Environmental performance of kitchens

– A case study of a Ballingslöv kitchen from a life cycle perspective

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Sammandrag

Kök är en grundläggande del av inredning i byggnader. Ett ökat fokus på hållbarhet i byggbranschen medför att det finns ett intresse att undersöka köks miljöprestanda. Genom att använda livscykelanalys (LCA) som verktyg undersöks tre olika bänkskivor (komposit, massivträ och laminat), en lucka, en stomme och även ett helt standardkök. En litteraturstudie om kundbeteende samt trender och drivkrafter på köksmarknaden kombineras med resultaten från LCA studierna för att undersöka hur resultaten kan användas för att påverka kundbeteendet.

Resultaten från LCA-studierna visar att bänkskivan i kompositmaterial har en större miljöpåverkan än bänkskivorna i massivträ och laminat. Råmaterialsfasen är den fas som bidrar med mest påverkan för alla bänkskivorna. Samma trend identifieras för luckan och stommen. I standardköket är komponenterna som bidrar med mest påverkan vitvarorna, elektriciteten i användningsfasen och kompositbänkskivan. För att förbättra miljöprestandan av ett standardkök bör vitvarorna som väljs till köket ha hög kvalité, en lång livslängd och dra lite energi i användningsfasen. En bänkskiva i massivträ eller laminat bör väljas istället för en bänkskiva i kompositmaterial. Användning av elektricitet från förnybara källor i produktion hos leverantörer samt att ha miljöanpassade transporter är ytterligare sätt att förbättra miljöprestandan på ett standardkök.

Resultaten från litteraturstudien visar att det finns en brist på studier som specifikt behandlar kundbeteende i koppling till köksmarknaden. Det är även en brist på information om köks miljöprestanda generellt. Några generella trender, drivkrafter och kundbeteenden kunde identifieras i ett större perspektiv. Det finns ett ökat intresse för hållbarhet hos kunder och en större efterfrågan på transparent och tillförlitlig information samt kommunikation inom ämnet. Det finns en koppling mellan tillförlitlig hållbarhetskommunikation och ett företags eller märkes trovärdighet och även till kundens motivation att köpa miljöanpassade produkter, även till ett högre pris.

För att tillgodose förfrågan från kunderna angående mer specifik information om miljöpåverkan från produkter så kan LCA vara ett bra verktyg. Det ger möjlighet att ge kunden råd angående vilka komponenter de ska välja till sitt kök för att förbättra den totala miljöprestandan. Kundbeteendet kan även påverkas genom att informera om vikten av att behålla köket länge eller uppmuntra till second-hand marknad när kunden vill byta kök (eller delar av köket).

Nyckelord

Kök, Livscykelanalys, Kundbeteende, Bänkskiva

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Abstract

Kitchens are an essential part of the interior design in buildings. With the increased focus on sustainability in the building industry it is therefore of interest to investigate the environmental performance of kitchens. By using life cycle assessment (LCA) as a tool three different tabletops (composite, solid wood and laminate), a door, a frame as well as the entire standard kitchen are investigated. A literature study on customer behaviour, trends and drivers on the market is combined with the results from the LCA studies to investigate how the results can be useful in affecting the behaviour of customers.

The results from the LCA studies show that the composite tabletop has a significantly higher impact than the solid wood and laminate tabletop. The trend for the tabletops is that the raw material phase contributes most to the total impact. The same trend is seen for the door and frame. For the standard kitchen the most impacting components are the white goods, the electricity in the user phase and the composite tabletop. To improve the environmental performance of a standard kitchen, the white goods should be of high quality with a long lifetime and require little electricity in the user phase. A solid wood or laminate tabletop should be chosen over a composite tabletop. Using electricity from renewable sources in the production in the supply chain as well as using sustainable transports are other means of improving the environmental performance.

The literature study shows that there is a lack of studies that specifically address customer behaviour in connection to the kitchen market. There is also a lack of information on environmental performance of kitchens in general. Some general trends, drivers and customer behaviours could be identified in a broader perspective. There is an increased interest for sustainability issues among customers and a higher demand for transparent and honest information as well as communication on this subject. There is a connection between honest sustainability communication and the credibility of the company or brand as well as the motivation to buy environmentally adapted products, even at a higher cost.

To adhere to the requests from customers on more specific information about the environmental impact of products LCA can be useful. It generates possibilities to advice the customer on which components they should choose to improve the environmental performance of their kitchen. The customer behaviour can also be affected by informing the customer of the importance to keep their kitchen longer or encourage the customer to second-hand trade when changing kitchen (or parts of it).

Keywords

Kitchen, Life cycle assessment, Consumer behaviour, Tabletop

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Preface

This master thesis has been done in collaboration with Ballingslöv International and is a final project at the end of my studies in Environmental engineering at Lunds Tekniska Högskola.

