhouse Gas Savings Potential of Extended Producer Responsibility for Mattresses and Boxsprings in the United States	LCA of an average mattress in the US and GHG reduction of recycling and reuse schemes.	Cradle-to-grave input-output LCA	An average mattress is found to have a carbon footprint of 108 kgCO_2-eq. Recycling has the potential to reduce GHG emissions by 43%. Reusing has the potential to reduce GHG emissions by 67%; however, there is a hygienic concern among consumers.
Linkosalmi et al. (2016)	Main factors influencing greenhouse gas emissions of wood-based furniture industry in Finland	LCA of 8 pieces of furniture in Finland	Cradle-to-gate LCA	The LCA result showed that materials constituted 38-90% of GHG emissions; processing and assembling 8-58%; and packing and transport 1-8%. The study concluded that the best practice to reduce GHG is by selecting low-emission materials and changing the energy system.
Mirabella et al. (2014)	LCA for assessing environmental benefit of eco-design strategies and forest wood short supply chain: a furniture case study	LCA of eco-design furniture in Northern Italy	Cradle-to-gate LCA	The result showed that most of the environmental impacts were from materials needed for manufacturing. The study concluded that eco-design is an effective means to reduce the environmental impacts of furniture.
Lanoë et al. (2013)	Improving the environmental performance of bedding products by using life cycle assessment at the design stage	LCA of 2 mattresses in Portugal and 2 scenario analyses to reduce environmental impacts	Cradle-to-grave LCA	LCA comparison of polyurethane foam mattress and pocket spring mattress was conducted. The polyurethane foam mattress was found to have lower environmental impacts. Most of the impacts are from the manufacturing process and waste management process. A comparison of two scenario analyses shows that decreasing manufacturing materials leads to lower environmental impacts than using recycling materials for manufacturing.
Fet et al. (2008)	Product category rules and environmental product declarations as tools to promote sustainable products: experiences from a case study of furniture production	Development of a simplified environmental impacts database based on LCA to be used for Environmental Product Declaration. Furniture was used as a case study.	Cradle-to-grave, allocation cut-off LCA	LCI was simplified and translated into an Excel file for ease of use. The Excel template accounted for 90% of LCA's environmental impacts in five categories: OPD, EP, GWP, AP, and POCP. 50 furniture EPD were created based on this methodology.
Spitzley et al. (2006)	Life-Cycle Assessment of Office Furniture Products	LCA of a chair and two desks from Steelcase, a company in the US	Cradle-to-grave LCA	The study showed LCA results of a chair and two desks from Steel Case in six impact categories. The study concluded that most of the environmental impacts were from materials and waste handling.

Summary of literature that combines MFA with LCA

To answer the research questions in this study, it is crucial to combine MFA with LCA. Literature that combines both methodologies is used as a guideline in this study. Only two studies were found that are specific to furniture. As a result, literature related to durables, waste management, and neighborhood is also considered. The combination of MFA and LCA among the studies varies depending on the scope of the projects; however, they can be categorized into four types: dynamic MFA & cradle-to-gate LCA, dynamic MFA & cradle-to-grave LCA, static MFA & cradle-to-gate LCA, and static MFA & cradle-to-grave LCA. Only one literature combines static MFA with cradle-to-grave LCA, which is the same methodology as this study.

Table 4 Summary of literature that combines MFA with LCA

Author	Tittle	Scope	Methodology	Result and Conclusion
Wiprächtiger et al. (2022)	An approach to the environmental assessment of waste prevention and its application to clothing and furniture in Switzerland	MFA and LCA of clothing in 2018 and furniture in 2017 in Switzerland. Six circular economy scenarios and the rebound effects were explored.	Dynamic MFA; Cradle-to-grave, allocation cut-off LCA	Two MFAs were created for clothing and furniture in Switzerland and environmental impacts were studied. Among the six circular economy scenarios explored – reuse, refuse, share, sufficiency, repair, and refurbish – sufficiency and refurbish were most effective at reducing environmental impacts for clothing (15%) and furniture (70%) respectively. Note that the rebound effect was considered in the environmental impacts.
Glöser - Chahoud et al. (2021)	The link between product service lifetime and GHG emissions	MFA and LCA of refrigerators and mobile phones in Europe	Dynamic MFA with system dynamics approach; LCI integration	The dynamic MFA showed that there is a trend toward an increasing lifetime of refrigerators and that a large number of mobile devices are being left unused. The LCA results pointed out that replacing older electronics with more energy-efficient ones does not reduce total GHG emissions.
Krych and Pettersen (2021b)	A stock-driven model for assessing environmental benefits of product lifetime extension in Norwegian households	MFA and LCA of 10 appliances and furniture in Norway between 1900-2100	Dynamic MFA, Cradle-to-gate LCA	There is a strong decrease in furniture lifetime since 1980. An extension of lifetime has the potential to reduce environmental impacts.
Lausselet et al. (2021)	Temporal analysis of the material flows and embodied greenhouse gas emissions of a neighborhood building stock	Methodology for combining MFA and LCA of zero-emission neighborhood building stock was developed. Ydalir, Elverum, Norway was used as a case study.	Dynamic MFA; cradle-to-grave, allocation cut-off LCA	It was found that Ydalir will have a material intensity of 1,049 kg/m^2 and in-use material of 43 ton/cap, which is equivalent to GEEs of 294 kgCO_2-eq/m^2, between 2019 to 2080. 52% of the emissions were from initial construction and 48% from material replacements over 45 years.
Mora Sojo and Pettersen (2021)	Quantifying the Norwegian households' clothing system and its environmental impacts for a transition towards a more circular economy			
Velásquez-Rodríguez et al. (2021)	Evaluation of the environmental impact of end-of-life refrigerators in Colombia by material flow analysis	MFA and LCA of refrigerators in Colombia between 1935-2050. Three scenarios were explored.	Dynamic MFA; Simplified end-of-life LCA	The dynamic MFA shows the penetration of refrigerators in Colombia. The LCA shows that, by building a recycling center, it's possible to reduce CO_2 emissions by 3 million tons compared to giving refrigerator waste to informal recyclers or throwing them in dumbs.
Lavers Westin et al. (2019)	Combining material flow analysis with life cycle assessment to identify environmental hotspots of urban consumption	MFA and LCA of 71 product types in Stockholm, Gothenburg, and Malmo, Sweden between 1996-2011	Static MFA; cradle-to-gate, cut-off LCA	MFA and LCA were used to identify hotspots of urban consumption. The study found that electronics and fuel were hotspots in the three cities; vehicles were a hotspot only in Gothenburg; machinery was a hotspot in Stockholm and Gothenburg.
Turner et al. (2016)	Combined material flow analysis and life cycle assessment as a support tool for solid waste management decision making	MFA and LCA of the solid waste management system of Cardiff, Wales in 2012. Four waste management scenarios were explored.	Static MFA; End-of-life, ISO 14040 and 14044 standards for LCA	The MFA showed that it is unlikely that Cardiff would meet its recycling goal in 2025. The LCA showed that most of the GHG emissions were from landfills. All scenarios showed improvements over the baseline, with enhanced food waste capture resulting in the highest recycling rate and most reduction of GHG.

Lopes Silva et al. (2015)	Combined MFA and LCA approach to evaluate the metabolism of service polygons: A case study on a university campus	MFA and LCA of energy, material, and water consumption of the Autonomous University of Barcelona, Spain in 2014	Static MFA; cradle-to-grave, ISO 14040 and 14044 standards for LCA	Both MFA and LCA reveal that energy is the consumption hotspot of the Autonomous University of Barcelona. It accounted for more than 50% of all inputs and 92% of climate change potential.

Summary of literature related to circular economy and consumer-based climate change mitigation measures

Literature related to circular economy and consumer-based climate change mitigation measures was reviewed to help shape the two circular economy scenarios explored in this study. The literature consists of studies about the reuse and recycling of furniture, alternative business models, households' willingness to engage in a circular economy, and the rebound effect. Most of the studies combine surveys and interviews with statistical analysis to understand household behaviors; however, many studies use input-output analysis to understand households' behaviors from a macro level.

Table 5 Summary of literature related to circular economy and consumer-based climate change mitigation measures

Author	Tittle	Scope	Methodology	Result and Conclusion
Chiu and Mont (2021)	Exploring consumer acceptance of furniture renting services: the case of students in Lund	Consumers' attitude toward rental furniture at Lund University, Sweden	Survey, interview	The study found that 70% of students expected rental furniture to be well-functioning, 27% expected like-new furniture, and 3% expected furniture to be brand new. 55% of the participants who had rented furniture in the past were satisfied with the furniture condition.
Cooper et al. (2021)	Furniture lifetimes in a circular economy: a state of the art review	Role of furniture in the circular economy in Europe	Literature review	Approximately 10 million tons of furniture are discarded annually in Europe; however, only about 10% are recycled. This is because of the low quality of materials in furniture, a business model that promotes sales of products with a short lifetime, and the lack of adequate take-back schemes.
Andac Guzel (2020)	Consumer Attitudes toward Preference and Use of Wood, Woodenware, and Furniture: A Sample from Kayseri, Turkey	Consumers' attitude toward wooden durables in Kayseri, Turkey	Survey, statistical analysis	The study used a survey to measure consumers' thoughts, knowledge, and awareness of wood materials. The result showed that 45.6% of the participants believed that wood is a natural and organic material; 43.7% associated wooden items with enjoyment and happiness; 82.5% had a least one piece of wooden furniture at home; 71.8% had composite wooden furniture; 57.8% believed that natural wood is an expensive material.
Chiu (2020)	Exploring rental business models as a way to extend furniture lifetime	An exploration of alternative furniture consumption model at Lund University, Sweden	Survey, interview	The study found that 89% of the survey participants were positive about renting furniture, 8% were unsure, and 3% had a negative attitude. 71% listed the convenience of acquiring furniture as the motivation for renting; follows by cheaper prices and unnecessity to own furniture at 42%, and environmental motivation at 39%.
Ottelin et al. (2020)	Rebound effects may jeopardize the resource savings of circular consumption: evidence from household material footprints	Material footprint, circular behaviors, and rebound effect of residents in 24 European countries in 2010.	Input-output analysis	The study found no clear best practices for circular consumption. Instead, the best practices depend on the demographic of households. In some cases, circular consumption can lead to higher material footprints, especially when the rebound effect was taken into account. Only shifting to a vegetarian diet has a clear but weak connection to a lower material footprint.
Cherry et al.	Public acceptance of	Public support of	Survey, Input-	There was high public acceptance for product

(2018)	resource-efficiency strategies to mitigate climate change	resource-efficiency strategies and carbon footprint of residents in the UK in 2013	output analysis	efficiency in the UK and could reduce household consumption emissions by 29 Mt CO_2-eq or 39% in 2013. Product sharing and extending product lifetimes are also viewed positively, though a high level of trust, convenience, affordability, and hygiene were prerequisites.
Lekve Bjelle et al. (2018)	Climate change mitigation potential of Norwegian households and the rebound effect	Consumption of Norwegian households in 2007	Input-output analysis, linear programming	Norwegian households have the potential to reduce their carbon footprint by 58%; however, because of the rebound effect, this reduction will likely be between 24-35%. With restricted re-spending, it is possible to reach 45%. The study concluded that curbing the rebound effect is necessary to reach the 2°C climate target.
Gullstrand Edbring et al. (2016)	Exploring consumer attitudes to alternative models of consumption: motivations and barriers	IKEA consumers' attitudes, motivations, and barriers toward circular furniture in Sweden.	Survey	Consumers had a positive attitude toward buying second-hand furniture, a positive attitude toward short-term renting, a negative attitude toward long-term renting, and a negative attitude toward sharing furniture. Consumers were mostly motivated by economic reasons and were mostly concerned about hygiene.
Gregson et al. (2009)	Practices of Object Maintenance and Repair	Consumers' practices of object maintenance in Northern England	Interview	The study shows that consumers view the idea of reparation as negative since it devalues furniture. Furthermore, consumers risk destroying furniture if they do not process the necessary reparation skills.
Watson (2008)	A Review of literature and research on public attitudes, perceptions and behaviour relating to remanufactured, repaired and reused products	Literature review about consumers' attitude on second-hand products mainly from the UK, but also from Japan and Finland	Literature review	The study concluded that the willingness to reuse products depends on the nature of the products as well as the demographic of the consumers. Overall, there is not enough research on this topic to give a clear direction for promoting sustainability.
King et al. (2006)	Reducing Waste: Repair, Recondition, Remanufacture or Recycle?	An analysis of European waste policies	Policy analysis	Four waste reduction policies in Europe were examined: repairing, reconditioning, remanufacturing, and recycling. The analysis concluded that remanufacturing was the best policy since it not only reduced waste but also created additional value in the new products.

Methodology

This chapter outlines the methodology used to answer the research questions defined in this study. MFA analysis was used to answer research question number 1 by determining the material flows of furniture in a newly built neighborhood. LCA was used to calculate the carbon footprint of furniture and answered research question number 2. Research question number 3, the potential for circular economy, was answered by using survey data, MFA and LCA.

The study was carried out in five steps (Figure 1). First, a reference neighborhood was defined for the study. Second, MFAs of furniture were created based on the work of Thongsawas (2021). Third, LCA was modeled based on the created MFAs. Finally, circular economy scenarios were created based on the survey data conducted by Thongsawas (2021) and modeled with both MFA and LCA. Finally, the results were analyzed and discussed.

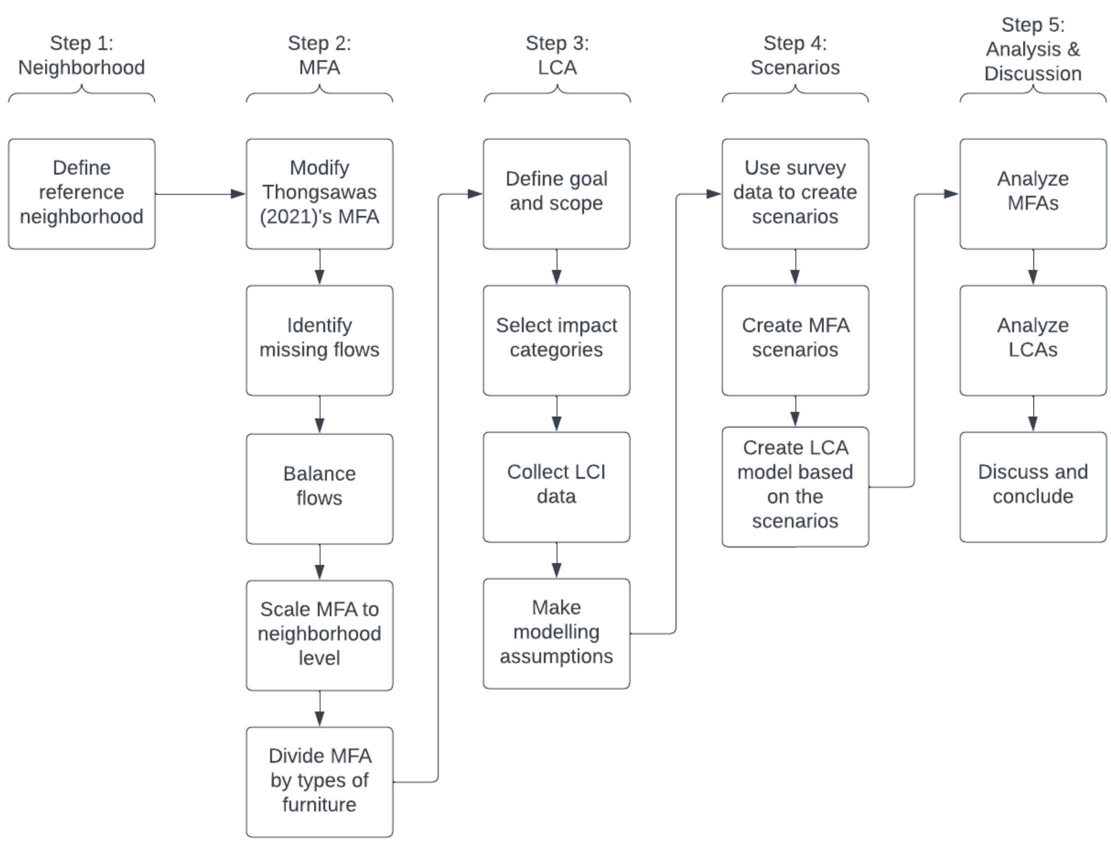


Figure 1 Workflow diagram of the study

The Reference Neighborhood

To study the flows, carbon footprint, and circular economy potential of furniture in a newly built neighborhood, a hypothetical neighborhood was created as a case study. This neighborhood is assumed to be equal in size to the Zero Emissions Neighborhood (ZEN) in Bergen. The neighborhood consists of 695 dwellings with a total floor space of 91,891 m^2 and can be occupied by 1,340 inhabitants (Lausselet et al., 2019). The neighborhood is assumed to locate at Miljøbyen Granås (red pin in Figure 2) in

Trondheim. This location was chosen because of the recent developments of several building projects in the area.

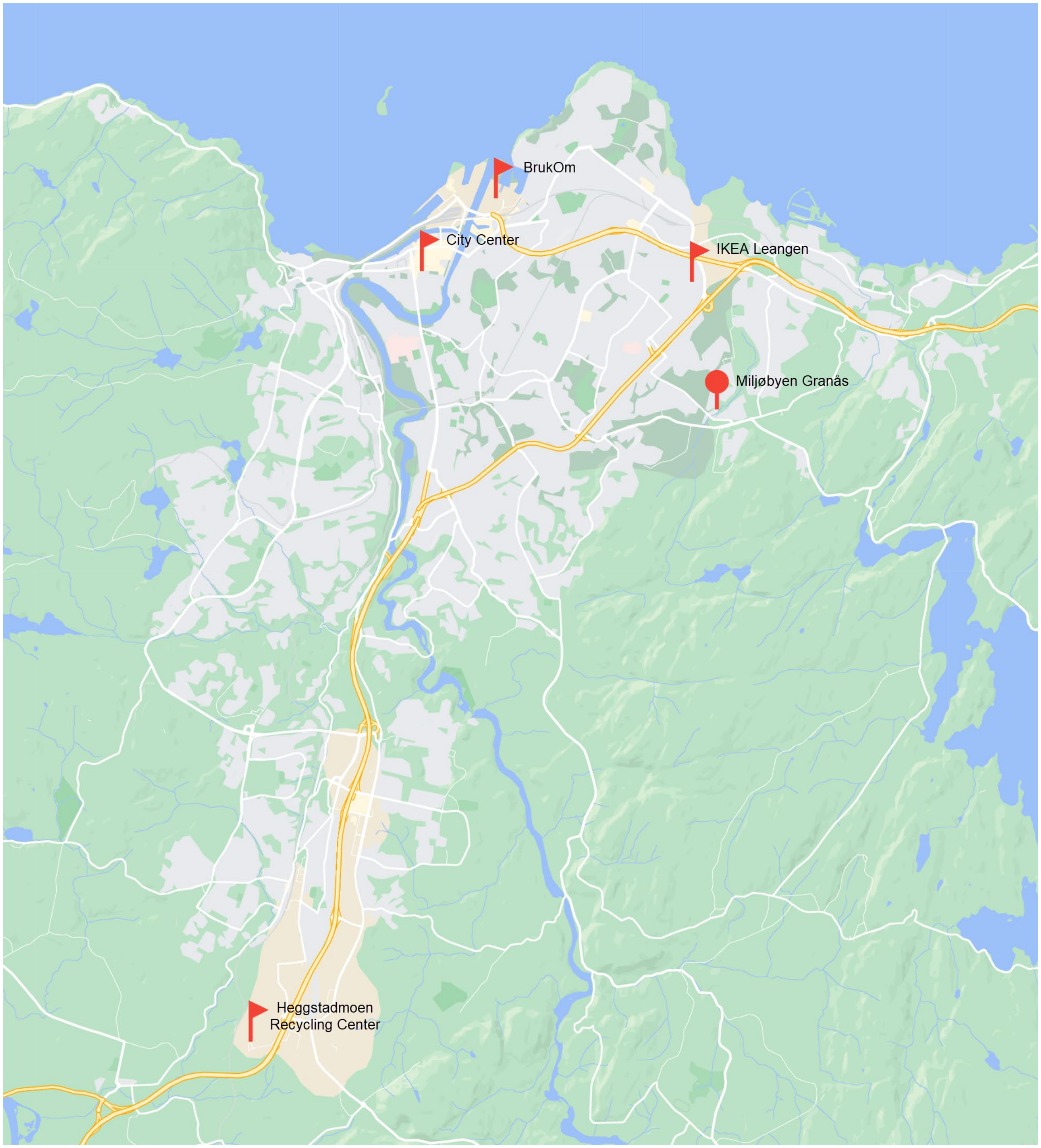


Figure 2 Map of the reference neighborhood at Miljøbyen Granås and other relevant locations

MFA Creation

System Definition

The system definition was based on the furniture MFA created by Thongsawas (2021). The MFA was a bottom-up MFA created based on a furniture survey. The MFA, however, was not completed due to the lack of data at the end of life. In this study, Thongsawas (2021)'s system definition was modified based on a conversation with a waste expert (Mattson, 2022). The modified system definition is shown in Figure 3.

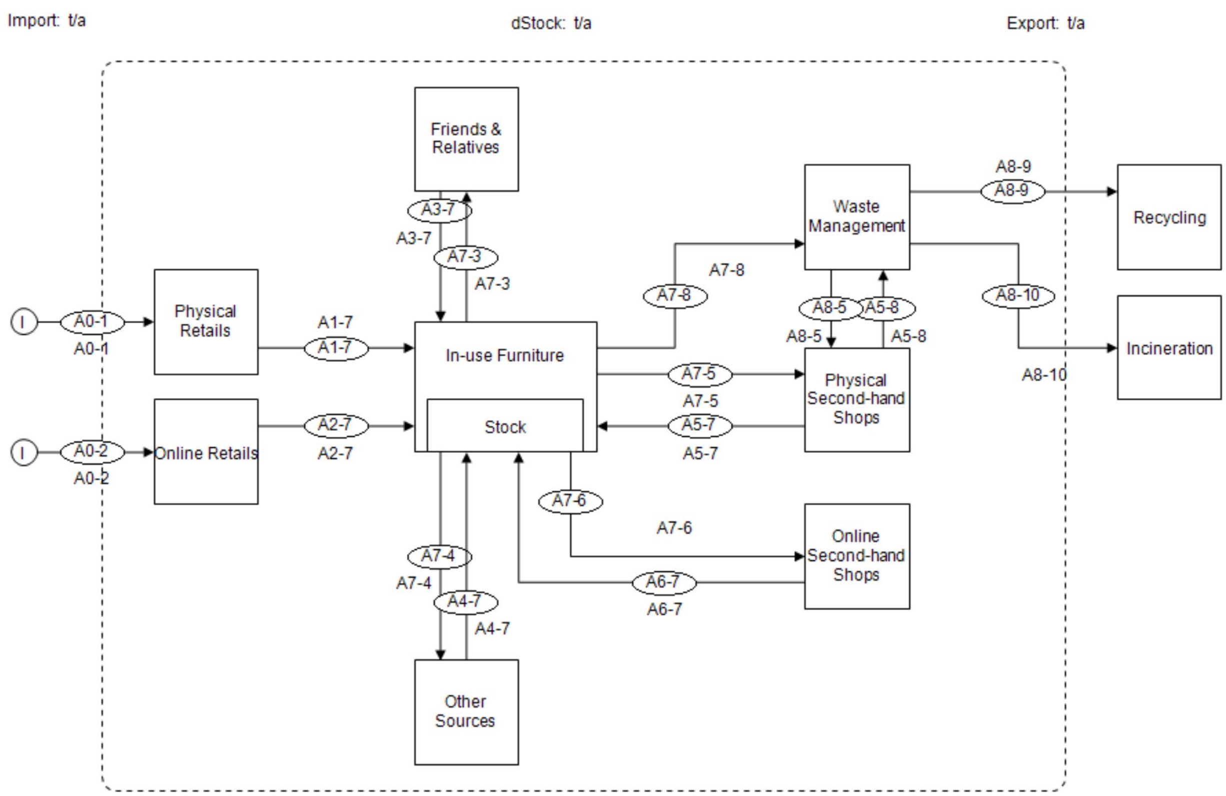


Figure 3 System definition of furniture in the neighborhood

Determination of Stocks and Flows

Four steps were taken to determine the stocks and flows of MFA in the newly built neighborhood (Figure 4). First, the missing flows in Thongsawas (2021)'s MFA were filled out using external data. Second, certain flows were assumed mass balance. Third, the MFA was scaled down from the municipality level to a neighborhood level. Finally, the MFA was divided into five smaller MFAs based on furniture categories.