Firstly, I would like to thank my supervisor Pål Börjesson and my examiner Lars J. Nilsson at the Department of Environmental and Energy Systems at LTH for the feedback and guidance you provided.

I would also like to say a BIG thank you to everyone at Ballingslöv International, especially Marie Webrandt and Magnus Hegdal, for making this master thesis possible and for the support and encouragement you have given me. I have truly felt that you believed in me from day one, thank you!

Additionally, I would like to thank Jens Nedersee at DFI Geisler and Fredrik Nyberg at Ballingslöv AB for putting up with my many questions and long emails.

Last, but definitely not the least, I cannot thank Pär Lindman at Miljögiraff AB enough for the amount of time and help you have given me. Without you I would not have been able to complete half of the things I have included in this master thesis. Thank you for the help with building the models and running the simulations, for the interesting discussions, for sharing your knowledge of LCA as well as being a great support and helping me out with problems that occurred along the way. This master thesis would not have been the same without you. Thank you!

Annie Johansson

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Abbreviations

BREEAM – Building Research Establishment Environmental Assessment Method

CO_2eq – Carbon dioxide equivalents

EPD – Environmental Product Declaration

GWP – Global Warming Potential

HVO – Hydrogenated Vegetable Oil

ISO – International Organization for Standardization

LCA – Life Cycle Assessment

LCI – Lice Cycle Inventory Analysis

LCIA – Life Cycle Impact Assessment

MDF – Medium density fibre board

NTM – Network for Transport Measures

1. Introduction

1.1 Background

In the building industry there has been a rapid development within the sustainability area and the demands for transparency and awareness of environmental performance have increased. This has in turn led to an increase of Environmental product declarations (EPDs) and reporting to environmental certification systems such as BREEAM and Sunda Hus. Recently the Swedish government also made demands for climate declarations on new buildings built from 1st January 2022 (Sveriges Byggindustrier, 2019). The increased focus on environmental performance has brought attention to the materials used in the buildings, for example concrete. An additional consequence of the increased requirements for environmental information regarding buildings is that more focus is put on the interior design as well.

When investigating the environmental performance of interior design, kitchens become an area of interest since they are a significant part of it. To some extent the kitchen business is already required to report to BREEAM and Sunda Hus because of the development within the building industry. The furniture industry has developed EPDs for many products and to a large extent they use the same materials as the kitchen industry (EPD International AB, n.d. b). Therefore, this development may also be seen in the kitchen industry within a not so distant future.

Since it is of interest to investigate the environmental performance of kitchens, and because there is a lack of information on the topic, this master thesis aims to provide an increased knowledge within this area. This master thesis will analyse the environmental performance of kitchens as a product and focus on mapping the components and materials to find out if there is a possibility to improve the overall environmental performance. Furthermore, an aim is to investigate how environmental information can be communicated to customers.

1.2 Purpose and research questions

The aim of this master thesis is to use life cycle assessment (LCA) as a tool to investigate the environmental impact of three different tabletops as well as understand the environmental impact of an entire kitchen. Additionally, an aim is to understand customer behaviour as well as trends and drivers on the kitchen market. This in order to see how providing environmental information of a kitchen can affect the customer's decisions.

The research questions this thesis aims to answer are:

- What difference is there in the environmental impact between tabletops made of different materials from a life cycle perspective?
- What is the environmental impact of a standard kitchen?
- How can the environmental performance of a standard kitchen be improved?
- What trends and drivers are there on the kitchen market?
- In what way is it possible to affect the decisions customers make when buying a kitchen as well as the customer behaviour during the lifetime of the kitchen?

1.3 General method and structure

This master thesis consists of 3 parts:

- Life cycle assessment of three tabletops of different materials to identify hot spots and determine which material is better from a life cycle perspective.
- Life cycle assessment of a standard kitchen to better understand the impact from individual parts of the kitchen as well as the overall environmental impact.
- A literature study of customer behaviour, trends and drivers on the kitchen market.

The general structure of the report will follow the work process described below (Figure 1). The *Theory* chapter covers both the general method of LCA and the method for the literature study. Next chapter, *Life cycle assessment*, includes LCA for tabletops, door and frame as well as LCA for a standard kitchen. It also includes a sensitivity analysis. The *Literature study* that follows, addresses customer behaviour, trends and drivers on the market. The *Discussion* ties together the results from the LCA with the results from the literature study and the most important takeaways from this report are summarized in the chapter *Conclusions*.

Figure 1: General work process and structure of master thesis.

2. Theory

2.1 Life cycle assessment according to the ISO standard

Life cycle assessment (LCA) is a tool that is used to investigate the environmental impact of a product during the entire life cycle, and the methodology is based on the ISO Standard 14040 series (ISO, 2006). LCA can be used to map environmental impact during the life cycle and identify possibilities to improve the environmental performance in the different phases. Some areas where LCA is beneficial are development and improvement of products, strategies and public policy as well as marketing.