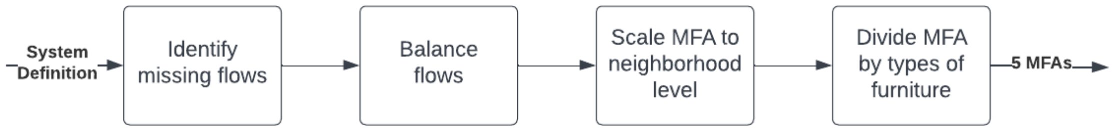


Figure 4 Steps taken to create the MFAs for 5 categories of furniture in the neighborhood

Identifying missing flows

Thongsawas (2021)'s MFA was a bottom-up MFA created based on survey data. As a result, end-of-life data were missing because most of the survey participants could not recall how they disposed of their furniture. To calculate the outflow of furniture (A7-8), an outflow-to-inflow ratio from Krych and Pettersen (2021a)'s dynamic modeling of furniture was used. Krych and Pettersen (2021a)'s model showed that the ratio between outflow and inflow of furniture in Norway in 2021 was 0.9057, which resulted in a stock accumulation of 9.43%. To determine how furniture waste was distributed after reaching Waste Management (A8-5, A8-9, A8-10), data from waste sampling analysis (Wågøynes et al., 2018) was used. The analysis showed that 24.08% of furniture waste was in good enough condition to be reused (A8-5), while the remaining furniture was separated into wood waste and other waste. Wood waste was further separated into three categories: untreated wood, mixed wood, and treated wood. 39.22% of untreated wooden furniture waste was sent to recycling, mainly for making particle boards. Mixed wood waste and treated wood waste were sent to incineration along with other types of furniture waste such as textile waste (Wågøynes et al., 2018). The amount of waste sent to landfills was not considered since the value is very small. By law, it is not legal to send waste to landfills in Norway if there are other treatment options (Miljøverndepartementet, 2002). Metal waste was also not considered since it is marginal in household furniture waste, contrary to office furniture waste (Mattson, 2022). For this study, chairs, storages, and tables were assumed to be treated as wood waste, while beds and sofas were assumed to be treated as textile waste.

Balancing flows

In Thongsawas (2021)'s MFA, flows of furniture between "In-use Furniture" and "Friends & relative" (A7-3, A3-7), "In-use Furniture" and "Other Sources" (A7-4, A4-7), "In-use Furniture" and "Physical Second-hand Shops" (A7-5, A5-7), and "In-use Furniture" and "Online Second-hand Shops" (A7-6, A6-7) were not balanced. For the first three pairs, the inflows were higher than the outflows since the survey participants did not fully recall the amounts of items they no longer had. In the last pair, the outflow was higher than the inflow. The participants were able to recall selling furniture online since it is a process that requires a lot of personal involvement. For all the four pairs, a mass balance was assumed, and the higher flows were used to represent both inflows and outflows. This assumption was made because of the nature of the flows (Thongsawas, 2021) and to simplify the LCA that would be carried out in the next section.

Scaling MFA to a neighborhood level

Since Thongsawas (2021)'s MFA was created at a municipal level, it had to be scaled down for this study. The ratio between the number of inhabitants in Trondheim to the neighborhood was used as the scaling factor. At the time of this study, Trondheim has a population of 209,802 while the neighborhood has 1,340 inhabitants.

Dividing MFA by furniture categories

The survey conducted by Thongsawas (2021) asked participants to identify a total of 33 types of furniture. All furniture was then combined into a single MFA. In this study, the 32 types of furniture were divided into five main categories: beds, chairs, sofas, storages, and tables. This was done to simplify the LCA which would be carried out in the next section. Note that piano was excluded from the MFA because it does not fit into any furniture category and has a very low number, which is marginal to the study.

Life Cycle Analysis

LCA was used as a tool to calculate the carbon footprint of the furniture flows of the reference neighborhood. LCA was chosen because of its ability to account for GHG emissions throughout the entire supply chain, from manufacturing to the treatment of waste. This study follows the EPD standard NS-EN 15804:2012 which outlines how the environmental impacts of construction products should be calculated (Standard Norge, 2019, 2021). Even though furniture is not technically a construction product, it can be argued that it is a component in buildings. Table 6 shows the EPD framework used in this study. “X” indicates that the process is considered; “MNR” stands for modules not relevant; “MND” stands for modules not declared. Finally, “X*” means that the process is considered, but not in all scenarios.

Table 6 EPD framework for calculating environmental impacts for construction products

EPD Framework																		
	Product stage			Construction process stage		Use stage							End of life stage				Benefits and loads beyond the system boundary	Lifecycle emission
Unit: ton CO_2-eq	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A1-D
Furniture category	Raw material supply	Transport	Manufacturing	Transport	Construction - Installation process	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction demolition	Transport	Waste processing	Disposal	Reuse, recovery, recycling, potential	Total
All	X	X	X	X	X	MNR	MND	X*	MNR	MNR	MNR	MNR	MNR	X	X	MND	MNR	X

LCA in this study was carried out in four steps (Figure 5). First, the goal and scope of the system were defined. Second, impact categories were selected. Third, data were collected to create a life cycle inventory (LCI). Finally, modeling assumptions were made to create the LCA model in SimaPro and Microsoft Excel.

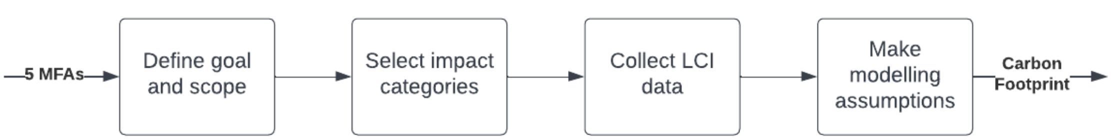


Figure 5 Steps taken to calculate the carbon footprint of furniture in the neighborhood

Goal

The goal of the LCA was to calculate the carbon footprint of the furniture flows of the reference neighborhood based on the MFAs in the previous section.

Scope

The scope of the LCA consists of the functional unit and initial system boundary. In this study, the functional unit was defined as the flows of furniture in a newly built neighborhood with 1,340 inhabitants in the year 2021. The system model used was "allocation, cut-off by classification" to be consistent with the Norwegian EPD standard (Standard Norge, 2019, 2021), or in other words, the LCA was carried out according to the polluter pays policy. The initial system boundary was considered from cradle to grave, which is similar to the MFAs in the previous section. Figure 6 shows the top layer of the initial system boundary. "MFA, All furniture" represents the functional unit of the system. The figure also shows that the "MFA, All furniture" is made up of 5 MFAs from each furniture category in the second layer. Each MFA by furniture category in the second layer is made up of individual furniture MFA in the previous section (Figure 3). Figure 7 illustrates a simplified version of the third layer of the LCA as well as a simplified version of the processes that made up the fourth layer, from manufacturing to waste handling. Appendix B and Appendix D show the detailed version of all layers in SimaPro's modeling format (PRé, 2016). Note that layers 5 and below are not shown in this report, but can be seen directly in SimaPro.

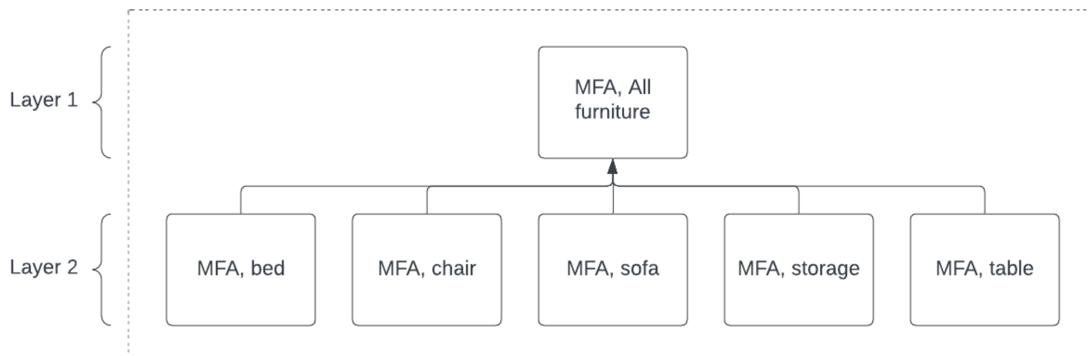


Figure 6 Layers 1 and 2 of the LCA model of furniture in the neighborhood

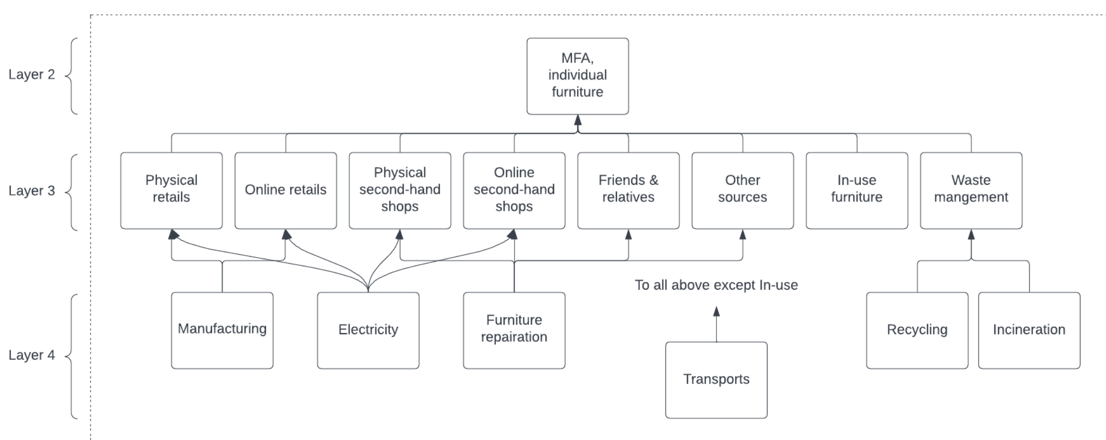


Figure 7 Simplified layers 2, 3, and 4 of the LCA model of furniture in the neighborhood

Impact Category

The goal of the study is to calculate the carbon footprint of furniture in the reference neighborhood; therefore, climate change is the only main impact category of concern. EPD indicates that four categories of GHG emissions (Table 7) should be considered when carrying out an LCA (Standard Norge, 2019, 2021). The LCI data collected in this study follows this standard for consistency and accuracy of results.

Table 7 Climate change impact categories according to the NS-EN 15804:2012 standard

Impact category	Indicator	Unit	Model
Climate change – total	Global Warming Potential total (GWP-total)	kg CO_2 eq.	Baseline model of 100 years of the IPCC based on IPCC 2013
Climate change – fossil	Global Warming Potential fossil fuels (GWP-fossil)	kg CO_2 eq.	Baseline model of 100 years of the IPCC based on IPCC 2013
Climate change – biogenic	Global Warming Potential biogenic (GWP-biogenic)	kg CO_2 eq.	Baseline model of 100 years of the IPCC based on IPCC 2013
Climate change – land use and land use change	Global Warming Potential land use and land use change (GWP-luluc)	kg CO_2 eq.	Baseline model of 100 years of the IPCC based on IPCC 2013

Life Cycle Inventory

This section outlines the LCI and sources of data. Only foreground data is listed since they are of the main interest. Background data can be viewed through SimaPro or the ecoinvent database. Assumptions and reasonings for certain inventories are also given.

Table 8 Life cycle inventory of the LCA model of furniture in the neighborhood

Inventory	Source	Assumption & Reasoning
New bed, manufacturing	Geyer et al. (2016)	Midpoint data from US manufacturing, so emission can be slightly higher than the European counterpart. US data was used since no EPD or European data was available at the midpoint.
New chair, manufacturing	EPD (2022c); Lauvland (2021)	Emission was converted to kg CO_2/kg furniture for all furniture, then the median value was selected.
New sofa, manufacturing	EPD (2022c); Lauvland (2021)	”
New storage, manufacturing	EPD (2022d); Lauvland (2021)	”
New table, manufacturing	EPD (2022a); Lauvland (2021)	”
Bed reparation	Lauvland (2021)	Assumed to be equivalent to 20% of manufacturing emissions.
Chair reparation	Lauvland (2021)	”
Sofa reparation	Lauvland (2021)	”
Storage reparation	Lauvland (2021)	”

Table reparation	Lauvland (2021)	”
Electricity, low voltage {NO}| market for | Cut-off, S	ecoinvent (2019)	Norwegian mix was used since the neighborhood is in Norway.
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	ecoinvent (2019)	Manufacturers were assumed to use large size lorries to transport furniture to retailers.
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	ecoinvent (2019)	Retailers and second-hand shops were assumed to use small lorries to transport furniture to consumers.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	ecoinvent (2019)	Consumers were assumed to use passengers to transport furniture. Note that electric cars are not included in the mix.
Waste wood, untreated {NO}| market for waste wood, untreated | Cut-off, S	ecoinvent (2019)	Estimated data on untreated wood treatment based on Riber (2008) and plastic treatment.
Municipal solid waste {NO}| treatment of, incineration | Cut-off, S	ecoinvent (2019)	The dataset was modeled for general municipal waste in Norway.

LCA Modelling Assumptions

Since this study carried out both MFA and LCA, modeling assumptions were necessary to combine the two modeling techniques. While the MFA gave an overview of the flows of furniture, it didn’t indicate how furniture was transported, the exact locations furniture was transported from and to, what other inputs were in the system, etc. To carry out an LCA, these questions needed to be answered. In this section, assumptions made in layer 3 (Figure 7) of the LCA model are outlined.

Physical retails

- Furniture was assumed to be manufactured and transported by large lorry from Zbaszynek, Poland to Trondheim, Norway. The distance between the two cities is 1,618 km. Zbaszynek is chosen because it is the largest IKEA furniture factory in Europe (National Geographic, 2018). In reality, different types of furniture are manufactured at different places; however, information about manufacturers is not disclosed by IKEA.
- Once furniture arrived in Trondheim, it was assumed that all inhabitants purchased furniture through physical retails by visiting IKEA Leangen, which is 3.05 km away from the neighborhood.
- On average, inhabitants were assumed to make 3 trips to IKEA Leangen to pick up furniture by passenger cars. It is assumed that 50% of inhabitants owned a trailer extension which allowed them to only make 2 trips back and forth to pick up furniture, while another 50% had to rent a trailer from IKEA, which resulted in 2 extra trips to get and return the trailer.
- By using a trailer extension, it was assumed that inhabitants, on average, carried 1 bed, 2.5 chairs, 1 sofa, 2 storages, or 1 table per visit.

- Electricity usage for physical retails was based on the electricity consumption of IKEA Leangen scaled down to the neighborhood level and scaled up based on IKEA's 40.9% market share of furniture (Rekdal, 2019). For detail on how electricity usage was calculated, see Appendix A.

Online retails

- Like physical retails, furniture was assumed to be manufactured and transported from Zbaszynek by a large lorry.
- Once furniture arrived in Trondheim, inhabitants were assumed to make purchases online through www.ikea.no.
- Ordered furniture was then delivered from IKEA Leangen's warehouse to the neighborhood 3.05 km away by a small lorry.
- Electricity usage for online retails was based on the electricity consumption of IKEA Leangen's warehouse, scaled downed to the neighborhood level and scaled up based on IKEA's 40.9% market share of furniture. Additional electricity for running the website was also included. For detail on how electricity usage was calculated, see Appendix A.

Physical second-hand shops

- Inhabitants were assumed to purchase second-hand furniture from the physical second-hand shop BrukOm, which is the largest second-hand furniture store in Trondheim.
- Like physical retails, inhabitants were assumed to make, on average, 3 trips to BrukOm to pick up furniture by passenger cars.
- By using a trailer extension, it was assumed that inhabitants, on average, carried 1 bed, 2.5 chairs, 1 sofa, 2 storages, or 1 table per visit.
- BrukOm was assumed to have repaired all furniture before selling them to customers.
- Repair materials were assumed to be manufactured and transported from Zbaszynek to Trondheim by a large lorry.
- It was assumed that BrukOm picked up repair materials in bulk with a small lorry from IKEA Leangen. The distance between them is 4.45 km.
- Electricity usage of physical second-hand shops was based on the electricity consumption of BrukOm, scaled downed to the neighborhood level. For detail on how electricity usage was calculated, see Appendix A.

Online second-hand shops

- Inhabitants were assumed to acquire second-hand furniture through an online platform www.finn.no, which is the largest platform for peer-to-peer trading in Norway (FINN, 2022).
- Once a purchase is made online, each inhabitant was assumed to pick up the furniture by a passenger car at the city center, which is 7.05 km away.
- Like physical retails, inhabitants were assumed to make, on average, 3 trips to the city center to pick up furniture.

- By using a trailer extension, it was assumed that inhabitants, on average, carried 1 bed, 2.5 chairs, 1 sofa, 2 storages, or 1 table per visit.
- It was assumed that repair was made by the sellers before furniture was sold.
- Repair materials were assumed to be manufactured and transported from Zbaszynek to Trondheim by a large lorry.
- Each seller was assumed to pick up the repair materials by a passenger car at IKEA Leangen, which is 5.95 km away from the city center.
- Electricity usage for running the website was included. For detail on how electricity usage was calculated, see Appendix A.

Friends & relatives

- It was assumed that furniture given by friends or relatives was picked up by passenger cars at the city center of Trondheim, which is 7.05 km away from the neighborhood.
- Like physical retails, inhabitants were assumed to make, on average, 3 trips to the city center to pick up furniture.
- By using a trailer extension, it was assumed that inhabitants, on average, carried 1 bed, 2.5 chairs, 1 sofa, 2 storages, or 1 table per visit.
- Reparation was assumed to be necessary once furniture was received.
- Repair materials were assumed to be manufactured and transported from Zbaszynek to Trondheim by a large lorry.
- Inhabitants were assumed to pick up repair materials from IKEA Leangen, which is 3.05 km away, by passenger cars.

Other sources

- Most of the other sources of furniture in Thongsawas (2021) were institutions or groups that handle furniture. In this study, it is assumed that the institutions or groups were located in the city center, which is 7.05 km away from the neighborhood.
- Like physical retails, inhabitants were assumed to make, on average, 3 trips to the city center to pick up furniture by passenger cars.
- By using a trailer extension, it was assumed that inhabitants, on average, carried 1 bed, 2.5 chairs, 1 sofa, 2 storages, or 1 table per visit.
- Reparation was assumed to be made by the furniture providers before furniture was given away.
- Repair materials were assumed to be manufactured and transported from Zbaszynek to Trondheim by a large lorry.
- It was assumed that the furniture providers picked up repair materials in bulk with a small lorry from IKEA Leangen. The distance between them is 5.95 km.
- Electricity was not taken into account due to the lack of data and the variety of furniture sources.

Waste Management

- In Trondheim, furniture waste is delivered to the recycling center Heggstadmoen Recycling Center, which is 14 km away from the neighborhood.

- Like physical retails, inhabitants were assumed to make, on average, 3 trips to the city center to pick up furniture by passenger cars.
- By using a trailer extension, it was assumed that inhabitants, on average, carried 1 bed, 2.5 chairs, 1 sofa, 2 storages, or 1 table per visit.
- Chair, storage, and table were assumed to be treated as wood waste.
- 39.22% of furniture wood waste was untreated wood (Wågøynes et al., 2018) and was recycled. The remaining wood waste was incinerated in a similar manner as municipal waste in Norway.
- Sofas and beds were assumed to be treated as textile waste.
- Textile wastes were assumed to be incinerated in a similar manner as municipal waste in Norway.
- The carbon footprint of selecting and reselling furniture waste (flows A8-5, A5-8) was not accounted for since it takes place within the recycling center and is carried out by hand, making the impacts marginal.

In-use furniture

- The impact of in-use furniture was not considered in this study since it is not relevant to circular economy. Furthermore, by nature, furniture requires very little input while using; thus, making the carbon footprint marginal.

Scenarios

To study the potential of circular economy of furniture, scenarios were considered based on the survey done by Thongsawas (2021). In the survey, depending on the type of furniture, 20-95% of participants responded that they were willing to engage in purchasing second-hand furniture while 28-82% responded that they were willing to perform minor repairs to extend furniture lifetime. On the other hand, participants showed a low willingness to send furniture for professional repair, co-own furniture, and rent furniture (Thongsawas, 2021). In this study, the two scenarios with the highest circular economy potentials – buying second-hand and extending lifetime – were considered. It should be noted that, since the survey data used measured participants' willingness to engage in circular economy practices, the scenarios in this study should therefore be viewed as the maximum potential. In reality, there will be a discrepancy between consumers' willingness and actual consumers' behaviors (Arli et al., 2018; Gupta & Sen, 2013).

Two steps were taken to study the potential of circular economy in these two scenarios. First, the MFA of the Baseline scenario (Figure 3) was modified to reflect the furniture flows of both scenarios. Second, the LCA of the Baseline scenario was adjusted with the new material flows from the MFA. Furthermore, additional modeling assumptions were made to reflect the scenarios.

Second-hand Scenario

In this scenario, inhabitants of the neighborhood were assumed to obtain a high amount of second-hand furniture instead of new furniture. The following adjustments were made to the MFA and LCA.

MFA

The system boundary of this scenario was the same as the Baseline scenario (Figure 3). However, flows of second-hand furniture were increased according to the survey data. 95% of chairs, 78% of sofas, 86% of storages, and 95% of tables within the system boundary were assumed to be acquired second-hand. The percentage of second-hand beds, however, was assumed to be the same as the Baseline scenario since the survey showed that participants were already using more second-hand beds than they were willing to – 42% vs 20%. The increased amount of second-hand furniture was distributed to “Physical second-hand shops” (flows A7-5, A5-7) and “Online second-hand shops” (flows A7-6, A6-7) with the same ratio between them as in the Baseline scenario, by furniture categories. It is worth noting that the increased amount of second-hand furniture was not distributed to “Friends & relatives” and “Other sources” since the survey asked the participants specifically if they were willing to buy second-hand furniture, implying an engagement in business transactions. In this study, it was assumed that the total consumption of furniture within the system boundary remains the same as the Baseline scenario; therefore, when inhabitants purchased more second-hand furniture, it was assumed that the amount of new furniture purchased would decrease by the same amount. The amount decreased was subtracted from “Physical retails” (flows A1-7, A0-1) and “Online retails” (flows A2-7, A02) with the same ratio as the Baseline scenario, by furniture categories. Furthermore, when inhabitants consumed more second-hand furniture, the amount of discarded furniture (flow A7-8) was assumed to decrease by the same amount, since furniture was resold instead of being thrown away. The ratio of furniture waste sent to recycling and incineration remained the same as in the Baseline scenario.

LCA

Since the system boundary of the Second-hand scenario was the same as the Baseline scenario’s, no change was made in LCA modeling and no additional assumption was made. Nevertheless, the amount of furniture in “Physical retails”, “Online retails”, “Physical second-hand shops”, “Online second-hand shops” and “Waste management” in layer 3 (Figure 7) were modified in accordance with the Second-hand scenario’s MFA. See Appendix B for details.

Lifetime Extension Scenario

In this scenario, inhabitants were assumed to have the knowledge, skills, and willingness to repair furniture. Instead of disregarding furniture at the end of life and buying new, inhabitants were assumed to fix furniture themselves to extend its lifetime. It should be noted that the length of lifetime extension was not addressed in this study. Any furniture that had its lifetime extended in 2021 and lasted beyond 2021 was considered as extended-lifetime furniture in the MFAs and LCAs presented in this study. The following modifications were made to the MFA and LCA.

MFA

A new element called “Lifetime extension” was added to the Baseline scenario’s MFA (Figure 8). The flows between “Lifetime extension” and “In-use furniture” represent the amount of furniture that had its lifetime extended, in other words, a loop of circular furniture use. In reality, however, there is no actual movement of furniture since inhabitants were assumed to fix furniture at their dwellings. The amount of furniture being fixed was determined by the survey data. 28% of beds, 82% of chairs, 66% of sofas, 80% of storages, and 82% of tables in the system were assumed to have their lifetime extended. Similar to the Second-hand scenario, it was assumed that the total amount of furniture consumption in the neighborhood in 2021 remained the same. As a result, by extending furniture lifetime, the amount of new furniture purchases decreased. The reduction was distributed between "Physical retails" (flows A1-7, A0-1) and "Online retails" (flows A2-7, A0-2) with the same ratio as the Baseline scenario, by furniture categories. Furthermore, since furniture was used longer instead of being thrown away, the amount of furniture waste (flow A7-8) was assumed to decrease respectively. The ratio of furniture waste sent to recycling and incineration remained the same as the Baseline scenario.

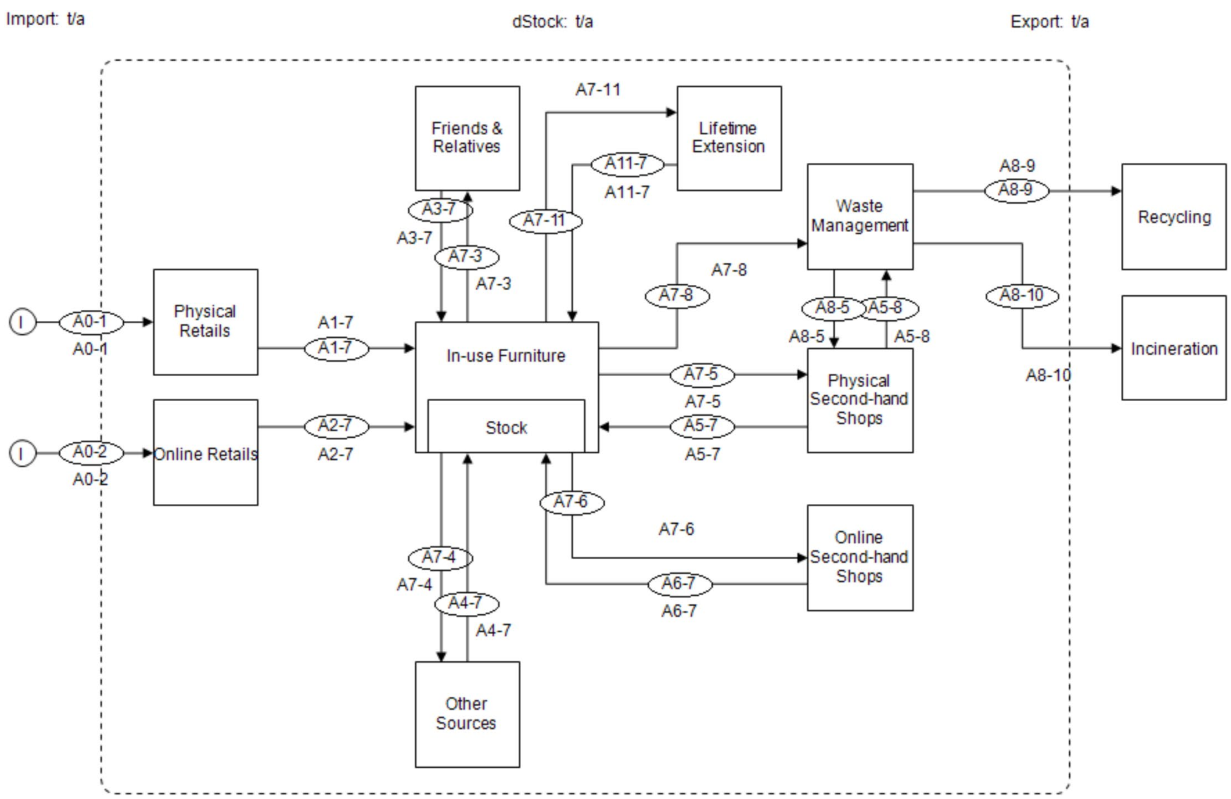


Figure 8 System definition of the Lifetime Extension scenario

LCA

Similar to the MFA, "Lifetime extension" was added to the LCA in layer 3 (Figure 9). Inhabitants were assumed to repair furniture by using materials equivalent to 20% of the original manufacturing materials (Lauvland, 2021). The repair materials were transported from Zbaszynek to Trondheim by large lorry and picked up at IKEA Leangen by passenger cars. It was assumed that inhabitants repaired one piece of furniture at a time and were able to transport all repair parts of furniture in a single trip. Besides this addition, the amount of furniture in "Physical retails", "Online retails", and "Waste management" in layer 3 (Figure 9) were adjusted to reflect the change represented in the Lifetime Extension scenario's MFA.