Generally, the methodology is divided into four different steps; goal and scope definition, inventory analysis, impact assessment and interpretation (Figure 2). In the *goal and scope definition* the goal, purpose and boundaries of the LCA are defined (ISO, 2006). In the *inventory analysis* all data is gathered and processed. The *impact assessment* includes the selection of impact categories, assignment of LCI results to selected categories and calculation of results. In the *interpretation* significant issues are identified and checks are made regarding completeness, sensitivity and consistency. The interpretation should also include conclusions, limitations and recommendations. The LCA work process is an iterative process, meaning that the definitions in goal and scope sets the course for the rest of the work with the LCA. Depending on the outcome in later steps in the LCA it may be necessary to go back and change the initial goal and scope to adjust to the findings.

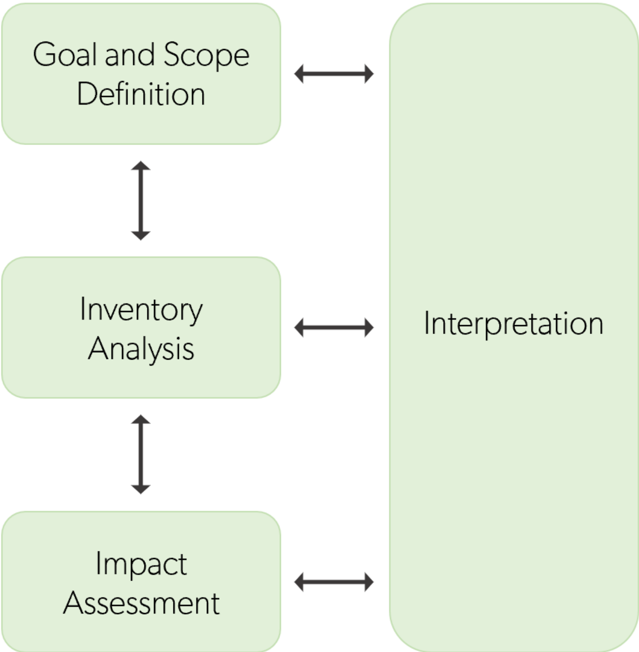

Figure 2: The iterative LCA work process, based on ISO 14044:2006

In chapter 3, *Life cycle assessment*, the process is described in detail for the products investigated in this report, specifically in section *3.1 LCA of tabletops*.

2.2 Literature study – Method

2.2.1 Database search

To answer the research questions regarding environmental performance of kitchens, customer behaviour, trends and drivers on the kitchen market a literature study was made. The database LubSearch was used for retrieving relevant academic journals regarding the subject.

The search words *kitchen* and *customer behaviour* were used in combinations with each other as well as with words connected to life cycle assessment, sustainability and market. The results of the literature study are presented in Table 12. The titles of the academic journals generated from the search led to new ideas of other search words and combinations. The references in some of the academic journals were also of interest for the study. Some of the academic journals that were suggested by the database after downloading a relevant article were also deemed relevant for the literature study.

2.2.2 Selection

One criterion for the selection of relevant academic journals from the database was that they should have been peer reviewed. Only academic journals that were peer reviewed were deemed relevant. Another criterion was that the academic journals were to be as recent as possible, no older than 10 years, meaning that they should be published after 2009.

The academic journals that had all or most of the specific search words as key words and/or a title that seemed relevant were reviewed. To be relevant the title had to seem connected to the purpose or contain all search words. If the academic journal seemed relevant the abstract was reviewed to determine whether it was related to the topic that the search words covered.

If the abstract seemed to connect to the purpose of the literature study the article was put through a first review, where the introduction as well as results and conclusions were read briefly and it was determined whether the academic journal/article contributed to fulfilling the purpose of the literature study. If it contributed to the purpose, the article was deemed relevant for the study and was thoroughly reviewed.

2.2.3 Other literature

Other literature than academic journals have been gathered from different authorities and organisations relevant to the topic such as the International Organisation for Standardization (ISO), EPD International, BREEAM and Certifiering.nu. To get an insight in the second-hand market the webpages Blocket.se and Citiboard.se were browsed. Some information regarding communication and trends connected to sustainability reporting was also retrieved from the Hallvarsson & Halvarsson webpage.

3. Life cycle assessment

This chapter will cover the LCA of three different tabletops, the LCA of the door and frame, the LCA of the standard kitchen and a separate section covering a sensitivity analysis.

3.1 LCA of tabletops

This section contains a thorough explanation of the work process for the LCA of tabletops, addressing goal and scope definition, life cycle inventory analysis (LCI) and life cycle impact assessment (LCIA). The life cycle impact assessment (LCIA) will cover the presentation of the results mainly for the impact category climate change. Life cycle interpretation covers the identification of hotspots for the impact category climate change. A sensitivity analysis is presented in a separate section after the sections LCA for door and frame and LCA for a standard kitchen.