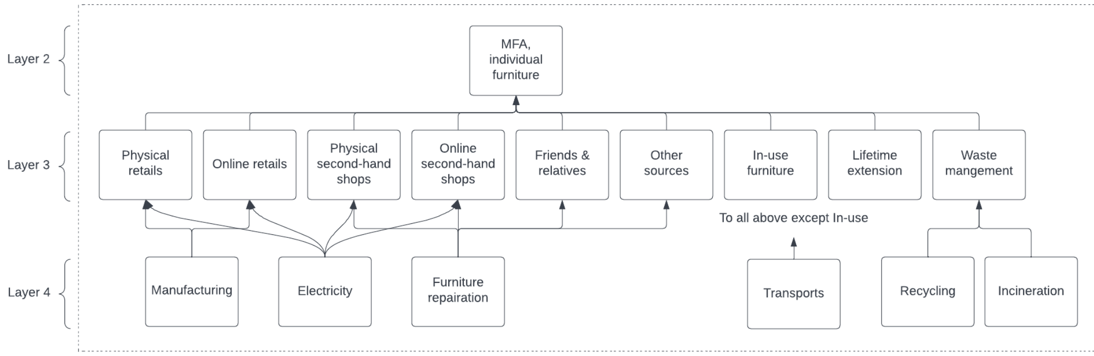


Figure 9 Simplified layers 2, 3, and 4 of the LCA model of the Lifetime Extension scenario

Results

This section presents the results of the study based on the three scenarios: Baseline, Second-hand, and Lifetime Extension. First, the MFAs of the three scenarios are presented to outline the stocks and flows of furniture in the system. Next, the carbon footprints of the three scenarios, calculated by LCA, are shown. Finally, MFA and LCA are combined to give a holistic picture of both material flows and carbon footprints in the system.

Material Flow Analysis

Baseline Scenario

Figure 10 shows the MFA of the Baseline scenario. The neighborhood had a total furniture stock of 961.68 tons, inflows of 52.13 tons, and outflows of 47.21 tons, which resulted in a stock change of 4.92 tons in 2021. In addition, there were a total of 59.79 tons of second-hand furniture circulating within the system. Figure 10 shows that most of the furniture flows through the system, which means that the inhabitants prefer to replace obsolete furniture with new furniture. In other words, the level of circularity of the system is low. At the end of life, it can be observed that most of the furniture waste was sent to incineration. Only 17% of the waste was reused 23% of the waste was recycled.

When it comes to inhabitants' furniture consumption behaviors, Figure 10 shows that 80% of new furniture was purchased from physical retails, while only 20% were purchased from online retails. The opposite behavior is observed when it comes to second-hand furniture. Inhabitants purchased 79% of second-hand furniture from online second-hand shops, while only 71% from physical second-hand shops. We can also observe that 47% of second-hand furniture was not purchased but received for free from friends & relatives or other sources.

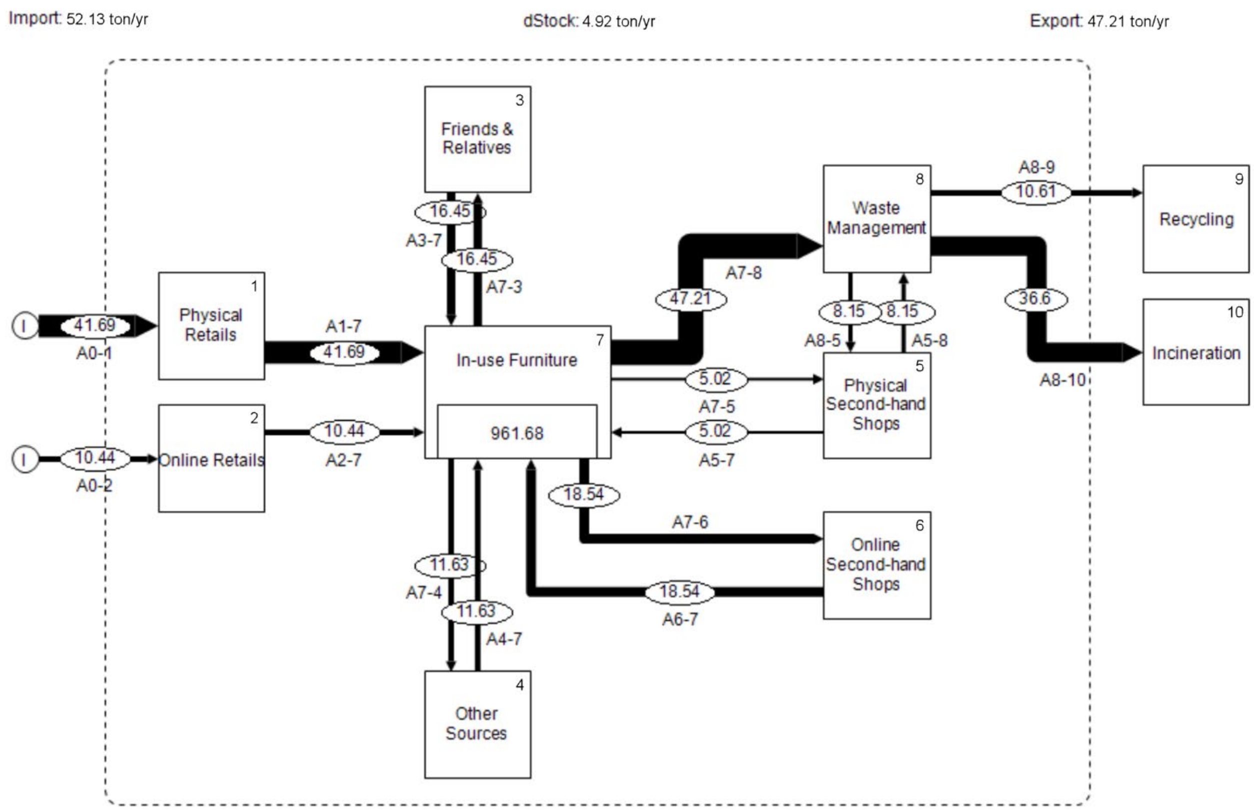


Figure 10 MFA of furniture in the Baseline scenario

The detailed stocks and flows of furniture by category are summarized by weight (Table 9) and by unit (Table 10). Comparing the two tables, we can see that storages have the highest amount of stock and flow both by weight and by unit. Chairs, however, have a low amount by weight, but a large amount by unit. Beds, sofas, and tables are proportionate both by weight and by unit. We can also see that textile furniture was treated differently from wood furniture at the end of life. Sofas were not recycled, while beds were both not resold and not recycled.

Table 9 Stocks and flows of furniture in the Baseline scenario by weight

Baseline Scenario										
Unit: ton, ton/year	Stock	New furniture flows		Second-hand furniture flows				Waste flows		
Furniture category	In-use	Physical shops	Online shops	Physical shops or flea markets	Online markets	Friends or relatives	Other sources	Resold	Recycling	Incineration
Bed	148.23	11.84	2.93	0.46	3.71	5.31	1.27	0.00	0.00	13.38
Chair	80.46	3.72	0.65	0.70	2.09	2.35	0.28	0.96	1.56	2.41
Sofa	119.61	6.23	1.24	0.65	3.65	1.40	1.65	1.63	0.00	6.77
Storage	504.25	14.78	4.79	1.99	5.33	5.00	8.06	4.27	6.95	10.77
Table	109.13	5.12	0.82	1.23	3.76	2.38	0.38	1.29	2.11	3.27
Total	961.68	41.69	10.44	5.02	18.54	16.45	11.63	8.15	10.61	36.60
		52.12		59.79					47.21	

Table 10 Stocks and flows of furniture in the Baseline scenario by unit

Baseline Scenario										
Unit: unit, unit/year	Stock	New furniture flows		Second-hand furniture flows				Waste flows		
Furniture category	In-use	Physical shops	Online shops	Physical shops or flea markets	Online markets	Friends or relatives	Other sources	Resold	Recycling	Incineration
Bed	1732.34	122.40	24.48	5.15	46.38	65.71	14.17	0.00	0.00	133.03
Chair	8469.22	351.75	63.13	79.88	167.50	266.71	60.56	90.49	147.38	228.39
Sofa	2329.03	128.85	41.23	20.62	46.38	36.08	46.38	37.10	0.00	154.04
Storage	11375.70	318.25	81.17	42.52	109.52	77.31	211.31	87.12	141.88	219.88
Table	4600.32	226.77	30.92	76.02	118.54	96.63	24.48	56.21	91.54	141.86
Total	28506.61	1148.02	240.94	224.19	488.33	542.44	356.90	270.92	380.80	877.20
		1388.96		1882.78					1257.99	

Second-hand Scenario

Figure 11 shows the MFA of the Second-hand scenario. Furniture stock and stock change remain the same as the Baseline scenario due to the assumptions made in the methodology section. However, the inflows and outflows decreased to 24.8 tons and 19.89 tons respectively. The amount of second-hand furniture circulating in the system increased to 80.53 tons because more inhabitants engaged in purchasing used furniture, which means that furniture no longer flowed through the system like in the Baseline scenario. Instead, the system now has a higher degree of circularity with an increase of 27.32 tons of second-hand furniture replacing new furniture.

Inhabitants’ furniture consumption behaviors remain the same as the Baseline scenario for the most part due to the assumptions made in the methodology section. The flows between in-use furniture and online second-hand shops (A6-7 and A7-6), however, became the largest flows within the system. This reflects inhabitants’ preferences to purchase second-hand furniture online instead of from physical stores. Furthermore, we can observe that inhabitants purchased significantly less furniture from physical retails (A1-7) and online retails (A2-7) and generate less furniture waste (A7-8).

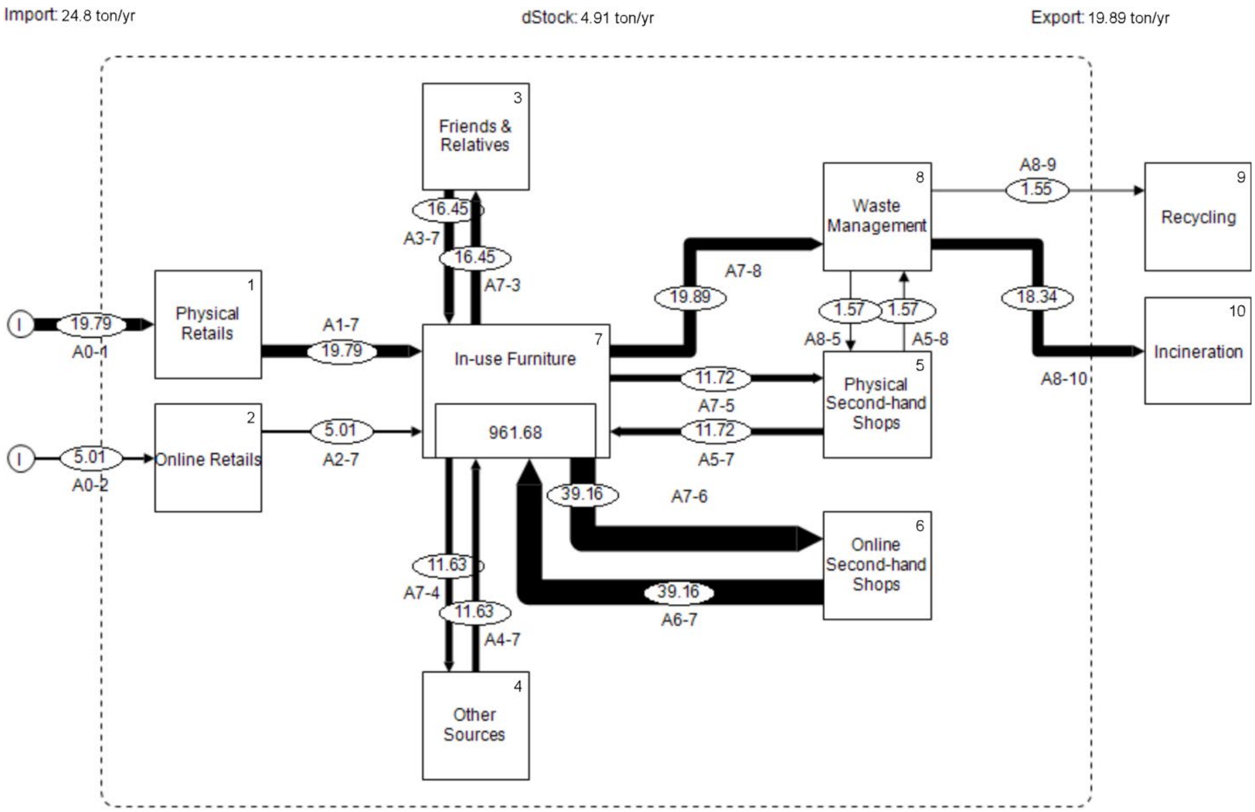


Figure 11 MFA of furniture in the Second-hand scenario

Table 11 and Table 12 shows the stocks and flows of furniture by category, both by weight and by unit respectively. By looking at both tables, we can see that the flows of beds are the same as in the Baseline scenario (Table 9 and Table 10). This is because inhabitants were already using second-hand beds more than they were willing to; thus, it was not possible to increase the flow of second-hand beds further. Besides beds, the proportion of furniture flows by category remains the same as in the Baseline scenario because of the shared assumptions.

Table 11 Stocks and flows of furniture in the Second-hand scenario by weight

Second-hand Scenario										
Unit: ton, ton/year	Stock	New furniture flows		Second-hand furniture flows				Waste flows		
Furniture category	In-use	Physical shops	Online shops	Physical shops or flea markets	Online markets	Friends or relatives	Other sources	Resold	Recycling	Incineration
Bed	148.23	11.84	2.93	0.46	3.71	5.31	1.27	0.00	0.00	13.38
Chair	80.46	0.42	0.07	1.67	5.01	2.35	0.28	0.02	0.03	0.05
Sofa	119.61	2.72	0.54	1.29	7.22	1.40	1.65	0.62	0.00	2.56
Storage	504.25	4.22	1.37	5.79	15.51	5.00	8.06	0.90	1.47	2.28
Table	109.13	0.59	0.09	2.52	7.72	2.38	0.38	0.03	0.05	0.08
Total	961.68	19.79	5.01	11.72	39.16	16.45	11.63	1.57	1.55	18.34
		24.80		80.53					19.89	

Table 12 Stocks and flows of furniture in the Second-hand scenario by unit

Second-hand Scenario										
Unit: unit, unit/year	Stock	New furniture flows		Second-hand furniture flows				Waste flows		
Furniture category	In-use	Physical shops	Online shops	Physical shops or flea markets	Online markets	Friends or relatives	Other sources	Resold	Recycling	Incineration
Bed	1732.34	122.40	24.48	5.15	46.38	65.71	14.17	0.00	0.00	133.03
Chair	8469.22	41.95	7.53	197.88	414.91	266.71	60.56	2.49	4.06	6.29
Sofa	2329.03	53.26	17.04	51.32	115.46	36.08	46.38	13.07	0.00	54.26
Storage	11375.70	93.71	23.90	121.33	312.52	77.31	211.31	19.25	31.36	48.59
Table	4600.32	25.23	3.44	165.51	258.08	96.63	24.48	1.05	1.71	2.66
Total	28506.61	336.55	76.39	541.19	1147.35	542.44	356.90	35.87	37.13	244.84
		412.94		2623.76					281.97	

Lifetime Extension Scenario

The MFA of the Lifetime Extension scenario is shown in Figure 12. Furniture stock and stock change remain the same as the Baseline scenario; however, the inflows decreased to 19 tons and the outflows decreased to 14.09 tons. Both inflows and outflows are lower than in the Second-hand scenario. The amount of second-hand furniture circulating in the system increased to 85.93 tons due to inhabitants' willingness to repair furniture to extend its lifetime. The level of circularity in this scenario is the highest of the three scenarios.

Unlike the previous two scenarios which share similar system definitions, 'Lifetime Extension' (process 11) is added to the system definition. 33.12 tons of furniture (A7-11 and A11-7) were found to have their lifetime extended in 2021. As a result, among all scenarios, the least amount of new furniture was purchased from physical retails (A1-7) and online retails (A2-7). Furthermore, the amount of furniture waste (A7-8) is also the smallest among the three scenarios. The rest of the flows remain the same as the Baseline scenario since it was assumed that inhabitants did not change other furniture consumption patterns.

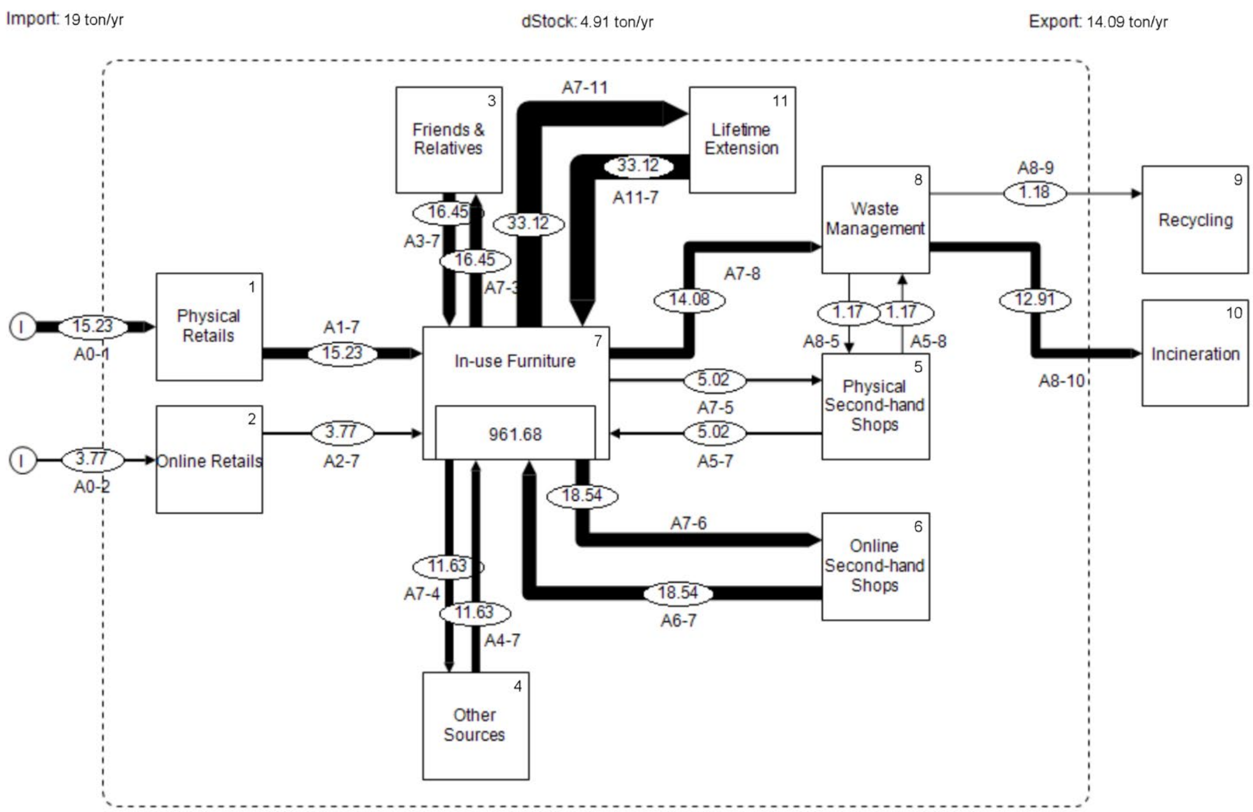


Figure 12 MFA of furniture in the Lifetime Extension scenario

The detailed stocks and flows of furniture by category are shown in Table 13 and Table 14 by weight and by unit respectively. In Table 13, we can see that storages constituted half of the lifetime-extended furniture by weight. By unit, storages became the second largest, behind chairs and before tables. On the other hand, textile furniture – bed and sofa – had the lowest values (Table 14).

Table 13 Stocks and flows of furniture in the Lifetime Extension scenario by weight

Lifetime Extension Scenario											
Unit: ton, ton/year	Stock	New furniture flows		Second-hand furniture flows					Waste flows		
Furniture category	In-use	Physical shops	Online shops	Physical shops or flea markets	Online markets	Friends or relatives	Other sources	Lifetime Extension	Resold	Recycling	Incineration
Bed	148.23	8.53	2.11	0.46	3.71	5.31	1.27	4.14	0.00	0.00	9.25
Chair	80.46	0.69	0.12	0.70	2.09	2.35	0.28	3.57	0.10	0.16	0.24
Sofa	119.61	2.12	0.42	0.65	3.65	1.40	1.65	4.93	0.44	0.00	1.84
Storage	504.25	2.96	0.96	1.99	5.33	5.00	8.06	15.65	0.50	0.81	1.26
Table	109.13	0.95	0.15	1.23	3.76	2.38	0.38	4.84	0.13	0.21	0.33
Total	961.68	15.23	3.77	5.02	18.54	16.45	11.63	33.12	1.17	1.18	12.91
		19.00		85.93						14.08	

Table 14 Stocks and flows of furniture in the Lifetime Extension scenario by unit

Lifetime Extension Scenario											
Unit: unit, unit/year	Stock	New furniture flows		Second-hand furniture flows					Waste flows		
Furniture category	In-use	Physical shops	Online shops	Physical shops or flea markets	Online markets	Friends or relatives	Other sources	Lifetime Extension	Resold	Recycling	Incineration
Bed	1732.34	88.13	17.63	5.15	46.38	65.71	14.17	41.13	0.00	0.00	91.91
Chair	8469.22	65.07	11.68	79.88	167.50	266.71	60.56	338.13	9.06	14.76	22.87
Sofa	2329.03	43.81	14.02	20.62	46.38	36.08	46.38	112.25	10.06	0.00	41.79
Storage	11375.70	63.65	16.23	42.52	109.52	77.31	211.31	319.54	10.17	16.56	25.66
Table	4600.32	41.95	5.72	76.02	118.54	96.63	24.48	210.02	5.63	9.17	14.21
Total	28506.61	302.61	65.28	224.19	488.33	542.44	356.90	1021.07	34.92	40.49	196.44
		367.89		2667.86						236.93	

Life Cycle Analysis

Baseline Scenario

Table 15 shows the carbon footprint of furniture in the Baseline scenario using the EPD format. In total, the system has a carbon footprint of 217.18 tons CO_2-eq. Of these, 45% are from the product stage and 33% are from the end-of-life stage. In other words, most of the emissions are from manufacturing and waste handling. The construction process stage has a carbon footprint of only 22% while the use stage is not considered in this study.

Table 15 Carbon footprint of furniture in the Baseline scenario

Baseline Scenario								
Unit: ton CO_2-eq	Product stage			Construction process stage		End of life stage		Lifecycle emission
	A1	A2	A3	A4	A5	C2	C3	A1-D
Furniture category	Raw material supply	Transport	Manufacturing	Transport	Construction - Installation process	Transport	Waste processing	Total
Bed	29.33			4.72	5.17	1.71	16.81	57.74
Chair	13.85			4.00	3.71	1.93	5.16	28.65
Sofa	17.75			3.37	3.97	1.98	8.50	35.57
Storage	18.71			7.57	5.06	2.32	23.04	56.69
Table	18.77			4.45	5.31	2.99	6.99	38.51
All	98.41			24.11	23.23	10.93	60.50	217.18

By sorting the GHG emissions by MFA process, the source of emissions can be inspected in more detail (Figure 13). For new furniture in ‘physical retails’ and ‘online retails’, almost all of the emissions are from manufacturing with a very small amount of emissions from transportation and electricity. In the ‘physical second-hand shops’, ‘online second-hand shops’, ‘friends and relatives’, and ‘other sources’, approximately half of the emissions are from materials needed to repair second-hand furniture. The other half is transportation and almost none from electricity. In 'waste management', incineration is the dominant source of emissions compared to recycling and transportation.

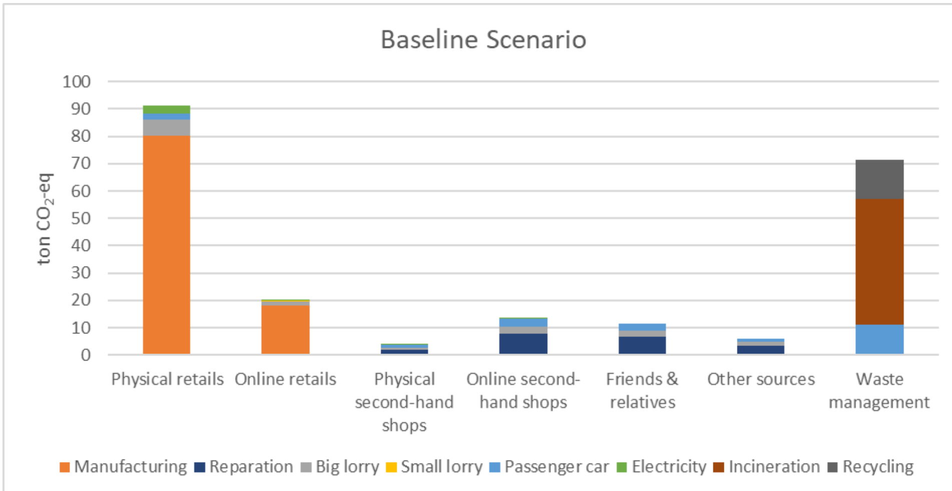


Figure 13 Carbon footprint of furniture in the Baseline scenario by MFA process

Second-hand Scenario

The carbon footprint of the Second-hand scenario is 134.22 tons CO_2-eq, 61% of the Baseline scenario. 34% of the emissions are from the product stage, 45% from the construction process stage, and 21% from the end-of-life stage (Table 16). There is a large increase in carbon footprint in the construction process stage compared to the Baseline scenario. This is due to the increase in the flows of second-hand furniture in the system.

Table 16 Carbon footprint of furniture in the Second-hand scenario

Second-hand Scenario								
	Product stage			Construction process stage		End of life stage		Lifecycle emission
Unit: ton CO_2-eq	A1	A2	A3	A4	A5	C2	C3	A1-D
Furniture category	Raw material supply	Transport	Manufacturing	Transport	Construction - Installation process	Transport	Waste processing	Total
Bed	29.33			4.72	5.17	1.71	16.81	57.74
Chair	1.55			5.22	5.95	0.04	0.10	12.85
Sofa	7.74			3.89	5.72	0.75	3.21	21.31
Storage	5.35			8.62	7.00	0.49	4.87	26.33
Table	2.16			5.27	8.32	0.07	0.16	15.99
All	46.14			27.72	32.15	3.05	25.16	134.22

Figure 14 shows the emissions by MFA process. Like the Baseline scenario, GHG emissions are highest in ‘physical retails’ with manufacturing as the main source of emissions. Emissions from incineration under ‘waste management’ also remain the second highest. Overall emissions are lower than the Baseline scenario in every MFA process except in ‘physical second-hand shops’ and ‘online second-hand shops’ due to the increase in second-hand furniture flows. More repair materials and transportation are needed, which leads to an increase in emissions. Emissions from electricity under these two processes remain marginal despite the increase in second-hand operations.

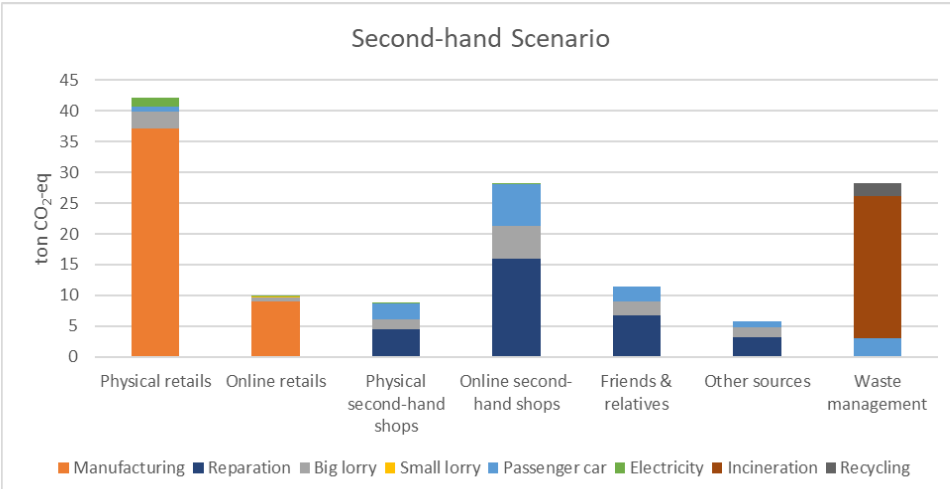


Figure 14 Carbon footprint of furniture in the Second-hand scenario by MFA process

Lifetime Extension Scenario

The carbon footprint of the Lifetime extension scenario is 115.11 tons CO_2-eq, which is equivalent to 53% of the Baseline scenario. 32% of the emissions are from the product stage, 22% from the construction process stage, and 18% from the end-of-life stage (Table 17). In addition, there are also emissions from reparation in the use stage, which makes up 28% of the total emissions. Unlike in the Second-hand scenario where all emissions from reparation are categorized under the construction-installation process, in this scenario, emissions from reparation are divided into two parts. For the second-hand furniture that changes ownership, the associated emissions are categorized under the construction-installation process as usual. However, when furniture gets its lifetime extended by the same users, the associated emissions are categorized under repair according to the EPD standard.

Table 17 Carbon footprint of furniture in the Lifetime Extension scenario

Lifetime Extension Scenario									
Unit: ton CO_2-eq	Product stage			Construction process stage		Use stage	End of life stage		Lifecycle emission
	A1	A2	A3	A4	A5	B3	C2	C3	A1-D
Furniture category	Raw material supply	Transport	Manufacturing	Transport	Construction - Installation process	Repair	Transport	Waste processing	Total

Bed	21.12	4.69	0.65	5.91	1.18	11.62	39.26
Chair	2.56	4.23	0.06	5.68	0.19	0.52	7.57
Sofa	6.03	3.30	0.17	5.83	0.54	2.31	12.35
Storage	3.74	7.71	0.26	6.89	0.27	2.69	14.67
Table	3.47	4.42	0.09	7.96	0.30	0.70	8.98
All	36.93	24.35	1.24	32.28	2.48	17.83	115.11

Emissions from manufacturing in 'physical retails' remain the highest source of emissions, followed by emissions from incineration in 'waste management'. Emissions from 'physical second-hand shops', 'online second-hand shops', 'friends and relatives', and 'other sources' are the same as the Baseline scenario because of the shared assumptions. However, in this scenario, there is an additional source of emissions from 'lifetime extension', which constitutes mostly of materials needed for reparation. Overall, emissions from transport are the smallest in this scenario compared to the previous scenarios. Emissions from electricity also remain marginal like in the other two scenarios.

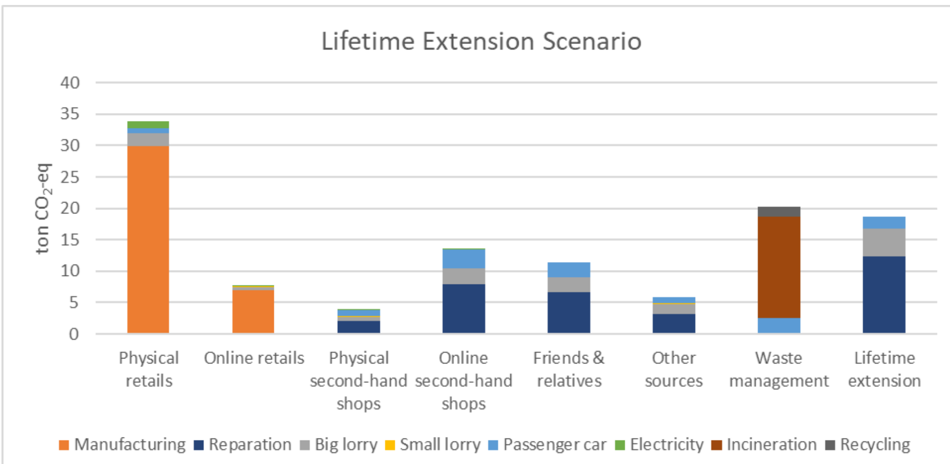


Figure 15 Carbon footprint of furniture in the Lifetime Extension scenario by MFA process

Comparison of Scenarios

Comparing the three scenarios, we can see that there is a potential to reduce carbon footprint by 39% in the Second-hand scenario and by 47% in the Lifetime extension scenario (Figure 16, Figure 17, and Figure 18). In all three scenarios, the largest sources of emission are physical retails and waste management respectively (Figure 16). The third-largest sources of emissions, however, are different in all scenarios. It is 'online retails' in the Baseline scenario; 'online second-hand shops' in the Second-hand scenario; and 'lifetime extension' in the Lifetime extension scenario (Figure 16). When we look at the contribution of the emissions, we can see that materials – manufacturing and reparation – make up approximately half of the emissions in all three scenarios (Figure 17). We also notice that manufacturing has a reverse relationship to reparation. The more furniture is repaired, the less new furniture is manufactured. Incineration is the second-largest source of emissions, though the amount decreases in the Second-hand and Lifetime Extension scenarios due to the decreases in furniture waste. Emissions from recycling display the same pattern as the emissions from incineration. Emissions from transportation decrease in both Second-hand and Lifetime extension scenarios. Emissions from electricity remain marginal in all three scenarios.

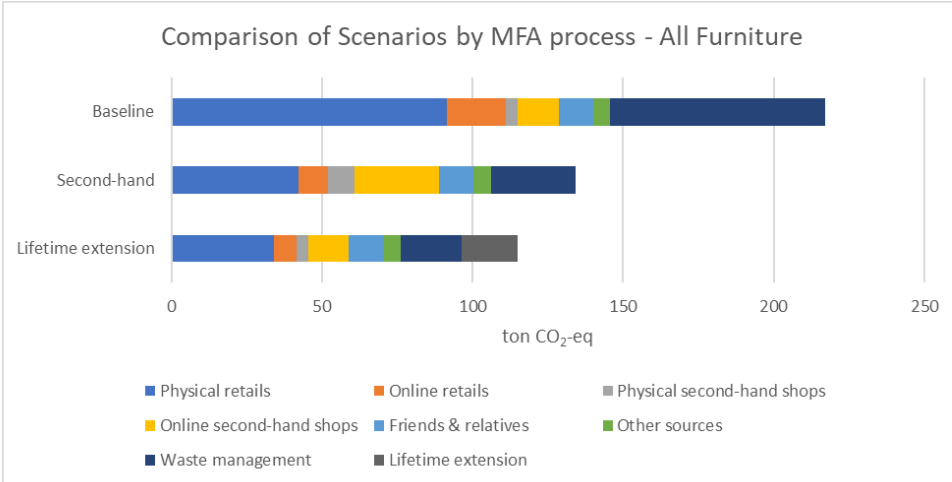


Figure 16 Carbon footprints of furniture in the three scenarios by MFA process

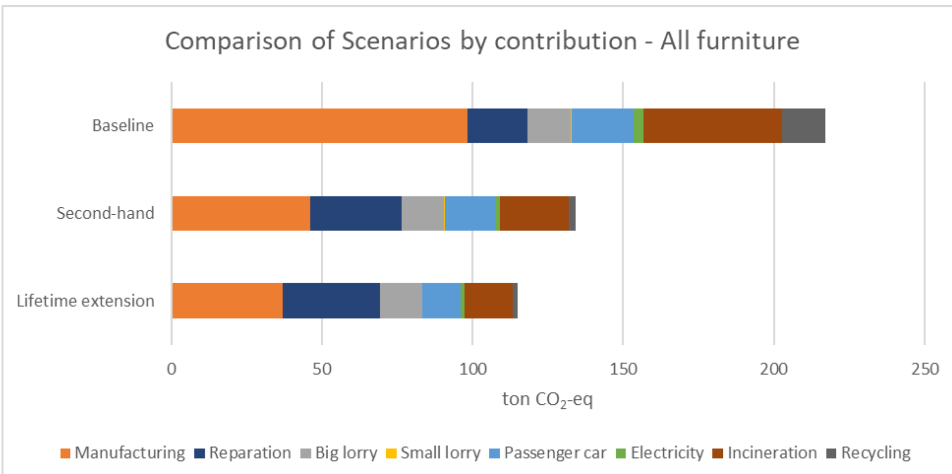


Figure 17 Carbon footprints of furniture in the three scenarios by contribution

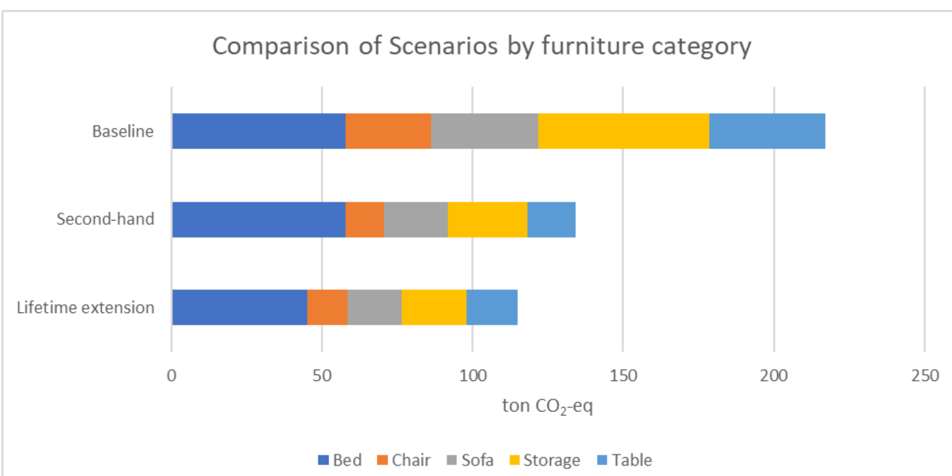


Figure 18 Carbon footprints of furniture in the three scenarios by furniture category

The LCA results for each type of furniture show that different circular economy approaches have different levels of effectiveness for different furniture. For beds, it is not possible to reduce the carbon footprint in the Second-hand scenario compared to the Baseline (Figure 19 and Figure 20) since the inhabitants are already using more used beds than they are willing to as stated in the methodology. For sofas (Figure 23 and Figure 24) and storages (Figure 25 and Figure 26), more carbon footprints are reduced in the Second-hand scenario than in the Lifetime Extension scenario. On the other hand, the opposite is true for chairs (Figure 21 and Figure 22) and tables (Figure 27 and Figure 28), more carbon footprint can be reduced in the Lifetime Extension scenario than in the Second-hand scenario.

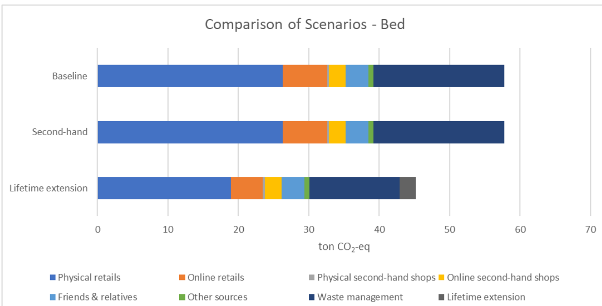


Figure 19 Carbon footprints of beds by MFA process

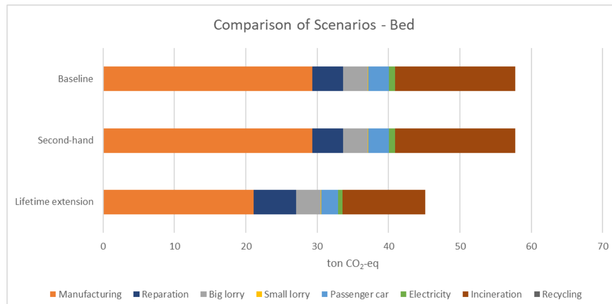


Figure 20 Carbon footprints of beds by contribution

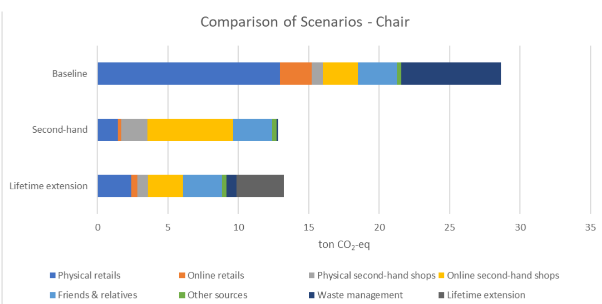


Figure 21 Carbon footprints of chairs by MFA process

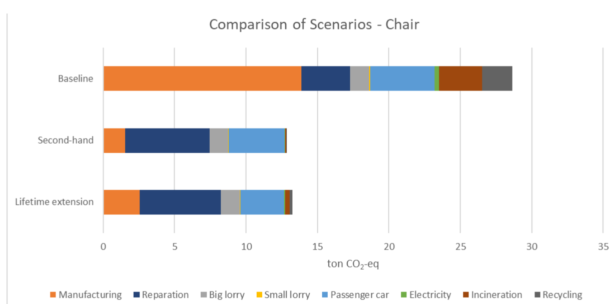


Figure 22 Carbon footprints of chairs by contribution

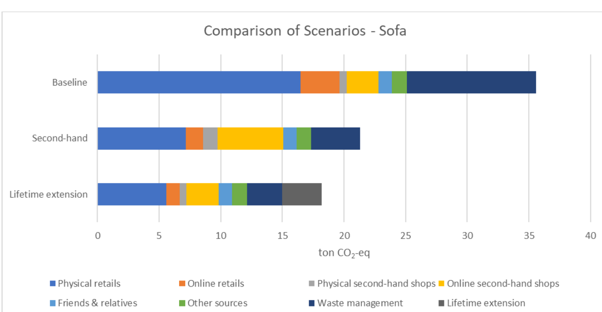


Figure 23 Carbon footprints of sofas by MFA process

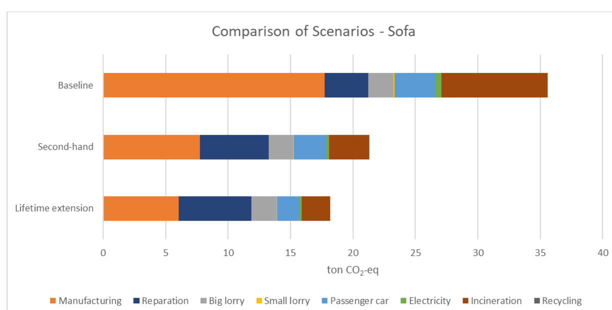


Figure 24 Carbon footprints of sofas by contribution

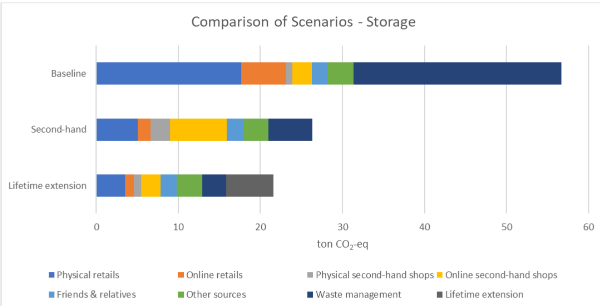


Figure 25 Carbon footprints of storages by MFA process

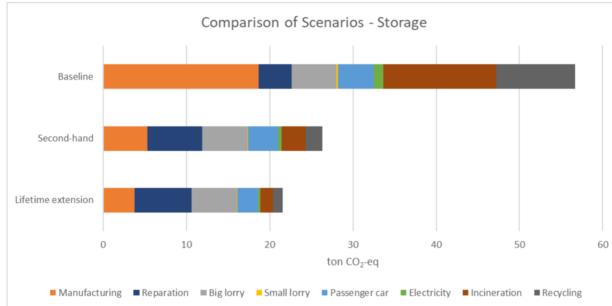


Figure 26 Carbon footprints of storages by contribution

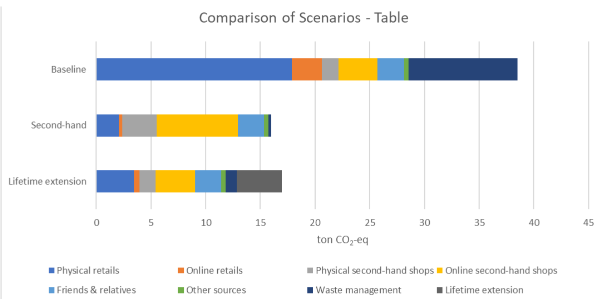


Figure 27 Carbon footprints of tables by MFA process

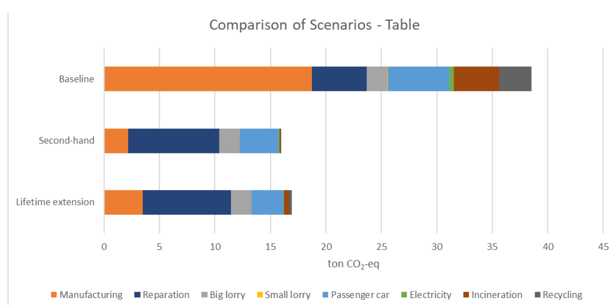


Figure 28 Carbon footprints of tables by contribution

Combination of MFA and LCA

To get a comprehensive understanding of the environmental impacts of furniture in the neighborhood, MFA is combined with LCA in a Sankey diagram format. Material flows of furniture in ton are represented by the Sankey flows in five furniture categories with different colors. Carbon footprint of furniture is represented by different colored dots based on the sources of emissions.

In the Baseline scenario (Figure 29), furniture has a flowthrough characteristic. Once old furniture reaches the end of life, inhabitants prefer to replace it with new furniture. This results in a very top- and bottom-heavy distribution of carbon footprint. Most emissions are allocated at the beginning and the end of the system. In the middle, some furniture flow in a circular manner. Of these, approximately half involve financial transactions while another half are given from peer to peer. Both types of circular flows have approximately the same amount of carbon footprint – mainly from reparation and transport. The nature of the transaction has a very marginal effect on the carbon footprint.

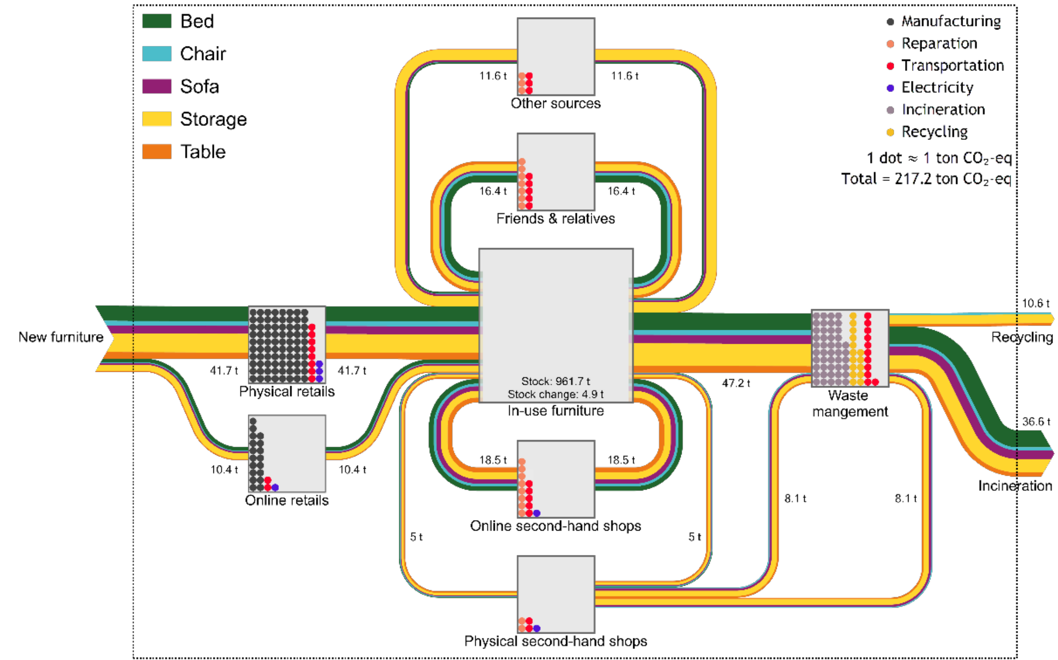


Figure 29 Sankey diagram with material flows and carbon footprint of furniture in the Baseline scenario

In the Second-hand scenario (Figure 30), the amount of furniture that flows through the system decreases by almost half. As a result, the carbon footprint at the beginning and the end of the system decreases accordingly. There is a large circulation of second-hand furniture in this scenario, especially through an online channel. Yet, despite the increased circulation, the carbon footprint of second-hand furniture does not increase proportionately. This illustrates the emission reduction potential of using second-hand furniture.

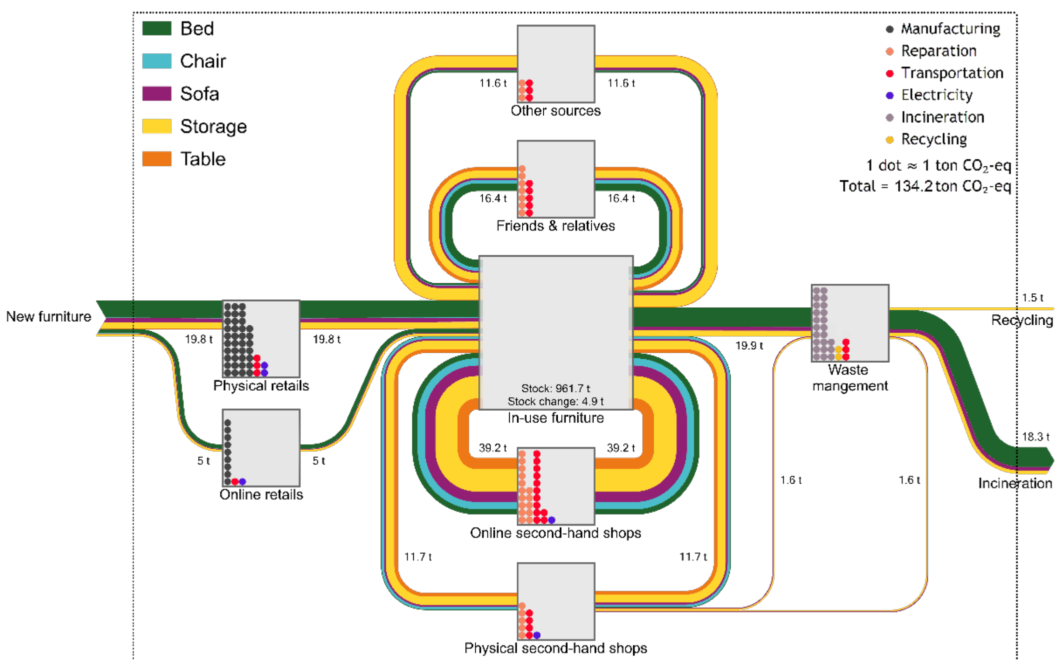


Figure 30 Sankey diagram with material flows and carbon footprint of furniture in the Second-hand scenario

In the Lifetime Extension scenario (Figure 31), furniture flows through the system the least among the three scenarios; thus, reducing the carbon footprint substantially. The circularity of furniture increases because inhabitants repair furniture to extend its lifetime. Since the reparation takes place at home, the amount of transportation required is a lot less than in the Second-hand scenario. As a result, the carbon footprint of this scenario is also the lowest among the three scenarios.

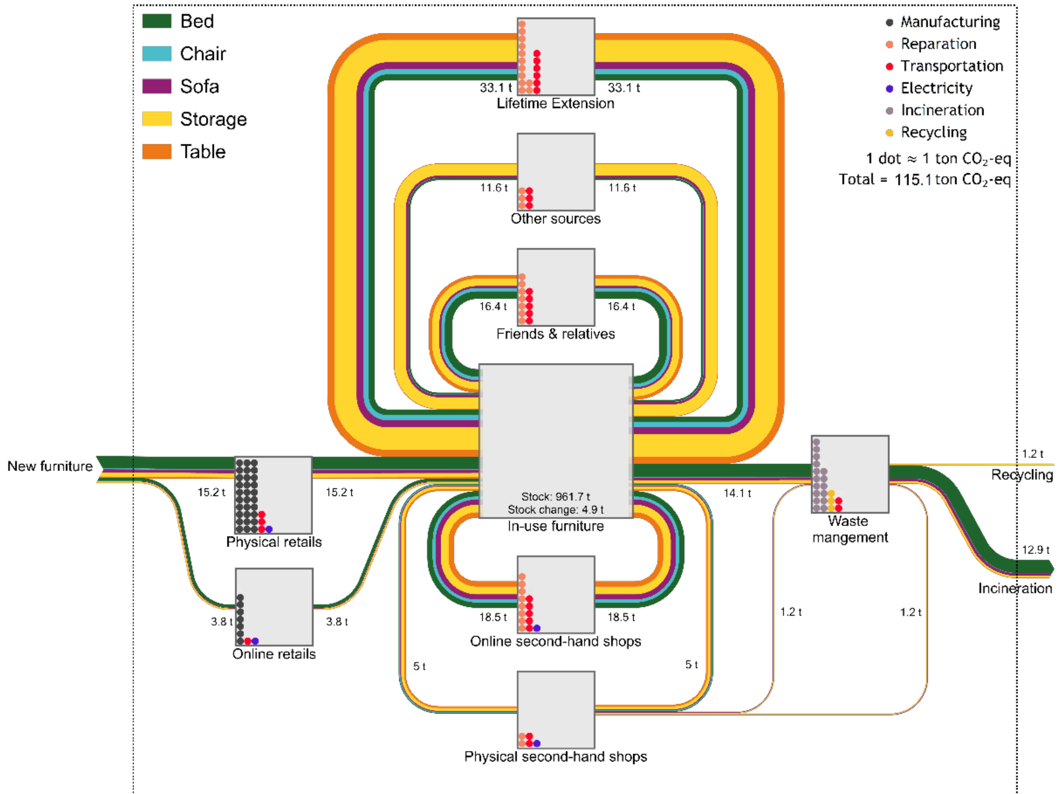


Figure 31 Sankey diagram with material flows and carbon footprint of furniture in the Lifetime Extension scenario

Discussion

This study aims to understand the consumption patterns of furniture in a neighborhood and to discern the carbon footprint associated with it. Furthermore, the study aims to explore alternative scenarios that can reduce carbon footprint and promote circular economy, in accordance with the national strategies (Klima- og miljødepartementet, 2021b; Regheringen, 2021). Three research questions were asked:

1. What are the material flows of furniture in a newly built neighborhood in 2021?
2. What is the carbon footprint of furniture in the neighborhood?
3. What are the potentials for circular economy in terms of material flows and carbon footprint?

A hypothetical neighborhood in Trondheim with the same characteristics as Zero Village Bergen was used as the reference neighborhood. MFA was used as a tool to answer the first question; LCA was used to answer the second research question, and scenario analysis was used to answer the third research question.

Scenarios

Baseline Scenario

The Baseline scenario represents the current furniture consumption pattern and the associated carbon footprint of the neighborhood. In other words, it answers the first and second research questions. The MFA result (Figure 10), when compared to Krych and Pettersen (2021b)'s dynamic MFA of furniture in Norway, shows a similar stock, inflows, and outflows ratios (Thongsawas, 2021). Furthermore, both studies show that the current consumption pattern of furniture in Norway has a high flowthrough characteristic and low level of circularity (Figure 29). This is likely because the perception of furniture has changed from being viewed as a lifelong durable in the past to a fashion item (Leslie & Reimer, 2003). Krych and Pettersen (2021a) also found that furniture lifetime in Norway has decreased from approximately 22 years to 10 years during the past century. The MFA also illustrated consumers' behaviors. Inhabitants prefer to purchase new furniture at physical stores but prefer to purchase second-hand furniture online. This could be because IKEA has a large furniture collection and arrange the stores in the same format as rooms in customers' homes; thus, making browsing a more enjoyable and convenient experience. On the other hand, browsing physical second-hand shops can be challenging due to the randomness of furniture selection and the lack of organization. It is often easier to browse online for a piece of specific second-hand furniture. Studies have shown that consumers rank convivence as a high priority when obtaining second-hand furniture (Chiu & Mont, 2021; Gullstrand Edbring et al., 2016). Furthermore, the selection of second-hand furniture is much larger online than in physical shops (Thongsawas, 2021); thus, giving consumers higher chances to find a piece of furniture that meet their needs and fashion styles. Approximately half of the second-hand furniture circulating in the system is peer-to-peer trading instead of business transactions. This implies that half of the second-hand exchanges are not included in the GDP. At the end of life, only a small percentage of furniture waste is recycled. Most go into incineration. This is very common in Norway where incineration is the primary mean of waste handling (Wågøynes et al., 2018).

The carbon footprint of furniture in the neighborhood displays a polarized characteristic. Most of the emissions in the system are concentrated in the production process and the waste treatment process

(Figure 13). This is in line with other studies, which stated that materials are the highest sources of emissions in furniture (Antov & Pancheva, 2017; Lanoë et al., 2013; Linkosalmi et al., 2016; Mirabella et al., 2014), follows by waste handling as the second largest (Geyer et al., 2016; Spitzley et al., 2006). The third biggest source of emissions is reparation. The model assumed that all furniture after reaching the end of life needs to be repaired if it is to be given or sold to a new owner. The average materials needed for reparation is 20% (Lauvland, 2021). In reality, since not all second-hand furniture needs repairing, it is possible that the calculated carbon footprint from reparation is overestimated. Furthermore, the percentage of materials needed for reparation varies depending on the type and condition of furniture. Lauvland (2021) stated that repair materials can range between 10-30%. Transport is the second-lowest source of emissions. This is similar to other EPDs of furniture where A2 and A4 are lower than A1 and A3 (EPD, 2022b). Upon closer inspection, the LCA result shows that most emissions associated with transport are from passenger cars instead of lorries. This is because of the large number of trips needed for inhabitants to pick up and deliver furniture. In most cases, since households only obtain one or two pieces of furniture at a time, the load efficiency is very low. On the contrary, companies' lorries usually try to load as much furniture as possible per trip; thus, making the load efficiency very high. Finally, the lowest source of emissions is electricity. It is marginal in this study due to the clean hydropower in Norway (Mjønerud, 2019). If the study is carried out in other countries, the emissions will be higher, but not by a significant amount since there is no electricity associated with the in-use phase of furniture. The main source of electricity consumption is the electricity needed to operate retail shops. Electricity needed to run websites is very low in comparison.

Second-hand scenario

The Second-hand scenario represents the inhabitants' willingness to obtain second-hand furniture in place of new furniture. Since the MFA model was created based on the consumer survey carried out by Thongsawas (2021), it should be noted that result should be seen as the highest possible potential. In reality, fewer inhabitants will engage in obtaining second-hand furniture. This is because of the intention-behavior discrepancy (Arli et al., 2018; Gupta & Sen, 2013). It is common for humans to not act according to their declared intentions (Ajzen et al., 2004). In this case, the reasons could include: wishing to look or feel good while answering the survey, high inconvenience from purchasing second-hand furniture, and the similarity of prices between new and second-hand furniture (Gullstrand Edbring et al., 2016). Given this understanding, the MFA shows that the inhabitants were willing to engage in obtaining a large portion of furniture second-hand, especially through online second-hand shops. The circularity of furniture in the system could increase by up to 35%, which translates to a 52% reduction in new furniture inflows and a 58% reduction in waste outflows (Figure 11). A similar study in Switzerland shows a slightly different result. Wiprächtiger et al. (2022) found that the degree of furniture circularity under the REUSE scenario can increase to 53%; however, the number of new furniture obtained could only be reduced by 32%. The discrepancy is likely due to the difference in consumers' furniture consumption patterns in Norway and Switzerland.

Emissions-wise, the Second-hand scenario has the potential to reduce emissions by 39% compared to the Baseline scenario (Figure 18). The result is lower than that of Lauvland (2021), where a maximum of 59% carbon footprint reduction could achieve by using second-hand furniture in commercial buildings. The potential is lower in this study because inhabitants' willingness to obtain second-hand furniture was used; while in Lauvland (2021), it was assumed that all furniture was obtained second-hand. On the other hand, Wiprächtiger et al. (2022) showed that only 17% emissions reduction could be achieved in the REUSE scenario. The lower saving potential in Wiprächtiger et al. (2022) was due to the rebound effect, which is not considered in this study. It is possible that, if the rebound effect is accounted for, the reduction of carbon footprint in this study will be considerably lower, based on the Norwegian consumers' rebound behaviors (Lekve Bjelle et al., 2018). In this scenario, beds were not considered to have GHG emissions reduction potential since, according to the survey conducted by Thongsawas (2021), Norwegian consumers were already using more used beds than they wish to. However, if beds are taken into consideration, their GHG emissions reduction potential could be up to 67% (Geyer et al., 2016). Distribution-wise, emissions from furniture production and waste handling remain the highest sources; however, the materials needed for repairing second-hand furniture have also increased due to the increase in the circularity of the system. This tradeoff is unavoidable, though it is still much lower than the decreased GHG emissions from the production of new furniture; thus, resulting in a large reduction potential. Emissions from transport, particularly passenger cars, also decrease in this scenario (Figure 17). This is because of the modeling choice. Inhabitants were modeled to use passenger cars to pick up new furniture, pick up second-hand furniture, and deliver waste. Since an increase in second-hand furniture means a decrease in both new furniture and waste, the number of trips associated with these activities is reduced roughly by a 2:1 ratio for every increase in second-hand furniture consumption. In contrast to this study, Mora Sojo and Pettersen (2021) found that scenarios with increased circularity have higher transportation. This is likely due to the nature of the items of study. For smaller items such as clothing in Mora Sojo and Pettersen (2021)'s study, consumers can dispose of waste directly in household waste bins, while for bigger items such as furniture, additional trips to the recycling center are required to dispose of the items.

Lifetime Extension Scenario

The Lifetime Extension scenario represents the inhabitants' willingness to extend furniture lifetime by reparation. This scenario is also developed based on the survey conducted by Thongsawas (2021); thus, it represents the maximum potential. In reality, fewer inhabitants will engage in repairing furniture at the end of life due to intention-behavior discrepancy (Arli et al., 2018; Gupta & Sen, 2013). This scenario has the highest level of circularity at 44% higher than the Baseline scenario. The amount of new furniture inflows decreased by 64% and the amount of waste outflows decreased by 70% (Figure 12). In Switzerland, it was found that, under the REDUCE scenario, the new furniture inflows could be decreased by 27% (Wiprächtiger et al., 2022), which is twice less than in this study. This is likely because the homeownership rate in Norway is almost twice higher than in Switzerland (Statista Research Department, 2021); thus, giving less incentive for inhabitants to relocate and more incentives to preserve older furniture.

The total carbon footprint of the Lifetime Extension scenario is 47% lower than the Baseline scenario (Figure 18); thus, making this scenario the one with the lowest carbon footprint. Despite having slightly lower consumers' willingness to engage in alternative consumption in four furniture categories compared to the Second-hand scenario, there is a higher willingness to repair beds than to buy second-hand beds (Thongsawas, 2021). As a result, the decrease in GHG emissions of beds contributes substantially to the overall reduction of carbon footprint. Furthermore, since furniture reparation was assumed to take place at the inhabitants' dwellings, transport as well electricity needed to run second-hand shops are also lower. The carbon footprint reduction potential is very close to the study by

Lauvland (2021), where a 46% reduction was achievable by extending the lifetime of all furniture in commercial buildings. On the contrary, Wiprächtiger et al. (2022) estimated that there would be no reduction in GHG emissions from extending furniture lifetime due to the rebound effect. Despite having the lowest carbon footprint among the three scenarios, it cannot be concluded that extending the lifetime is the best measure to reduce the carbon footprint. The type of furniture also plays an important role in determining the most suitable measure. Lifetime extension is most appropriate for furniture with low manufacturing GHG emissions such as sofas (Figure 23 and Figure 24) and storages (Figure 25 and Figure 26), and furniture that is not suitable to be reused such as beds (Figure 19 and Figure 20). For furniture that has high manufacturing GHG emissions such as chairs and tables, the total carbon footprints are lower in the Second-hand scenario.

System performance

The LCA results were normalized by weight and by unit (Figure 32 and Figure 33) so that they could be compared to the LCA of furniture in other literature. It should be noted that the carbon footprint by weight is the same for all three scenarios because of the shared methodology. The carbon footprint by unit, while approximately the same in all scenarios, has a slight variation due to conversion. For illustration, the carbon footprint from the Baseline scenario was used to show the system performance. By weight, chairs and tables have the highest carbon footprint, followed by sofas, storages, and beds. By unit, the results are almost the opposite. Chairs and tables have the lowest carbon footprint, followed by storages sofas and beds. This indicates that chairs and tables have higher carbon footprint densities than other types of furniture and that textile furniture such as beds and sofas don't have high carbon density but have more materials per unit; thus, resulting in a higher carbon footprint per unit. When compared to other literature, cradle-to-grave carbon footprint per unit of chairs and tables are in the same range as Spitzley et al. (2006) while cradle-to-gate carbon footprint per kg of storage is close to Linkosalmi et al. (2016). There is, however, a lack of LCA literature for beds and sofas, besides the inventory data sources used in this study, for comparison. This is because, unlike office furniture, household furniture is generally not required to declare environmental impacts.

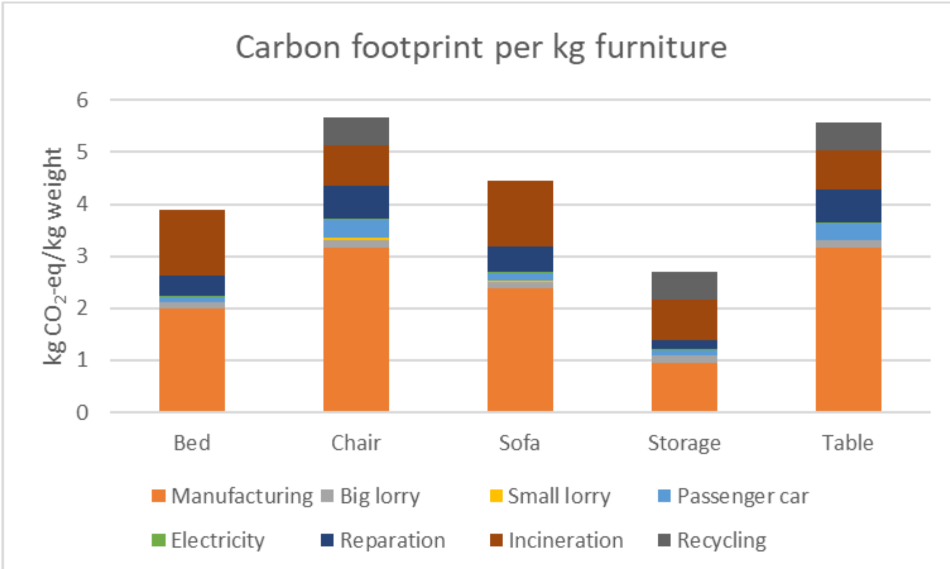


Figure 32 Carbon footprint of furniture by weight

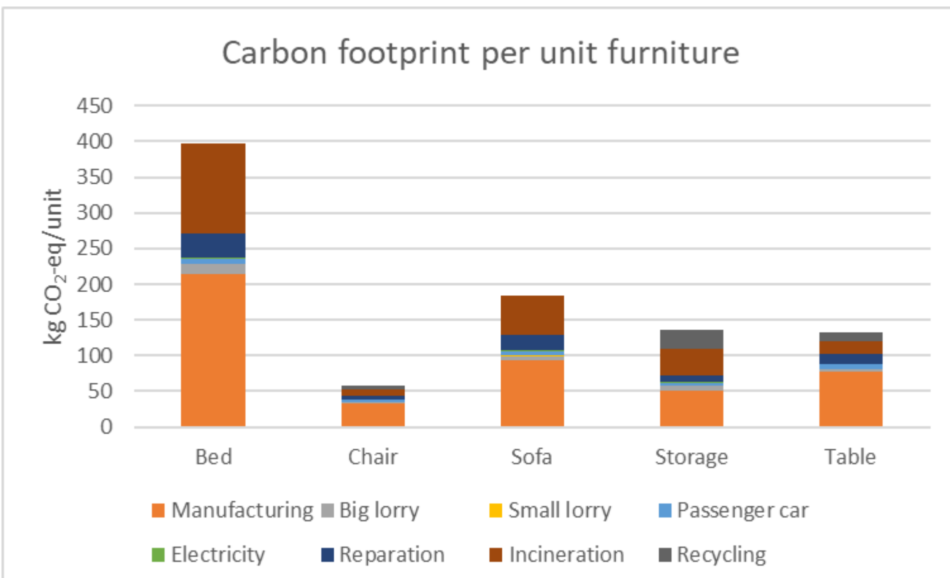


Figure 33 Carbon footprint of furniture by unit

Contextualization with Furniture Stock

While the carbon footprint of in-use furniture stock was not the main focus of this study since it doesn't affect the potential for circular economy of furniture, its carbon footprint is nonetheless calculated to give context to the results of this study. Note that the carbon footprint of stock in the three scenarios was the same because an assumption of constant stock and stock change was assumed in the methodology. Both the stock and flows were also normalized by area and population to show the intensity of carbon footprint. The result shows that, in this neighborhood, furniture stock has more carbon intensity than furniture flows, between 4.07 times in the Baseline scenario and 7.67 times in the

Lifetime Extension scenario. In other words, there is a substantial potential for reduction of carbon intensity in both scenarios (Table 18, Table 19, and Table 20).

Table 18 Carbon footprint of stock and flows of furniture in the Baseline scenario by area and population

Baseline Scenario				
kg CO_2-eq	Per m^2	Per dwelling	Per inhabitant	Per household
Stock	38.43	5081.09	2635.34	5244.33
Flows	9.45	1249.95	648.29	1290.11
Stock & flows	47.88	6331.04	3283.64	6534.43

Table 19 Carbon footprint of stock and flows of furniture in the Second-hand scenario by area and population

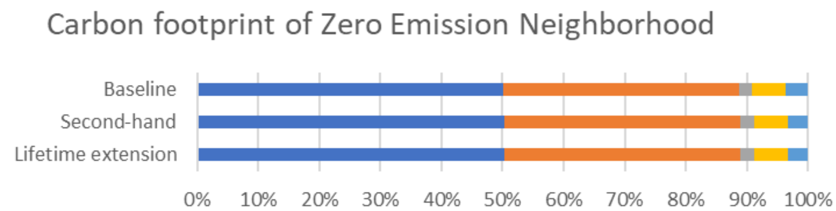
Second-hand Scenario				
kg CO_2-eq	Per m^2	Per dwelling	Per inhabitant	Per household
Stock	38.43	5081.09	2635.34	5244.33
Flows	5.84	772.50	400.66	797.32
Stock & flows	44.27	5853.59	3036.00	6041.65

Table 20 Carbon footprint of stock and flows of furniture in the Lifetime Extension scenario by area and population

Lifetime Extension Scenario				
kg CO_2-eq	Per m^2	Per dwelling	Per inhabitant	Per household
Stock	38.43	5081.09	2635.34	5244.33
Flows	5.01	662.51	343.61	683.79
Stock & flows	43.44	5743.60	2978.96	5928.12

Contextualization with Zero Emission Neighborhood

The carbon footprint of furniture for both stock and flows were combined and put into the context of Zero Emission Neighborhood (Lausselet et al., 2019) under the assumption that buildings in the neighborhood have a lifetime of 60 years (Standard Norge, 2011, 2018) while furniture has a lifetime of 15 years (EPD, 2022b; Lauvland, 2021); thus, four cycles of furniture is needed. Zero Emission Village in Bergen (Lausselet et al., 2019) is used as a reference since this study based the neighborhood size and population on the village. The result shows that the carbon footprints of furniture, in the Baseline scenario, Second-hand scenario, and Lifetime Extension scenario, constitute 3.62%, 3.36%, and 3.3% of the total emissions of the neighborhood respectively. However, if only emissions from buildings and furniture are considered, emissions from furniture constitute 7.23%, 6.69%, and 6.56% respectively. The values are in a close range with Lauvland (2021) where emissions from furniture in commercial buildings were averaged to be 8.73%, 3.87% and 4.95% in respective scenarios. It is likely that the values in Lauvland (2021) for the Baseline scenario were higher than in this study because the literature assumed that all furniture were new, while in this study, a mixture of new and second-hand furniture that reflects the current consumption pattern is assumed. On the other hand, the values for the Second-hand and Lifetime Extension scenarios in Lauvland (2021) are lower than in this study because the literature assumed that all furniture were obtained second-hand or all had thier lifetime extended respectively. While in this study, consumers' willingness to obtain second-hand furniture and extend furniture lifetime were used respectively.



ton CO_2-eq	Lifetime extension	Second-hand	Baseline
Buildings	60840	60840	60840
Mobility	46800	46800	46800
Open spaces and networks	2691	2691	2691
On-site energy	6669	6669	6669
Furniture	3992	4068	4400

Buildings Mobility Open spaces and networks On-site energy Furniture

Figure 34 Carbon footprint of the zero-emission neighborhood with furniture included

Limitations and Uncertainties

In the study, both MFA and LCA models yield accurate results. The result from the MFA model is in line with Krych and Pettersen (2021a); and the result from the LCA model is in line with Lauvland (2021); Linkosalmi et al. (2016); Spitzley et al. (2006); Wiprächtiger et al. (2022). Nonetheless, in the process of creating the MFA and LCA models, several assumptions were made to best reflect the reality. As a result, there are uncertainties related to the models. In the MFA, the survey by Thongsawas (2021) was used as the source of data to determine the material flows of the neighborhood. Thongsawas (2021) stated that the sample size of the participants might not be big enough to accurately represent the average residents of Trondheim. The participants were younger, had higher incomes, and were more environmentally conscious than average. This study addressed the problem by framing the neighborhood to be suitable for this demographic since it's likely that it's the population in this age group who is looking to purchase a first home. Another problem associated with using a survey is that participants were not able to recall the items they no longer have (Thongsawas, 2021); thus, resulting in very low outflows. This problem was addressed by using the data from the furniture dynamics model (Krych & Pettersen, 2021b) in combination with waste sampling data (Wågøynes et al., 2018). It was, however, necessary to assume that inflows and outflows between processes involving second-hand furniture and furniture waste were the same due to the limited availability of the end-of-life data. In reality, the combination of all inflows and outflows should be the same, but each pair of the inflow and outflow would be different.

The LCA model developed is a simplification of reality. The GHG emissions inventory data used for chairs, sofas, storages, and tables were average data from EPD, which documents mostly office furniture. As a result, the emissions used were likely higher than the emissions associated with household furniture. In addition, the GHG emissions inventory data used for chairs was based on a study in the United States since European data was not available at the midpoint. Thus, it is likely that the emissions used were higher than in reality since the USA used more coal and oil as energy sources than the EU (eia, 2021; eurostat, 2022). Transportation is another element that was simplified in the model. From manufacturers to retailers, it was assumed that all productions took place in Zbaszynek, Poland while in reality, furniture is produced at various locations. Furthermore, it was assumed that the inhabitants picked up all new furniture at IKEA and all second-hand furniture at the city center or BurkOm. In reality, these locations are not fixed and are diverse. An assumption was also made that the inhabitants picked up a certain number of furniture at a time with fixed car types and fuel types. Since Norway has a higher distribution of electric cars than most countries (Carlier, 2022), the emissions associated with transport should be lower. Electricity usage by shops and websites was also estimated based on research and average data. It is uncertain if the real value is higher or lower. When it comes to reparation, the materials needed were assumed to be 20% while Lauvland (2021) stated that they can range from 10% to 30% in practice, depending on the conditions of furniture. Finally, due to the lack of accurate data, only wooden furniture – chair, storage, and table – were assumed to be partially recycled. All textile furniture such as beds and sofas were assumed to be incinerated. While the assumption is generally true in Norway, in reality, what is recycled is determined by automated waste-handling processes; thus, it’s likely that every piece of furniture has a different recycling rate. Of all the input data and factors influencing the LCA model, GHG emissions associated with the manufacturing and waste handling process are the most influential factors that determine the carbon footprint. Emissions from materials are the most sensitive factors, follows by emissions from incineration.

It is also important to keep in mind that this study does not take into account intention-action discrepancy; thus, making the study represents the best-case scenario. In practice, there is a high probability that the inhabitants will not use as much second-hand furniture or repair as much furniture at the end of life as they intended. Furthermore, it is very likely that the reduction of the carbon footprint from both Second-hand and Lifetime Extension scenarios will not be as big as the results in this study due to the rebound effect (Lekve Bjelle et al., 2018; Ottelin et al., 2020). Wiprächtiger et al. (2022) suggested that the rebound effect of circular furniture consumption can completely cancel out all the emissions reduction.

Policies

The result of this study shows that there is a potential to reduce the carbon footprint associated with furniture in a neighborhood by half by shifting consumers’ behaviors. For furniture with high carbon density such as chairs and tables, it is more effective to promote the use of second-hand furniture. This can be done by campaigning for consumers to be more environmentally conscious and less wasteful. Given that consumers, in general, are open to using second-hand items to reduce their environmental impacts (Cherry et al., 2018; Chiu, 2020; Gullstrand Edbring et al., 2016; Watson, 2008), promoting such behavior change should not receive much resistance. It’s the role of the government and non-profit environmental organizations – Framtiden I våre hender, Naturvernforbundet, Spire, and others – to encourage this behavior change. Infrastructure will also be needed to allow consumers to have easy access to second-hand furniture. Current infrastructure such as second-hand shops – BurkOm and others – already exist; however, they do not match consumers' preferences and behaviors. Instead of expanding physical second-hand shops, which will lead to more inventory costs, digitalization of the inventory system should be the focus since consumers prefer to obtain second-hand furniture online (Thongsawas, 2021). This will increase the rate of turnover without significantly increasing operating and inventory costs. Furthermore, the advertising fee on Finn.no should be lowered for second-hand items. Lowering the fixed cost of selling second-hand furniture will encourage consumers to sell more of their furniture at the end of life instead of throwing them away; thus, increasing the availability and selection of second-hand furniture. The challenge; however, is the potential loss of profit for Finn.no. If the increase in the number of advertisements from lowering advertising fees does not break even the existing profit, the government can subsidize the company by giving carbon credits for each successful transaction of second-hand furniture. For furniture with low carbon density such as storage and sofa and furniture that is not suitable for second-hand usage such as beds, lifetime extension should be promoted to reduce the carbon footprint. Thongsawas (2021) and Watson (2008) have shown that consumers are willing to repair furniture to extend their lifetime; however, there are two main challenges. First, consumers may not have the skills to repair furniture besides making simple reparations (Gregson et al., 2009). To address this problem, training workshops should be organized to provide the needed skills to consumers, especially with a focus on textile furniture which is more difficult to fix. Second, there is currently no dedicated place where consumers can purchase materials needed for reparation. It is currently the responsibility of the consumers to find compatible materials if they wish to repair furniture. The process is time-consuming and inconvenient since consumers have to spend time searching for compatible parts; thus, reducing their incentives to engage in furniture reparation (Gullstrand Edbring et al., 2016). If furniture retailers are required by law to have repair parts for sale, the likelihood of consumers engaging in furniture reparation will be higher since they can easily acquire needed materials directly from retailers. Unfortunately, with more reparation, sales of new furniture will also go down, which will decrease the revenue of retailers; thus, disincentivizing them from selling repair parts. This dilemma can be solved by introducing new circular business models such as renting with reparation services (Chiu & Mont, 2021; Gullstrand Edbring et al., 2016). It is important to keep in mind that schemes that promote circular economy of furniture are not exclusive to one another. Policy makers should mix and match them to speed up Norway's transition from the linear economy.

Current environmental trends should also be considered. Several of the emissions associated with furniture will eventually be reduced if the Norwegian government carries out the climate change mitigation plan outlined in the "Klimaplan for 2021–2030". In terms of transport, the government plans to increase the share of electric cars in new passenger car sales to 90% by 2025 and 95% by 2030 (Klima- og miljødepartementet, 2021b). For trucks and bigger vehicles, the government plans to increase the share of electric and biofuel vehicles in new car sales to 75% by 2030 (Klima- og miljødepartementet, 2021b). To reduce the emission from the incineration of waste, the government plans to install carbon capture storage (CCS) technology to waste handling facilities in Oslo, Bergen, and Trondheim by 2030 (Lind, 2020). Regarding electricity, 96% of Norway is already using hydropower as a low-emission electric source (Olje- og energidepartementet, 2022). However, the challenge remains whether Norway will have enough electricity in the future, especially under the energy crisis in Europe. There is an ongoing discussion in parliament about the possibility of building more capacity through offshore wind power (Klassekampen, 2022). If the government can develop enough electricity capacity to meet the nation's demand, then there will be no need to relapse to dirtier energy sources such as oil and gas. Finally, for materials, the government plans to increase the carbon tax to 2,000 NOK per ton by 2030. This will be a substantial cost for furniture producers; thus, giving them incentives to select low-emission materials in the manufacturing processes. There is a loophole behind this policy, however. Since the Norwegian government can only implement its policies within the national borders, companies can move their factories abroad to countries with less-strict climate regulations, causing a climate leakage. No national or international policy exists today to address this problem in a legally binding manner.

From a bigger perspective, this study shows that emissions from furniture constitute approximately 7% compared to direct emissions from zero-emission buildings, or 3% if emissions from mobility, outdoor space, and energy are included. These are relatively low numbers; however, it is to be expected since zero-emission neighborhoods have a higher initial carbon footprint than regular neighborhoods (Lausselet & Brattebø, 2021). As more buildings and neighborhoods in Norway are built or renovated with low or zero-emission standards (Brattebø et al., 2016; Sandberg et al., 2017), it will be more crucial than ever to focus on reducing emissions associated with construction materials, which is the largest source of emissions. Policymakers should prioritize reducing emissions from construction materials, transportation, energy use, and furniture in that order. Needless to say, policies promoting the reduction of carbon footprints are not exclusive to one another. They can be pursued at the same time to maximize the potential to reduce GHG emissions.

Future work

There is a lack of literature related to households' furniture and associated environmental impacts; thus, resulting in a research gap. This study attempted to fill the gap by using MFA and LCA to calculate the furniture consumption of a neighborhood, the associated carbon footprint, and the potential for circular economy. It provides the baseline emission as well as shows the possibilities to reduce carbon footprint; however, it does not go into detail on how the scenarios and policies can be translated into practice. Therefore, there are opportunities for future research to study furniture-related policies, rebound effects as well as intention-behavior discrepancies of Norwegian consumers in the furniture market. This will lead to a more accurate result of circular economy of furniture. The effect of furniture lifetime extension should also be studied in detail since this study assumed that all furniture could have its lifetime increased by the same amount. Dynamic MFA modeling combined with LCA can give a clearer picture of the potential of extending furniture lifetime. On the supplier side, more LCA is needed for household furniture. Currently, there is a lack of data since there is no legal requirement like office furniture. Life cycle inventory needs to be built in the near future if the furniture industry wishes to report the environmental impacts of furniture to avoid the upcoming carbon tax. Environment impacts in other categories besides GHG emissions should also be studied and recorded. Last but not least, more studies on the environmental impacts of furniture in buildings and neighborhoods are needed to provide a better understanding of furniture in a wider circular economy context.

Conclusion

This study aims to understand the material flows of furniture in a neighborhood with a population of 1,340 inhabitants, the associated carbon footprint, and the potential for circular economy. Material Flow Analysis (MFA) was used to quantify the flows of furniture and Life Cycle Analysis (LCA) was used to calculate the carbon footprint. Two scenarios – Second-hand and Lifetime Extension – were created based on a consumer survey. Both MFA and LCA were carried out for the scenarios.

The result shows that the neighborhood has a furniture stock of 961.68 tons. The Baseline scenario has furniture inflows of 52.13 tons, outflows of 47.21 tons, and used furniture of 59.79 tons circulating within the system. The scenario has a total carbon footprint of 217.18 tons CO_2-eq. Most of the emissions are from manufacturing and waste handling. Transport has a minor contribution and electricity has a marginal contribution. The Second-hand scenario has the potential to reduce furniture inflows to 24.8 tons, outflows to 19.89 tons, and increases the used furniture in the system to 80.53 tons. The scenario has a carbon footprint of 134.22 tons CO_2-eq, a 39% reduction from the Baseline scenario. The Lifetime Extension scenario has furniture inflows of 19 tons, outflows of 14.09 tons, and used furniture of 85.93 tons within the system. The scenario's carbon footprint is 115.11 tons CO_2-eq, which is 47% reduction from the Baseline scenario.

To maximize the potential of reducing carbon footprint, it is recommended that policymakers promote both the Second-hand and Lifetime Extension policies concurrently. For furniture with high carbon density such as chairs and tables, more carbon footprint can be reduced by encouraging inhabitants to use second-hand items. For furniture with low carbon density such as sofas and storages, it is more effective to extend their lifetime. For furniture that consumers have a low willingness to use second-hand due to hygiene reasons such as beds, lifetime extension is the only feasible option. When comparing the emissions of furniture to other emissions in the reference zero-emission neighborhood, furniture constitutes approximately 3% of all emissions, or 7% compared to construction materials. Because of the relatively low percentage, it is recommended that furniture should be the fourth area of prioritization for carbon footprint reduction in a neighborhood, after building materials, mobility, and energy respectively.

References

Ajzen, I., Brown, T. C., & Carvajal, F. (2004). Explaining the Discrepancy between Intentions and Actions: The Case of Hypothetical Bias in Contingent Valuation. *Pers Soc Psychol Bull*, *30*(9), 1108-1121. https://doi.org/10.1177/0146167204264079

Andac Guzel, T. (2020). Consumer attitudes toward preference and use of wood, woodenware, and furniture: A sample from Kayseri, Turkey. *Bioresources*, *15*(1), 28. https://doi.org/10.15376/biores.15.1.28-37

Antov, P., & Pancheva, T. (2017). *Carbon footprint of furniture products*.

Arli, D., Tan, L. P., Tjiptono, F., & Yang, L. (2018). Exploring consumers' purchase intention towards green products in an emerging market: The role of consumers' perceived readiness. *International journal of consumer studies*, *42*(4), 389-401. https://doi.org/10.1111/ijcs.12432

Brattebø, H., O'Born, R., Sandberg, N. H., & Vestrum, M. I. (2016). *Fremtidig utvikling i energiforbruk og CO2-utslipp for Norges boligmasse*. https://www.ntnu.no/documents/1201072460/1201115133/D3.2_NO_Final_Report_04.02.2016.pdf/2d19c3f0-9b91-4ec1-a301-4da1b2036b81

Carlier, M. (2022). *Estimated number of plug-in electric vehicles in use in selected countries as of 2021*. https://www.statista.com/statistics/244292/number-of-electric-vehicles-by-country/

Carlsson Kanyama, A., Nässén, J., & Benders, R. (2021). Shifting expenditure on food, holidays, and furnishings could lower greenhouse gas emissions by almost 40. *Journal of Industrial Ecology*, *25*(6), 1602-1616. https://doi.org/10.1111/jiec.13176

CGRi. (2020). *The Circularity Gap Report Norway*. https://www.circularity-gap.world/2020

Cherry, C., Scott, K., Barrett, J., & Pidgeon, N. (2018). Public acceptance of resource-efficiency strategies to mitigate climate change. *Nature climate change*, *8*(11), 1007-1012. https://doi.org/10.1038/s41558-018-0298-3

Chiu, Y.-T. (2020). Exploring rental business models as a way to extend furniture lifetime: Establishing rental furnishing service for students in Lund. *IIIEE Master Thesis*.

Chiu, Y.-t., & Mont, O. (2021). Exploring consumer acceptance of furniture renting services: the case of students in Lund.

Circular Norway. (2020). *The Circularity Gap Report Norway*. https://de312f73-4ba4-4a83-b0e6-01dc20f54c34.filesusr.com/ugd/8853d3_4878d746a9fc40f0a9aacd113e090abc.pdf

Climate Action Tracker. (2021). *Norway*. https://climateactiontracker.org/countries/norway/

Cooper, T., Kaner, J., Furmston, K., & Cutts, A. (2021). Furniture lifetimes in a circular economy: a state of the art review.

DraftLogic. (2022). *Google Maps Area Calculator Tool*. https://www.daftlogic.com/projects-google-maps-area-calculator-tool.htm

Eckelman, M. J., & Chertow, M. R. (2009). Using Material Flow Analysis to Illuminate Long-Term Waste Management Solutions in Oahu, Hawaii. *Journal of Industrial Ecology*, *13*(5), 758-774. https://doi.org/10.1111/j.1530-9290.2009.00159.x

ecoinvent. (2019). *ecoinvent 3.6* https://ecoinvent.org/the-ecoinvent-database/data-releases/ecoinvent-3-6/#1592220812641-df7fe628-a0f21598366392497

eia. (2021). *U.S. energy facts explained*. https://www.eia.gov/energyexplained/us-energy-facts/

EPD. (2022a). *Bord / Benkebord*. https://www.epd-norge.no/bord-benkebord/category331.html

EPD. (2022b). *Møbel*. https://www.epd-norge.no/mobel/category328.html

EPD. (2022c). *Sittemøbler*. https://www.epd-norge.no/sittemobler/category329.html

EPD. (2022d). *Skap / Reoler*. https://www.epd-norge.no/skap-reoler/category535.html

eurostat. (2022). *Energy statistics - an overview*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_statistics_-_an_overview

Fet, A. M., Skaar, C., & Michelsen, O. (2008). Product category rules and environmental product declarations as tools to promote sustainable products: experiences from a case study of furniture production. *Clean technologies and environmental policy*, *11*(2), 201-207. https://doi.org/10.1007/s10098-008-0163-6

FINN. (2022). *FINN.no – Mulighetenes marked*. https://www.finn.no/finn/article/finn_about_us?template=templates/static_template.jsp

Geyer, R., Kuczenski, B., & Trujillo, M. (2016). Assessing the Greenhouse Gas Savings Potential of Extended Producer Responsibility for Mattresses and Boxsprings in the United States: EPR for Mattresses and Boxsprings in the U.S. *Journal of Industrial Ecology*, *20*(4), 917-928. https://doi.org/10.1111/jiec.12313

Glöser‐Chahoud, S., Pfaff, M., & Schultmann, F. (2021). The link between product service lifetime and GHG emissions: A comparative study for different consumer products. *Journal of Industrial Ecology*, *25*(2), 465-478. https://doi.org/10.1111/jiec.13123

Gregson, N., Metcalfe, A., & Crewe, L. (2009). Practices of Object Maintenance and Repair: How consumers attend to consumer objects within the home. *Journal of consumer culture*, *9*(2), 248-272. https://doi.org/10.1177/1469540509104376

Gullstrand Edbring, E., Lehner, M., & Mont, O. (2016). Exploring consumer attitudes to alternative models of consumption: motivations and barriers. *Journal of cleaner production*, *123*, 5-15. https://doi.org/10.1016/j.jclepro.2015.10.107

Gupta, R., & Sen, S. (2013). The effect of evolving resource synergy beliefs on the intentions–behavior discrepancy in ethical consumption. *Journal of consumer psychology*, *23*(1), 114-121. https://doi.org/10.1016/j.jcps.2012.07.004

Harder, R., Kalmykova, Y., Morrison, G. M., Feng, F., Mangold, M., & Dahlén, L. (2014). Quantification of Goods Purchases and Waste Generation at the Level of Individual Households. *Journal of Industrial Ecology*, *18*(2), 227-241. https://doi.org/10.1111/jiec.12111

Høgevold, N. M. (2011). A corporate effort towards a sustainable business model: A case study from the Norwegian furniture industry. *European business review*, *23*(4), 392-400. https://doi.org/10.1108/09555341111145771

King, A. M., Burgess, S. C., Ijomah, W., & McMahon, C. A. (2006). Reducing waste: repair, recondition, remanufacture or recycle? *Sust. Dev*, *14*(4), 257-267. https://doi.org/10.1002/sd.271 (Sustainable Development)

Klassekampen. (2022). Statsministeren la fram havvind-plan. https://klassekampen.no/utgave/2022-06-08/statsministeren-la-fram-havvind-plan

Klima- og miljødepartementet. (2021a). *Klimaendringer og norsk klimapolitikk*. Regjeringen. https://www.regjeringen.no/no/tema/klima-og-miljo/innsiktsartikler-klima-miljo/klimaendringer-og-norsk-klimapolitikk/id2636812/

Klima- og miljødepartementet. (2021b). *Meld. St. 13 (2020–2021), Klimaplan for 2021–2030*. https://www.regjeringen.no/no/dokumenter/nasjonal-strategi-for-ein-gron-sirkular-okonomi/id2861253/

Krych, K., & Pettersen, J. B. (2021a). *Lifetime of appliances and furniture in Norwegian households*. Norwegian University of Science and Technology (NTNU).

Krych, K., & Pettersen, J. B. (2021b). A stock-driven model for assessing environmental benefits of product lifetime extension in Norwegian households.

Krystofik, M., Luccitti, A., Parnell, K., & Thurston, M. (2018). Adaptive remanufacturing for multiple lifecycles: A case study in office furniture. *Resources, conservation and recycling*, *135*, 14-23. https://doi.org/10.1016/j.resconrec.2017.07.028

Lanoë, T., Simões, C. L., & Simoes, R. (2013). Improving the environmental performance of bedding products by using life cycle assessment at the design stage. *Journal of cleaner production*, *52*, 155-164. https://doi.org/10.1016/j.jclepro.2013.03.013

Lausselet, C., Borgnes, V., & Brattebø, H. (2019). LCA modelling for Zero Emission Neighbourhoods in early stage planning. *Building and environment*, *149*, 379-389. https://doi.org/10.1016/j.buildenv.2018.12.034

Lausselet, C., & Brattebø, H. (2021). Environmental co-benefits and trade-offs of climate mitigation strategies applied to net-zero-emission neighbourhoods. *The international journal of life cycle assessment*, *26*(11), 2263-2277. https://doi.org/10.1007/s11367-021-01973-3

Lausselet, C., Urrego, J. P. F., Resch, E., & Brattebø, H. (2021). Temporal analysis of the material flows and embodied greenhouse gas emissions of a neighborhood building stock. *Journal of Industrial Ecology*, *25*(2), 419-434. https://doi.org/10.1111/jiec.13049

Lauvland, H. J. (2020). *Carbon footprint of furniture*. Norwegian University of Science and Technology (NTNU).

Lauvland, H. J. (2021). *The Carbon Footprint of Furniture* Norwegian University of Science and Technology (NTNU)].

Lavers Westin, A., Kalmykova, Y., Rosado, L., Oliveira, F., Laurenti, R., & Rydberg, T. (2019). Combining material flow analysis with life cycle assessment to identify environmental hotspots of urban consumption. *Journal of cleaner production*, *226*, 526-539. https://doi.org/10.1016/j.jclepro.2019.04.036

Lekve Bjelle, E., Steen-Olsen, K., & Wood, R. (2018). Climate change mitigation potential of Norwegian households and the rebound effect. *Journal of cleaner production*, *172*, 208-217. https://doi.org/10.1016/j.jclepro.2017.10.089

Leslie, D., & Reimer, S. (2003). Fashioning furniture: restructuring the furniture commodity chain. *Area (London 1969)*, *35*(4), 427-437. https://doi.org/10.1111/j.0004-0894.2003.00192.x

Lind, C. (2020). *Klimakur2030 - hva sier den om avfallsektoren?* Retrieved 2022 from https://avfallnorge.no/bransjen/nyheter/klimakur2030-hva-sier-den-om-klima-og-avfall

Linkosalmi, L., Husgafvel, R., Fomkin, A., Junnikkala, H., Witikkala, T., Kairi, M., & Dahl, O. (2016). Main factors influencing greenhouse gas emissions of wood-based furniture industry in Finland. *Journal of cleaner production*, *113*, 596-605. https://doi.org/10.1016/j.jclepro.2015.11.091

Liu, J., Wang, M., Zhang, C., Yang, M., & Li, Y. (2020). Material flows and in-use stocks of durable goods in Chinese urban household sector. *Resources, conservation and recycling*, *158*, 104758. https://doi.org/10.1016/j.resconrec.2020.104758

Lopes Silva, D. A., de Oliveira, J. A., Saavedra, Y. M. B., Ometto, A. R., Rieradevall i Pons, J., & Gabarrell Durany, X. (2015). Combined MFA and LCA approach to evaluate the metabolism of service polygons: A case study on a university campus. *Resources, conservation and recycling*, *94*, 157-168. https://doi.org/10.1016/j.resconrec.2014.11.001

Mattson, K. R. (2022). *Interview about Norwegian waste processing system* [Interview].

Michelsen, O., Fet, A. M., & Dahlsrud, A. (2006). Eco-efficiency in extended supply chains: A case study of furniture production. *J Environ Manage*, *79*(3), 290-297. https://doi.org/10.1016/j.jenvman.2005.07.007

Forskrift om deponering av avfall, (2002). https://lovdata.no/dokument/LTI/forskrift/2002-03-21-375

Mirabella, N., Castellani, V., & Sala, S. (2014). LCA for assessing environmental benefit of eco-design strategies and forest wood short supply chain: a furniture case study. *The international journal of life cycle assessment*, *19*(8), 1536-1550. https://doi.org/10.1007/s11367-014-0757-7

Mjønerud, I. (2019). *Vannkraft – Slik produseres strøm i Norge*. https://xn--strm-ira.no/vannkraft

Mora Sojo, M. C. (2020). *Norwegian Consumption of Durables: A Model to Analyze Different Circular Economy Strategies*. Norwegian University of Science and Technology (NTNU).

Mora Sojo, M. C., & Pettersen, J. B. K. K. (2021). *Quantifying the Norwegian households' clothing system and its environmental impacts for a transition towards a more circular economy* NTNU].

National Geographic. (2018). *MEGA FACTORIES: IKEA*. https://www.natgeotv.com/ca/megafactories/ikea-facts

Norske Utslipp. (2021). *Klimagasser (CO2-ekv)*. Miljødorektoratet. https://www.norskeutslipp.no/no/Komponenter/Utslipp/Klimagasser-CO2-ekvivalenter/?ComponentType=utslipp&ComponentPageID=1166&SectorID=90

Oguchi, M., Kameya, T., Yagi, S., & Urano, K. (2008). Product flow analysis of various consumer durables in Japan. *Resources, conservation and recycling*, *52*(3), 463-480. https://doi.org/10.1016/j.resconrec.2007.06.001

Olje- og energidepartementet. (2022). *NORSK ENERGIFORSYNING*. https://energifaktanorge.no/norsk-energiforsyning/

Ooghe, V., Athanassiadis, A., Van der Linden, M., Hermesse, J., & Bouillard, P. (2019). WIM project: wood flow analysis in Heyvaert district. In *IOP Conf. Ser.: Earth Environ. Sci* (Vol. 225, pp. 12054). Bristol: Bristol: IOP Publishing.

Ottelin, J., Cetinay, H., & Behrens, P. (2020). Rebound effects may jeopardize the resource savings of circular consumption: evidence from household material footprints. *Environ. Res. Lett*, *15*(10), 104044. https://doi.org/10.1088/1748-9326/abaa78

PRé. (2016). SimaPro Tutorial. In M. Goedkoop, M. Oele, M. Vieira, J. Leijting, T. Ponsioen, & E. Meijer (Eds.).

Qiu, X., Cano-Kollmann, M., & Mudambi, R. (2017). Competitiveness and connectivity in design innovation: a study of Norwegian furniture industry. *Competitiveness review*, *27*(5), 533-548. https://doi.org/10.1108/CR-03-2017-0025

Regheringen. (2021). *Nasjonal strategi for ein grøn, sirkulær økonomi*. https://www.regjeringen.no/no/dokumenter/nasjonal-strategi-for-ein-gron-sirkular-okonomi/id2861253/

Rekdal, K. E. (2019). *Møbel og interiørbransjene 2019*

Sandberg, N. H., Sartori, I., Vestrum, M. I., & Brattebø, H. (2017). Using a segmented dynamic dwelling stock model for scenario analysis of future energy demand: The dwelling stock of Norway 2016–2050. *Energy and buildings*, *146*, 220-232. https://doi.org/10.1016/j.enbuild.2017.04.016

Schiller, G., Müller, F., & Ortlepp, R. (2017). Mapping the anthropogenic stock in Germany: Metabolic evidence for a circular economy. *Resources, conservation and recycling*, *123*, 93-107. https://doi.org/10.1016/j.resconrec.2016.08.007

SINTEF. (2020). *Studie av potensialet for verdiskaping og sysselsetting av sirkulærøkonomiske tiltak. Utvalgte tiltak og case.* https://sintef.brage.unit.no/sintef-xmlui/bitstream/handle/11250/2690052/2020_00958%2BStudie%2Bav%2Bpotensialet%2Bfor%2Bverdiskaping%2Bog%2Bsysselsetting%2Bav%2Bsirkul%25C3%25A6r%25C3%25B8konomiske%2Btiltak.pdf?sequence=1&isAllowed=y

Spitzley, D. V., Dietz, B. A., & Keoleian, G. A. (2006). Life cycle assessment of office furniture products. *Ann Arbor*.

SSB. (2018). *Dette bruker nordmenn penger på*. Statistisk Sentralbyrå. https://www.ssb.no/nasjonalregnskap-og-konjunkturer/artikler-og-publikasjoner/dette-bruker-nordmenn-penger-pa

SSB. (2020). *Nordmenns forbruk nest høyest i Europa*. Statistisk Sentralbyrå. https://www.ssb.no/priser-og-prisindekser/artikler-og-publikasjoner/nordmenns-forbruk-nest-hoyest-i-europa

NS-EN 15978:2011 Bærekraftige byggverk - Vurdering av bygningers miljøprestasjon - Beregningsmetode, (2011).

NS 3720:2018 Metode for klimagassberegninger for bygninger, (2018).

NS-EN 15804:2012+A2:2019 Bærekraftige byggverk - Miljødeklarasjoner - Grunnleggende produktkategoriregler for byggevarer, (2019).

NS-EN 15804:2012+A2:2019/AC:2021 RETTELSE - Bærekraftige byggverk - Miljødeklarasjoner - Grunnleggende produktkategoriregler for byggevarer, (2021).

Statista Research Department. (2021). *Home ownership rate in selected European countries in 2019 and 2020, by country*. https://www.statista.com/statistics/246355/home-ownership-rate-in-europe/

Steen-Olsen, K., Wood, R., & Hertwich, E. G. (2016). The Carbon Footprint of Norwegian Household Consumption 1999-2012. *Journal of Industrial Ecology*, *20*(3), 582-592. https://doi.org/10.1111/jiec.12405

Thongsawas, P. (2021). *Furniture consumption pattern of households in Trondheim*. Norwegian University of Science and Technology (NTNU).

Turner, D. A., Williams, I. D., & Kemp, S. (2016). Combined material flow analysis and life cycle assessment as a support tool for solid waste management decision making. *Journal of cleaner production*, *129*, 234-248. https://doi.org/10.1016/j.jclepro.2016.04.077

Velásquez-Rodríguez, O. F., Løvik, A. N., & Moreno-Mantilla, C. E. (2021). Evaluation of the environmental impact of end-of-life refrigerators in Colombia by material flow analysis. *Journal of cleaner production*, *314*, 127884. https://doi.org/10.1016/j.jclepro.2021.127884

Wågøynes, T., Sørensen, G., & Syversen, F. (2018). *Materialgjenvinning av returtrevirke*. https://avfallnorge.no/fagomraader-og-faggrupper/rapporter/materialgjenvinning-av-returtrevirke

Watson, M. (2008). A Review of literature and research on public attitudes, perceptions and behaviour relating to remanufactured, repaired and reused products. *Report for the Centre for Remanufacturing and Reuse*, 1-26.

Website Carbon Calculator. (2022). *The original Website Carbon calculator*. https://www.websitecarbon.com/

Whetstone, A., Kalmykova, Y., Rosado, L., & Lavers Westin, A. (2020). Informing Sustainable Consumption in Urban Districts: A Method for Transforming Household Expenditures into Physical Quantities. *Sustainability (Basel, Switzerland)*, *12*(3), 802. https://doi.org/10.3390/su12030802

Wiprächtiger, M., Rapp, M., Hellweg, S., Shinde, R., & Haupt, M. (2022). Turning trash into treasure: An approach to the environmental assessment of waste prevention and its application to clothing and furniture in Switzerland. *Journal of Industrial Ecology*.

Zhang, C., Chen, W.-Q., Liu, G., & Zhu, D.-J. (2017). Economic Growth and the Evolution of Material Cycles: An Analytical Framework Integrating Material Flow and Stock Indicators. *Ecological economics*, *140*, 265-274. https://doi.org/10.1016/j.ecolecon.2017.04.021

Zhang, C., Chen, W.-Q., & Ruth, M. (2018). Measuring material efficiency: A review of the historical evolution of indicators, methodologies and findings. *Resources, conservation and recycling*, *132*, 79-92. https://doi.org/10.1016/j.resconrec.2018.01.028

Appendix A – Electricity Calculation

Since electricity usage data of retail shops, second-hand shops, or websites were not directly available to the public, it had to be estimated based on research data and assumptions. This section outlines the methodology used to calculate electricity usage inputted into the LCA model.

For physical shops, electricity usage was calculated based on the areas of facilities. The areas were obtained from satellite images (DraftLogic, 2022). If a facility has more than one floor, the floor area was multiplied by the number of floors to get the total area. The total area was then multiplied by the average kWh/m^2/yr of Norwegian buildings to obtain electricity usage per year. For retails, the value is 243 kWh/m^2/yr; and for warehouses, the value is 177 kWh/m^2/yr. Since an assumption was made that the calculated values obtained represented the electricity usage for stores serving the entire population of Trondheim, the values were scaled down to the neighborhood size to match the scale of this study. Thereafter, the values were allocated based on the furniture flows by category in each scenario (Table 9, Table 11, and Table 13), and scaled up again based on the market share of the stores (Rekdal, 2019).

For online stores, electricity usage was obtained from an online website carbon calculator (Website Carbon Calculator, 2022). The value was not scaled down to the neighborhood size since the calculator did not fully disclose the traffic of websites. However, it was adjusted based on furniture type and scenario. As a result, the values are higher than the real value. Since electricity usage of websites is very small, to begin with, there is almost no impact on the final carbon footprint.

Table 21 shows the electricity usage of representative buildings and websites before market share adjustment. For the final electricity usage, see Appendix B under the outputs of interest.

Table 21 Electricity usage of representative buildings and websites

kWh/year		Scenario		
Location	Furniture	Baseline	Second-hand	Lifetime Extension
IKEA Leangen retail and warehouse for physical customers	Bed	17067.60	17067.60	12288.67
	Chair	5368.55	599.94	993.18
	Sofa	8976.94	3917.18	3052.16
	Storage	21297.62	6089.41	4259.52
	Table	7374.49	850.49	1364.28
	Total	60085.21	28524.62	21957.82
IKEA Leangen warehouse for online customers	Bed	309.32	309.32	222.71
	Chair	69.03	7.71	12.77
	Sofa	131.20	57.25	44.61
	Storage	504.54	144.26	100.91
	Table	86.06	9.92	15.92
	Total	1100.15	528.47	396.92
Ikea.no	Bed	70.85	70.85	51.01
	Chair	15.81	1.77	0.33
	Sofa	30.05	13.11	4.46

	Storage	115.57	33.04	6.61
	Table	19.71	2.27	0.42
	Total	252.00	121.05	62.83
Brukom	Bed	385.09	385.09	385.09
	Chair	586.35	1405.73	586.35
	Sofa	548.41	1086.16	548.41
	Storage	1678.48	4879.14	1678.48
	Table	1036.50	2126.03	1036.50
	Total	3198.33	7756.12	3198.33
Finn.no	Bed	39.62	39.62	39.62
	Chair	22.30	53.46	22.30
	Sofa	38.92	77.09	38.92
	Storage	56.97	165.60	56.97
	Table	40.19	82.43	40.19
	Total	198.00	418.20	198.00

Appendix B – LCA Modelling in SimaPro

This section shows the LCA model in the same format as in SimaPro. The layer of the model is listed on the top of the table while the name, which is the same as the output, is underlined. Three layers of the model (Figure 6 and Figure 7) are presented, with the addition of layers 2.5 and layer 3.5. These layers are added because of the modeling requirements in SimaPro. In practice, they do not influence the results of the model.

The section is also divided into three scenarios: Baseline, Second-hand, and Lifetime Extension. Each scenario has different assumptions and inputs. It is advised that the reader who wishes to study the model in detail read this section alongside the methodology to see how the assumptions made affect the model.

Baseline Scenario

MFA, all furniture

Layer 1			
Output (life cycle)			
<u>MFA, all furniture</u>	1	p	
Inputs (life cycles)			
MFA, bed	1	p	
MFA, chair	1	p	
MFA, sofa	1	p	
MFA, storage	1	p	
MFA, table	1	p	

MFA, individual furniture

Layer 2			
Output (life cycle)			
<u>MFA, bed</u>	1	p	
Input (assembly)			
Total retails, bed	1	p	
Input (waste/disposal scenario)			
Waste disposal, bed	1	p	
Inputs (life cycles)			
Physical second-hand shops, bed	1	p	
Online second-hand shops, bed	1	p	
Friends & relatives, bed	1	p	
Other sources, bed	1	p	
In-use, bed	1	p	

Layer 2			
Output (life cycle)			
<u>MFA, chair</u>	1	p	

Input (assembly)			
Total retails, chair	1	p	
Input (waste/disposal scenario)			
Waste disposal, chair	1	p	
Inputs (life cycles)			
Physical second-hand shops, chair	1	p	
Online second-hand shops, chair	1	p	
Friends & relatives, chair	1	p	
Other sources, chair	1	p	
In-use, chair	1	p	

Layer 2			
Output (life cycle)			
MFA, sofa	1	p	
Input (assembly)			
Total retails, sofa	1	p	
Input (waste/disposal scenario)			
Waste disposal, sofa	1	p	
Inputs (life cycles)			
Physical second-hand shops, sofa	1	p	
Online second-hand shops, sofa	1	p	
Friends & relatives, sofa	1	p	
Other sources, sofa	1	p	
In-use, sofa	1	p	

Layer 2			
Output (life cycle)			
MFA, storage	1	p	
Input (assembly)			
Total retails, storage	1	p	
Input (waste/disposal scenario)			
Waste disposal, storage	1	p	
Inputs (life cycles)			
Physical second-hand shops, storage	1	p	
Online second-hand shops, storage	1	p	
Friends & relatives, storage	1	p	
Other sources, storage	1	p	
In-use, storage	1	p	

Layer 2			
Output (life cycle)			
MFA, table	1	p	

Input (assembly)			
Total retails, table	1	p	
Input (waste/disposal scenario)			
Waste disposal, table	1	p	
Inputs (life cycles)			
Physical second-hand shops, table	1	p	
Online second-hand shops, table	1	p	
Friends & relatives, table	1	p	
Other sources, table	1	p	
In-use, table	1	p	

Total retails

Layer 2.5			
Output (assembly)			
Total retails, bed	1	p	
Inputs (assemblies)			
Physical retails, bed	1	p	
Online retails, bed	1	p	

Layer 2.5			
Output (assembly)			
Total retails, chair	1	p	
Inputs (assemblies)			
Physical retails, chair	1	p	
Online retails, chair	1	p	

Layer 2.5			
Output (assembly)			
Total retails, sofa	1	p	
Inputs (assemblies)			
Physical retails, sofa	1	p	
Online retails, sofa	1	p	

Layer 2.5			
Output (assembly)			
Total retails, storage	1	p	
Inputs (assemblies)			
Physical retails, storage	1	p	
Online retails, storage	1	p	

Layer 2.5
Output (assembly)

<u>Total retails, table</u>	1	p	
Inputs (assemblies)			
Physical retails, table	1	p	
Online retails, table	1	p	

From online retails

Layer 3			
Output (assembly)			
<u>Online retails, bed</u>	1	p	
Input (assembly)			
New beds to online retails	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	827	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	74.7	tkm	3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
<u>Online retails, chair</u>	1	p	
Input (assembly)			
New chairs to online retails	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	185	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	193	tkm	3.05 Distance between Miljøbyen Granås and IKEA

Layer 3
Output (assembly)

<u>**Online retails, sofa**</u>	1	p	
Input (assembly)			
New sofas to online retails	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	351	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	126	tkm	3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
<u>**Online retails, storage**</u>	1	p	
Input (assembly)			
New storages to online retails	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	1.35E3	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	248	tkm	3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
<u>**Online retails, table**</u>	1	p	
Input (assembly)			
New tables to online retails	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	230	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture.

			https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	94.3	tkm	3.05 Distance between Miljøbyen Granås and IKEA

From physical retails

Layer 3			
Output (assembly)			
Physical retails, bed	1	p	
Input (assembly)			
New beds to physical retails	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	4.17E4	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.12E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
Physical retails, chair	1	p	
Input (assembly)			
New chairs to physical retails	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	1.31E4	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.29E3	km	2.5 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
Physical retails, sofa	1	p	
Input (assembly)			
New sofas to physical retails	1	p	
Inputs (processes)			

Electricity, low voltage {NO}| market for | Cut-off, S	2.19E4	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.18E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
Physical retails, storage	1	p	
Input (assembly)			
New storages to physical retails	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	5.21E4	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.46E3	km	2 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
Physical retails, table	1	p	
Input (assembly)			
New tables to physical retails	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	1.8E4	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	2.07E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

To online retails

Layer 3.5			
Output (assembly)			
New beds to online retails	1	p	
Input (assembly)			

New bed, manufacturing	2.93	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	4.75E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
<u>New chairs to online retails</u>	1	p	
Input (assembly)			
New chair, manufacturing	0.66	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.06E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
<u>New sofas to online retails</u>	1	p	
Input (assembly)			
New sofa, manufacturing	1.24	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.01E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
<u>New storages to online retails</u>	1	p	
Input (assembly)			
New storage, manufacturing	4.79	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	7.74E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
<u>New tables to online retails</u>	1	p	
Input (assembly)			

New table, manufacturing	0.816	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.32E3	tkm	Distance between Zbaszynek and Trondheim

To physical retails

Layer 3.5			
Output (assembly)			
New beds to physical retails	1	p	
Input (assembly)			
New bed, manufacturing	11.8	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.92E4	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
New chairs to physical retails	1	p	
Input (assembly)			
New chair, manufacturing	3.72	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	6.03E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
New sofas to physical retails	1	p	
Input (assembly)			
New sofa, manufacturing	6.23	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.01E4	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			

<u>**New storages to physical retails**</u>	1	p	
Input (assembly)			
New storage, manufacturing	14.8	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.39E4	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
<u>**New tables to physical retails**</u>	1	p	
Input (assembly)			
New table, manufacturing	5.12	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	8.28E3	tkm	Distance between Zbaszynek and Trondheim

Friends & relatives

Layer 3			
Output (life cycle)			
<u>**Friends & relatives, bed**</u>	1	p	
Inputs (processes)			
Bed reparation	5.31	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	8.6E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	927	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	401	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>**Friends & relatives, chair**</u>	1	p	
Inputs (processes)			
Chair reparation	2.35	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market	3.8E3	tkm	Repair materials transported to Trondheim.

for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.5E3	km	2.5 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.63E3	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Friends & relatives, sofa</u>	1	p	
Inputs (processes)			
Sofa reparation	1.4	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.27E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	509	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	220	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Friends & relatives, storage</u>	1	p	
Inputs (processes)			
storage reparation	5	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	8.1E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	545	km	2 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	472	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Friends & relatives, bed</u>	1	p	
Inputs (processes)			

Bed reparation	2.38	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	3.85E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.36E3	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	589	km	Spare parts are assumed to be available at IKEA.

Online second-hand shops

Layer 3			
Output (life cycle)			
<u>Online second-hand shops, bed</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	39.62	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/
Bed reparation	3.71	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	6E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	654	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	552	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Online second-hand shops, chair</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	22.30	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/
Chair reparation	2.09	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	3.38E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5	945	km	2.5 items per trip

{RER}| market for | Cut-off, S			2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.99E3	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Online second-hand shops, sofa</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	38.92	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/
Sofa reparation	3.65	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	5.9E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	654	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	552	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Online second-hand shops, storage</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	56.97	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/
Storage reparation	5.33	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	8.63E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	772	km	2 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.3E3	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
Online second-hand shops, table	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	40.19	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/
Table reparation	3.76	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	6.09E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	836	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.41E3	km	Spare parts are assumed to be available at IKEA.

Other sources

Layer 3			
Output (life cycle)			
Other sources, bed	1	p	
Inputs (processes)			
Bed reparation	1.27	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.05E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	200	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	7.53	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
Other sources, chair	1	p	
Inputs (processes)			
Sofa reparation	0.28	ton	

Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	445	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	342	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	1.64	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Other sources, sofa</u>	1	p	
Inputs (processes)			
Sofa reparation	1.65	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.67E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	654	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	9.82	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Other sources, storage</u>	1	p	
Inputs (processes)			
Storage reparation	8.06	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.3E4	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.49E3	km	2 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5	48	tkm	Spare parts are assumed to be available at IKEA.

metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S			

Layer 3			
Output (life cycle)			
<u>Other sources, table</u>	1	p	
Inputs (processes)			
Table reparation	0.38	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	617	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	345	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	2.27	tkm	Spare parts are assumed to be available at IKEA.

Physical second-hand shops

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, bed</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	385.09	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Bed reparation	0.48	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	739	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	116	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	2.03	tkm	Spare parts are assumed to be available at IKEA.

Layer 3

Output (life cycle)			
<u>Physical second-hand shops, chair</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	586.35	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Chair reparation	0.7	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.13E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	719	km	2.5 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	3.09	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, sofa</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	548.41	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Sofa reparation	0.65	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.05E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	464	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	2.89	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, storage</u>	1	p	

Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	1678.5	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Storage reparation	1.99	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	3.22E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	478	km	2 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	8.86	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, table</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	1036.5	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Table reparation	1.23	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.99E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.71E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	5.47	tkm	Spare parts are assumed to be available at IKEA.

Disposal scenario

Layer 3			
Output (disposal scenario)			
<u>Waste disposal, bed</u>	1	p	
Referring to assembly			
Total retails, bed	1	p	

Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	6.17E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Layer 3			
Output (disposal scenario)			
<u>Waste disposal, chair</u>	1	p	
Referring to assembly			
Total retails, chair	1	p	
Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	6.97E3	km	2.5 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Layer 3			
Output (disposal scenario)			
<u>Waste disposal, sofa</u>	1	p	
Referring to assembly			
Total retails, sofa	1	p	
Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	7.14E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Layer 3			
Output (disposal scenario)			
<u>Waste disposal, storage</u>	1	p	
Referring to assembly			
Total retails, storage	1	p	
Input (process)			
Transport, passenger car, EURO 5	8.39E3	km	2 items per trip

{RER}| market for | Cut-off, S			3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Layer 3			
Output (disposal scenario)			
Waste disposal, table	1	p	
Referring to assembly			
Total retails, table	1	p	
Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.08E4	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Second-hand Scenario

MFA, all furniture

Layer 1			
Output (life cycle)			
MFA, all furniture, ss	1	p	
Inputs (life cycles)			
MFA, bed, ss	1	p	
MFA, chair, ss	1	p	
MFA, sofa, ss	1	p	
MFA, storage, ss	1	p	
MFA, table, ss	1	p	

MFA, individual furniture

Layer 2			
Output (life cycle)			
MFA, bed, ss	1	p	
Input (assembly)			
Total retails, bed, ss	1	p	
Input (waste/disposal scenario)			
Waste disposal, bed, ss	1	p	
Inputs (life cycles)			
Physical second-hand shops, bed, ss	1	p	
Online second-hand shops, bed, ss	1	p	
Friends & relatives, bed	1	p	
Other sources, bed	1	p	
In-use, bed	1	p	

Layer 2			
Output (life cycle)			
MFA, chair, ss	1	p	
Input (assembly)			
Total retails, chair, ss	1	p	
Input (waste/disposal scenario)			
Waste disposal, chair, ss	1	p	
Inputs (life cycles)			
Physical second-hand shops, chair, ss	1	p	
Online second-hand shops, chair, ss	1	p	
Friends & relatives, chair	1	p	
Other sources, chair	1	p	
In-use, chair	1	p	

Layer 2
Output (life cycle)

MFA, sofa, ss	1	p	
Input (assembly)			
Total retails, sofa, ss	1	p	
Input (waste/disposal scenario)			
Waste disposal, sofa, ss	1	p	
Inputs (life cycles)			
Physical second-hand shops, sofa, ss	1	p	
Online second-hand shops, sofa, ss	1	p	
Friends & relatives, sofa	1	p	
Other sources, sofa	1	p	
In-use, sofa	1	p	

Layer 2			
Output (life cycle)			
MFA, storage, ss	1	p	
Input (assembly)			
Total retails, storage, ss	1	p	
Input (waste/disposal scenario)			
Waste disposal, storage, ss	1	p	
Inputs (life cycles)			
Physical second-hand shops, storage, ss	1	p	
Online second-hand shops, storage, ss	1	p	
Friends & relatives, storage	1	p	
Other sources, storage	1	p	
In-use, storage	1	p	

Layer 2			
Output (life cycle)			
MFA, table, ss	1	p	
Input (assembly)			
Total retails, table, ss	1	p	
Input (waste/disposal scenario)			
Waste disposal, table, ss	1	p	
Inputs (life cycles)			
Physical second-hand shops, table, ss	1	p	
Online second-hand shops, table, ss	1	p	
Friends & relatives, table	1	p	
Other sources, table	1	p	
In-use, table	1	p	

Total retails

Layer 2.5

Output (assembly)			
<u>Total retails, bed, ss</u>	1	p	
Inputs (assemblies)			
Physical retails, bed, ss	1	p	
Online retails, bed, ss	1	p	

Layer 2.5			
Output (assembly)			
<u>Total retails, chair, ss</u>	1	p	
Inputs (assemblies)			
Physical retails, chair, ss	1	p	
Online retails, chair, ss	1	p	

Layer 2.5			
Output (assembly)			
<u>Total retails, sofa, ss</u>	1	p	
Inputs (assemblies)			
Physical retails, sofa, ss	1	p	
Online retails, sofa, ss	1	p	

Layer 2.5			
Output (assembly)			
<u>Total retails, storage, ss</u>	1	p	
Inputs (assemblies)			
Physical retails, storage, ss	1	p	
Online retails, storage, ss	1	p	

Layer 2.5			
Output (assembly)			
<u>Total retails, table, ss</u>	1	p	
Inputs (assemblies)			
Physical retails, table, ss	1	p	
Online retails, table, ss	1	p	

From online retails

Layer 3			
Output (assembly)			
<u>Online retails, bed, ss</u>	1	p	
Input (assembly)			
New beds to online retails, ss	1	p	
Inputs (processes)			
Electricity, low voltage {NO}|	827	kWh	Electricity use for IKEA 20% warehouse scaled to

market for | Cut-off, S			the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	74.7	tkm	3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
<u>Online retails, chair, ss</u>	1	p	
Input (assembly)			
New chairs to online retails, ss	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	20.6	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	23	tkm	3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
<u>Online retails, sofa, ss</u>	1	p	
Input (assembly)			
New sofas to online retails, ss	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	153	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5	52	tkm	3.05 Distance between Miljøbyen Granås and IKEA

metric ton, EURO6 | Cut-off, S			

Layer 3			
Output (assembly)			
Online retails, storage, ss	1	p	
Input (assembly)			
New storages to online retails, ss	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	386	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	72.9	tkm	3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
Online retails, table, ss	1	p	
Input (assembly)			
New tables to online retails, ss	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	26.5	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	10.5	tkm	3.05 Distance between Miljøbyen Granås and IKEA

From physical retails

Layer 3			
Output (assembly)			
Physical retails, bed, ss	1	p	
Input (assembly)			
New beds to physical retails, ss	1	p	

Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	4.17E4	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.12E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
Physical retails, chair, ss	1	p	
Input (assembly)			
New chairs to physical retails, ss	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	1.47E3	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	154	km	2.5 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
Physical retails, sofa, ss	1	p	
Input (assembly)			
New sofas to physical retails, ss	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	9.58E3	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	487	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
Physical retails, storage, ss	1	p	
Input (assembly)			

New storages to physical retails, ss	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	1.49E4	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	429	km	2 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
<u>**Physical retails, table, ss**</u>	1	p	
Input (assembly)			
New tables to physical retails, ss	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	2.08E3	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	231	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

To online retails

Layer 3.5			
Output (assembly)			
<u>**New beds to online retails, ss**</u>	1	p	
Input (assembly)			
New bed, manufacturing, ss	2.93	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	4.75E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
<u>**New chairs to online retails, ss**</u>	1	p	
Input (assembly)			
New chair, manufacturing, ss	0.07	ton	
Input (process)			

Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	118	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
<u>New sofas to online retails, ss</u>	1	p	
Input (assembly)			
New sofa, manufacturing, ss	0.54	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	879	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
<u>New storages to online retails, ss</u>	1	p	
Input (assembly)			
New storage, manufacturing, ss	1.37	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.21E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
<u>New tables to online retails, ss</u>	1	p	
Input (assembly)			
New table, manufacturing, ss	0.09	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	152	tkm	Distance between Zbaszynek and Trondheim

To physical retails

Layer 3.5			
Output (assembly)			
<u>New beds to physical retails, ss</u>	1	p	
Input (assembly)			

New bed, manufacturing, ss	11.8	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.92E4	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
New chairs to physical retails, ss	1	p	
Input (assembly)			
New chair, manufacturing, ss	0.416	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	673	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
New sofas to physical retails, ss	1	p	
Input (assembly)			
New sofa, manufacturing, ss	2.72	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	4.4E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
New storages to physical retails, ss	1	p	
Input (assembly)			
New storage, manufacturing, ss	4.22	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	6.84E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
New tables to physical retails, ss	1	p	
Input (assembly)			

New table, manufacturing, ss	0.59	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	955	tkm	Distance between Zbaszynek and Trondheim

Friends & relatives

Layer 3			
Output (life cycle)			
Friends & relatives, bed	1	p	
Inputs (processes)			
Bed reparation	5.31	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	8.6E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	927	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	401	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
Friends & relatives, chair	1	p	
Inputs (processes)			
Chair reparation	2.35	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	3.8E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.5E3	km	2.5 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.63E3	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
Friends & relatives, sofa	1	p	
Inputs (processes)			

Sofa reparation	1.4	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.27E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	509	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	220	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Friends & relatives, storage</u>	1	p	
Inputs (processes)			
storage reparation	5	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	8.1E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	545	km	2 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	472	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Friends & relatives, bed</u>	1	p	
Inputs (processes)			
Bed reparation	2.38	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	3.85E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.36E3	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	589	km	Spare parts are assumed to be available at IKEA.

Online second-hand shops

Layer 3			
Output (life cycle)			
Online second-hand shops, bed, ss	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	39.62	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/
Bed reparation	3.71	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	6E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	654	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	552	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
Online second-hand shops, chair, ss	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	53.46	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/
Chair reparation	5.01	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	8.1E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	2.34E3	km	2.5 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	4.94E3	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
Online second-hand shops, sofa, ss	1	p	
Inputs (processes)			
Electricity, low voltage {NO}|	77.09	kWh	Electricity use by website scaled by furniture.

market for | Cut-off, S			https://www.websitecarbon.com/website/finn-no/
Sofa reparation	7.22	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.17E4	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.63E3	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.37E3	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Online second-hand shops, storage, ss</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	165.6	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/
Storage reparation	15.5	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.51E4	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	2.2E3	km	2 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	3.72E3	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Online second-hand shops, table, ss</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	82.43	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/
Table reparation	7.72	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric	1.25E4	tkm	Repair materials transported to Trondheim.

ton, EURO6 | Cut-off, S			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.82E3	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	3.07E3	km	Spare parts are assumed to be available at IKEA.

Other sources

Layer 3			
Output (life cycle)			
<u>Other sources, bed</u>	1	p	
Inputs (processes)			
Bed reparation	1.27	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.05E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	200	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	7.53	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Other sources, chair</u>	1	p	
Inputs (processes)			
Sofa reparation	0.28	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	445	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	342	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	1.64	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Other sources, sofa</u>	1	p	
Inputs (processes)			
Sofa reparation	1.65	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.67E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	654	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	9.82	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Other sources, storage</u>	1	p	
Inputs (processes)			
Storage reparation	8.06	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.3E4	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.49E3	km	2 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	48	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Other sources, table</u>	1	p	
Inputs (processes)			
Table reparation	0.38	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	617	tkm	Repair materials transported to Trondheim.

Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	345	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	2.27	tkm	Spare parts are assumed to be available at IKEA.

Physical second-hand shops

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, bed, ss</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	385.09	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Bed reparation	0.48	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	739	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	116	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	2.03	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, chair, ss</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	1405.73	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Chair reparation	1.67	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.7E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.78E3	km	2.5 items per trip 3 trips back and forth (50% makes 2 extra

			trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	7.42	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, sofa, ss</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	1086.16	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Sofa reparation	1.29	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.08E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.15E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	5.73	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, storage, ss</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	4879.2	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Storage reparation	5.79	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	9.36E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.36E3	km	2 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer)

			7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	25.7	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, table, ss</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	2126.03	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Table reparation	2.52	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	4.08E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	3.72E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	11.2	tkm	Spare parts are assumed to be available at IKEA.

Disposal scenario

Layer 3			
Output (disposal scenario)			
<u>Waste disposal, bed, ss</u>	1	p	
Referring to assembly			
Total retails, bed, ss	1	p	
Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	6.17E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Layer 3

Output (disposal scenario)			
<u>Waste disposal, chair, ss</u>	1	p	
Referring to assembly			
Total retails, chair, ss	1	p	
Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	831	km	2.5 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Layer 3			
Output (disposal scenario)			
<u>Waste disposal, sofa, ss</u>	1	p	
Referring to assembly			
Total retails, sofa, ss	1	p	
Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	2.95E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Layer 3			
Output (disposal scenario)			
<u>Waste disposal, storage, ss</u>	1	p	
Referring to assembly			
Total retails, storage, ss	1	p	
Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	2.47E3	km	2 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Layer 3			
Output (disposal scenario)			
<u>Waste disposal, table, ss</u>	1	p	

Referring to assembly			
Total retails, table, ss	1	p	
Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.2E4	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Lifetime Extension scenario

MFA, all furniture

Layer 1			
Output (life cycle)			
<u>MFA, all furniture, les</u>	1	p	
Inputs (life cycles)			
MFA, bed, les	1	p	
MFA, chair, les	1	p	
MFA, sofa, les	1	p	
MFA, storage, les	1	p	
MFA, table, les	1	p	

MFA, individual furniture

Layer 2			
Output (life cycle)			
<u>MFA, bed, les</u>	1	p	
Input (assembly)			
Total retails, bed, les	1	p	
Input (waste/disposal scenario)			
Waste disposal, bed, les	1	p	
Inputs (life cycles)			
Physical second-hand shops, bed	1	p	
Online second-hand shops, bed	1	p	
Friends & relatives, bed	1	p	
Other sources, bed	1	p	
In-use, bed	1	p	
Lifetime extension, bed	1	p	

Layer 2			
Output (life cycle)			
<u>MFA, chair, les</u>	1	p	
Input (assembly)			
Total retails, chair, les	1	p	
Input (waste/disposal scenario)			
Waste disposal, chair, les	1	p	
Inputs (life cycles)			
Physical second-hand shops, chair	1	p	
Online second-hand shops, chair	1	p	
Friends & relatives, chair	1	p	
Other sources, chair	1	p	
In-use, chair	1	p	
Lifetime extension, chair	1	p	

Layer 2			
Output (life cycle)			
<u>MFA, sofa, les</u>	1	p	
Input (assembly)			
Total retails, sofa, les	1	p	
Input (waste/disposal scenario)			
Waste disposal, sofa, les	1	p	
Inputs (life cycles)			
Physical second-hand shops, sofa	1	p	
Online second-hand shops, sofa	1	p	
Friends & relatives, sofa	1	p	
Other sources, sofa	1	p	
In-use, sofa	1	p	
Lifetime extension, sofa	1	p	

Layer 2			
Output (life cycle)			
<u>MFA, storage, les</u>	1	p	
Input (assembly)			
Total retails, storage, les	1	p	
Input (waste/disposal scenario)			
Waste disposal, storage, les	1	p	
Inputs (life cycles)			
Physical second-hand shops, storage	1	p	
Online second-hand shops, storage	1	p	
Friends & relatives, storage	1	p	
Other sources, storage	1	p	
In-use, storage	1	p	
Lifetime extension, storage	1	p	

Layer 2			
Output (life cycle)			
<u>MFA, table, les</u>	1	p	
Input (assembly)			
Total retails, table, les	1	p	
Input (waste/disposal scenario)			
Waste disposal, table, les	1	p	
Inputs (life cycles)			
Physical second-hand shops, table	1	p	
Online second-hand shops, table	1	p	
Friends & relatives, table	1	p	
Other sources, table	1	p	
In-use, table	1	p	

Lifetime extension, table	1	p	

Total retails

Layer 2.5			
Output (assembly)			
Total retails, bed, les	1	p	
Inputs (assemblies)			
Physical retails, bed, les	1	p	
Online retails, bed, les	1	p	

Layer 2.5			
Output (assembly)			
Total retails, chair, les	1	p	
Inputs (assemblies)			
Physical retails, chair, les	1	p	
Online retails, chair, les	1	p	

Layer 2.5			
Output (assembly)			
Total retails, sofa, les	1	p	
Inputs (assemblies)			
Physical retails, sofa, les	1	p	
Online retails, sofa, les	1	p	

Layer 2.5			
Output (assembly)			
Total retails, storage, les	1	p	
Inputs (assemblies)			
Physical retails, storage, les	1	p	
Online retails, storage, les	1	p	

Layer 2.5			
Output (assembly)			
Total retails, table, les	1	p	
Inputs (assemblies)			
Physical retails, table, les	1	p	
Online retails, table, les	1	p	

From online retails

Layer 3			
Output (assembly)			
Online retails, bed, les	1	p	

Input (assembly)			
New beds to online retails, les	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	596	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	53.8	tkm	3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
Online retails, chair, les	1	p	
Input (assembly)			
New chairs to online retails, les	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	31.5	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	35.6	tkm	3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
Online retails, sofa, les	1	p	
Input (assembly)			
New sofas to online retails, les	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	114	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-

			com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	42.8	tkm	3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
<u>Online retails, storage, les</u>	1	p	
Input (assembly)			
New storages to online retails, les	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	253	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	49.5	tkm	3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
<u>Online retails, table, les</u>	1	p	
Input (assembly)			
New tables to online retails, les	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	39.3	kWh	Electricity use for IKEA 20% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway. Electricity use for website scaled by furniture. https://www.websitecarbon.com/website/ikea-com-no
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	17.4	tkm	3.05 Distance between Miljøbyen Granås and IKEA

From physical retails

Layer 3
Output (assembly)

Physical retails, bed, les	1	p	
Input (assembly)			
New beds to physical retails, les	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	3E4	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	806	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
Physical retails, chair, les	1	p	
Input (assembly)			
New chairs to physical retails, les	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	2.43E3	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	238	km	2.5 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
Physical retails, sofa, les	1	p	
Input (assembly)			
New sofas to physical retails, les	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	7.46E3	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	401	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

Layer 3

Output (assembly)			
<u>Physical retails, storage, les</u>	1	p	
Input (assembly)			
New storages to physical retails, les	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	1.04E4	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	291	km	2 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

Layer 3			
Output (assembly)			
<u>Physical retails, table, les</u>	1	p	
Input (assembly)			
New tables to physical retails, les	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	3.34E3	kWh	Electricity use for IKEA 80% warehouse scaled to the neighborhood by inhabitants and furniture. IKEA has a 40.9% furniture share in Norway.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	806	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 3.05 Distance between Miljøbyen Granås and IKEA

To online retails

Layer 3.5			
Output (assembly)			
<u>New beds to online retails, les</u>	1	p	
Input (assembly)			
New bed, manufacturing	2.11	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	3.42E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5
Output (assembly)

New chairs to online retails, les	1	p	
Input (assembly)			
New chair, manufacturing	0.12	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	196	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
New sofas to online retails, les	1	p	
Input (assembly)			
New sofa, manufacturing	0.42	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	685	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
New storages to online retails, les	1	p	
Input (assembly)			
New storage, manufacturing	0.96	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.55E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
New tables to online retails, les	1	p	
Input (assembly)			
New table, manufacturing	0.151	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	244	tkm	Distance between Zbaszynek and Trondheim

To physical retails

Layer 3.5			
Output (assembly)			
New beds to physical retails, les	1	p	
Input (assembly)			
New bed, manufacturing	8.53	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.38E4	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
New chairs to physical retails, les	1	p	
Input (assembly)			
New chair, manufacturing	0.69	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.11E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
New sofas to physical retails, les	1	p	
Input (assembly)			
New sofa, manufacturing	2.12	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	3.43E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
New storages to physical retails, les	1	p	
Input (assembly)			
New storage, manufacturing	2.96	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	4.78E3	tkm	Distance between Zbaszynek and Trondheim

Layer 3.5			
Output (assembly)			
<u>New tables to physical retails, les</u>	1	p	
Input (assembly)			
New table, manufacturing	0.947	ton	
Input (process)			
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.53E3	tkm	Distance between Zbaszynek and Trondheim

Friends & relatives

Layer 3			
Output (life cycle)			
<u>Friends & relatives, bed</u>	1	p	
Inputs (processes)			
Bed reparation	5.31	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	8.6E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	927	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	401	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Friends & relatives, chair</u>	1	p	
Inputs (processes)			
Chair reparation	2.35	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	3.8E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.5E3	km	2.5 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.63E3	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
Friends & relatives, sofa	1	p	
Inputs (processes)			
Sofa reparation	1.4	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.27E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	509	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	220	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
Friends & relatives, storage	1	p	
Inputs (processes)			
storage reparation	5	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	8.1E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	545	km	2 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	472	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
Friends & relatives, bed	1	p	
Inputs (processes)			
Bed reparation	2.38	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	3.85E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.36E3	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the

			city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	589	km	Spare parts are assumed to be available at IKEA.

Online second-hand shops

Layer 3			
Output (life cycle)			
<u>Online second-hand shops, bed</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	39.62	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/
Bed reparation	3.71	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	6E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	654	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	552	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Online second-hand shops, chair</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	22.30	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/
Chair reparation	2.09	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	3.38E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	945	km	2.5 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.99E3	km	Spare parts are assumed to be available at IKEA.

Layer 3

Output (life cycle)			
<u>Online second-hand shops, sofa</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	38.92	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/
Sofa reparation	3.65	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	5.9E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	654	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	552	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Online second-hand shops, storage</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	56.97	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/
Storage reparation	5.33	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	8.63E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	772	km	2 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.3E3	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Online second-hand shops, table</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	40.19	kWh	Electricity use by website scaled by furniture. https://www.websitecarbon.com/website/finn-no/

Table reparation	3.76	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	6.09E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	836	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.41E3	km	Spare parts are assumed to be available at IKEA.

Other sources

Layer 3			
Output (life cycle)			
Other sources, bed	1	p	
Inputs (processes)			
Bed reparation	1.27	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.05E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	200	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	7.53	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
Other sources, chair	1	p	
Inputs (processes)			
Sofa reparation	0.28	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	445	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	342	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5	1.64	tkm	Spare parts are assumed to be available at IKEA.

metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S			

Layer 3			
Output (life cycle)			
<u>Other sources, sofa</u>	1	p	
Inputs (processes)			
Sofa reparation	1.65	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.67E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	654	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	9.82	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Other sources, storage</u>	1	p	
Inputs (processes)			
Storage reparation	8.06	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.3E4	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.49E3	km	2 items per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	48	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Other sources, table</u>	1	p	
Inputs (processes)			
Table reparation	0.38	ton	

Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	617	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	345	km	1 item per trip 2 trips back and forth 7.05 Distance between Miljøbyen Granås and the city center
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	2.27	tkm	Spare parts are assumed to be available at IKEA.

Physical second-hand shops

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, bed</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	385.09	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Bed reparation	0.48	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	739	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	116	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	2.03	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, chair</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	586.35	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Chair reparation	0.7	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32	1.13E3	tkm	Repair materials transported to Trondheim.

metric ton, EURO6 | Cut-off, S			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	719	km	2.5 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	3.09	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, sofa</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	548.41	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Sofa reparation	0.65	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.05E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	464	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	2.89	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, storage</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	1678.5	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Storage reparation	1.99	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	3.22E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5	478	km	2 items per trip

{RER}| market for | Cut-off, S			3 trips back and forth (50% makes 2 extra trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	8.86	tkm	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>Physical second-hand shops, table</u>	1	p	
Inputs (processes)			
Electricity, low voltage {NO}| market for | Cut-off, S	1036.5	kWh	Electricity use for BrukOm warehouse scaled to the neighborhood by inhabitants and furniture.
Table reparation	1.23	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.99E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.71E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 7.5 Distance between Miljøbyen Granås and BrukOm
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER}| market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cut-off, S	5.47	tkm	Spare parts are assumed to be available at IKEA.

Lifetime extension

Layer 3			
Output (life cycle)			
<u>Lifetime extension, bed</u>	1	p	
Inputs (processes)			
Bed reparation	4.14	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	6.69E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	251	km	Spare parts are assumed to be available at IKEA.

Layer 3
Output (life cycle)

<u>**Lifetime extension, chair**</u>	1	p	
Inputs (processes)			
Chair reparation	3.57	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	5.77E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	2.06E3	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>**Lifetime extension, sofa**</u>	1	p	
Inputs (processes)			
Sofa reparation	4.93	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	7.98E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	685	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>**Lifetime extension, storage**</u>	1	p	
Inputs (processes)			
Storage reparation	15.6	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	2.53E4	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.95E3	km	Spare parts are assumed to be available at IKEA.

Layer 3			
Output (life cycle)			
<u>**Lifetime extension, table**</u>	1	p	
Inputs (processes)			
Table reparation	4.84	ton	
Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	7.82E3	tkm	Repair materials transported to Trondheim.
Transport, passenger car, EURO 5	1.28E3	km	Spare parts are assumed to be available at IKEA.

{RER}| market for | Cut-off, S			

Disposal scenario

Layer 3			
Output (disposal scenario)			
<u>Waste disposal, bed, les</u>	1	p	
Referring to assembly			
Total retails, bed, les	1	p	
Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	6.17E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Layer 3			
Output (disposal scenario)			
<u>Waste disposal, chair, les</u>	1	p	
Referring to assembly			
Total retails, chair, les	1	p	
Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	831	km	2.5 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Layer 3			
Output (disposal scenario)			
<u>Waste disposal, sofa, les</u>	1	p	
Referring to assembly			
Total retails, sofa, les	1	p	
Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	2.95E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Layer 3			
Output (disposal scenario)			
<u>**Waste disposal, storage, les**</u>	1	p	
Referring to assembly			
Total retails, storage, les	1	p	
Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	2.47E3	km	2 items per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Layer 3			
Output (disposal scenario)			
<u>**Waste disposal, table, les**</u>	1	p	
Referring to assembly			
Total retails, table, les	1	p	
Input (process)			
Transport, passenger car, EURO 5 {RER}| market for | Cut-off, S	1.2E3	km	1 item per trip 3 trips back and forth (50% makes 2 extra trips to return trailer) 14 Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
Input (waste scenario)			
Waste scenario	100	%	

Appendix C – Life Cycle Inventory

This section shows the life cycle inventory used in the model, which is at layer 4 (Figure 7). Only user-inputted inventory is shown. Inventory from ecoinvent and inventory at Layer 5 and below are not shown because of the large amount of detail. Instead, it can be viewed directly in SimaPro.

Material - Manufacturing

Layer 4			
Output (product)			
New bed, manufacturing	1	kg	Waste type: textile
Output			
Carbon dioxide	1.99	kg	Assessing the Greenhouse Gas Savings Potential of Extended Producer Responsibility for Mattresses and Boxsprings in the United States

Layer 4			
Output (product)			
New chair, manufacturing	1	kg	Waste type: wood
Output (product)			
Carbon dioxide	3.16	kg	EPD data, Median (A1-A3)

Layer 4			
Output (product)			
New sofa, manufacturing	1	kg	Waste type: textile
Output (product)			
Carbon dioxide	2.38	kg	EPD data, Median (A1-A3)

Layer 4			
Output (product)			
New storage, manufacturing	1	kg	Waste type: wood
Output (product)			
Carbon dioxide	0.96	kg	EPD data, Median (A1-A3)

Layer 4			
Output (product)			
New table, manufacturing	1	kg	Waste type: wood
Output (product)			
Carbon dioxide	3.16	kg	EPD data, Median (A1-A3)

Processing – Reparation

Layer 4			
Product			
Bed reparation	1	kg	

Input (material)			
New bed, manufacturing	0.2	kg	

Layer 4			
Product			
Chair reparation	1	kg	
Input (material)			
New chair, manufacturing	0.2	kg	

Layer 4			
Product			
Sofa reparation	1	kg	
Input (material)			
New sofa, manufacturing	0.2	kg	

Layer 4			
Product			
Storage reparation	1	kg	
Input (material)			
New storage, manufacturing	0.2	kg	

Layer 4			
Product			
Table reparation	1	kg	
Input (material)			
New table, manufacturing	0.2	kg	

Waste scenario

Layer 4			
Product			
Waste scenario	1	kg	
Input (material)			
Waste wood, untreated {NO}| market for waste wood, untreated | Cut-off, S	39.22	%	Wood (chair, table, storage)
Municipal solid waste {NO}| treatment of, incineration | Cut-off, S	100	%	

Distance parameters used in all scenarios

Distance			
distance_to_retail	1618	km	Distance between Zbaszynek and Trondheim

distance_to_ikea	3.05	km	Distance between Miljøbyen Granås and IKEA
distance_to_recycling	14	km	Distance between Miljøbyen Granås and Heggstadmoen Gjenvinningsstasjon
distance_to_brukom	7.5	km	Distance between Miljøbyen Granås and BrukOm
distance_to_sentrum	7.05	km	Distance between Miljøbyen Granås and the city center
distance_brukom_ikea	4.45	km	Distance between BrukOm and IKEA
distance_setrum_ikea	5.95	km	Distance between Sentrum and IKEA

Appendix D – SimaPro's Sankey Diagram

Figure 35, Figure 36, and Figure 37 show the Sankey diagrams generated in SimaPro for the Baseline, Second-hand, and Lifetime Extension scenarios respectively. Due to the large size of the diagrams, it is not possible to show the details in this report. For details, please refer to the SimaPro model. The diagrams in this section are meant to illustrate how the LCA model in Appendix B and C are visualized. The box at the top represents all furniture in the neighborhood in layer 1 (Figure 6). The five boxes below represent the MFA of individual furniture in layer 2 (Figure 6). From left to right are beds, chairs, sofas, storages, and tables. The third row, layer 3 (Figure 7), represents the MFA processes of each category of furniture. Finally, all the boxes below are layers 3.5 and layer 4 (Figure 7).

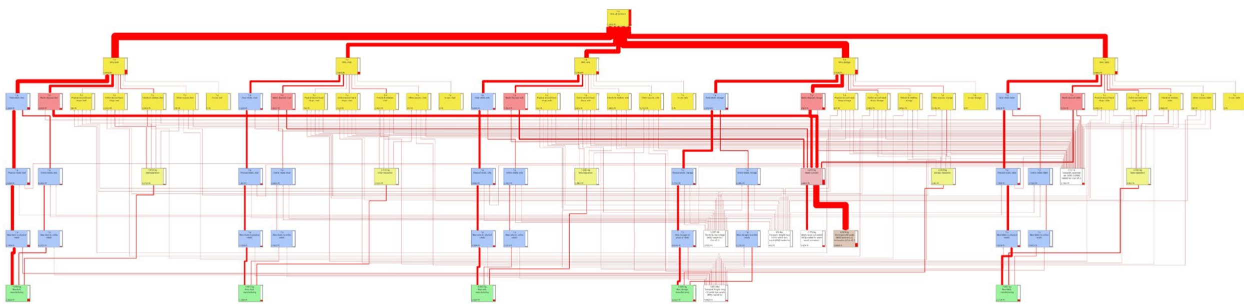


Figure 35 SimaPro's Sankey diagram of the Baseline scenario

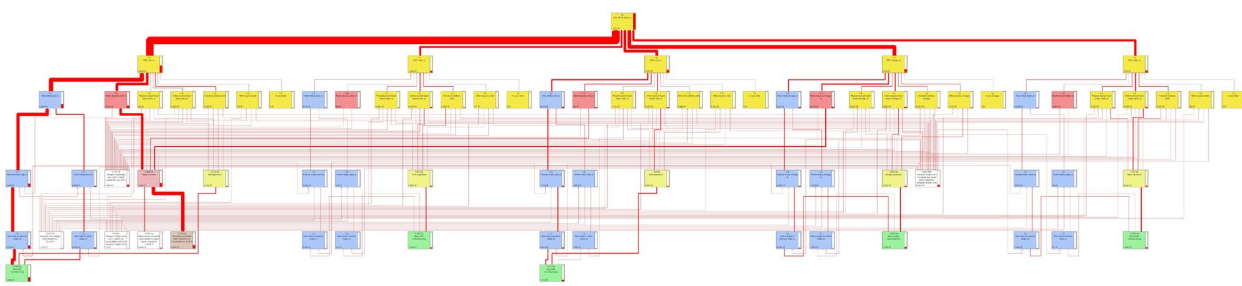


Figure 36 SimaPro's Sankey diagram of the Second-hand scenario

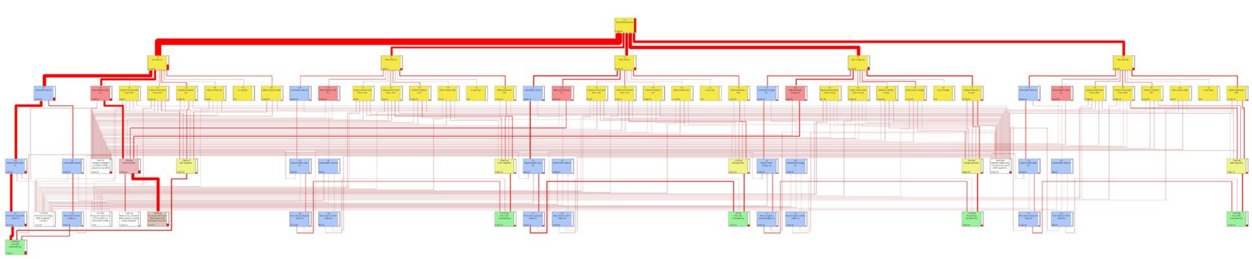


Figure 37 SimaPro's Sankey diagram of the Lifetime Extension scenario

Peerapas Thongsawas

NTNU

Norwegian University of
Science and Technology