3.1.1 Goal and scope definition

3.1.1.1 Background

Within the building industry there has been an increased interest for sustainability and information on environmental performance. The same interest is seen in the furniture industry. When investigating the overall environmental performance of buildings, it is relevant to focus on the interior design. Kitchens are a major part of the interior design and it is of interest to investigate the environmental performance of kitchens as well as the individual parts of kitchens. One essential part is the tabletop. The material in the tabletop can vary from stone to wood, and the purpose of this LCA is to investigate which type of material in tabletops that has the largest environmental impact in a life cycle perspective.

The goal is to compare three tabletops of different materials (composite, solid wood and laminate) to determine which is better from a life cycle perspective and which improvements that can be made during the lifecycle.

3.1.1.2 System

Functional Unit

The functional unit (FU) is a reference unit used in LCA which all input and output data are normalized to.

In this LCA the functional unit is *1m^2 of tabletop with a thickness of 30 mm and a lifetime of 20 years*.

The lifetime of 20 years is based on a best estimate from Ballingslöv AB. The technical lifetime is longer, but the assumption is based on the customer behaviour on the kitchen market. Kitchens are often changed due to trends or the customer’s desire to change the kitchen when buying a new house.

System boundary

The system boundary in this LCA is assumed to go from cradle to grave (Figure 3). The life cycle starts with the extraction and/or production of raw material. The raw material goes through several production- and manufacturing processes which results in the tabletop itself. The life cycle ends with an end-of-life phase, where the tabletop is assumed to follow the fate of the complete kitchen. The end-of-life reflects what happens to the tabletop based on different cases. The total impact is an aggregation of three scenarios: keeping the tabletop, second-hand trade and prolonged life or waste management of the tabletop.

In this LCA only the tabletop itself is examined, without sinks, taps or any other appliances that are generally attached to a tabletop when installed in a kitchen. Therefore, production of these falls outside the system boundary.

The geographical boundary is set to Europe and the USA to cover the production in Denmark as well as the production at known suppliers located in Europe and the USA.

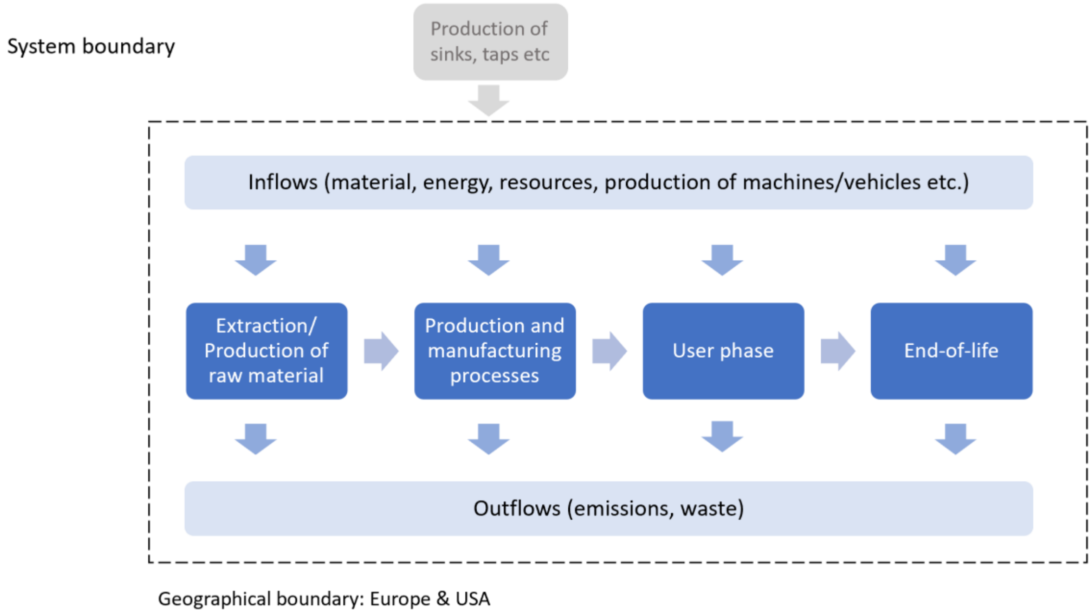

Figure 3: Description of system boundary for the LCA. The geographical boundary is Europe and the USA.

Description of product system

The three different tabletops that are investigated are composite, solid wood and laminate. Composite is made from a mix of glass/mirror, cristobalite, quartz/silica sands, resin, pigment, feldspar and catalyser. The solid wood tabletop is made from oak wood and glue. The laminate tabletop consists of a particle board with laminate attached on top of it and balancing paper underneath it and ABS (plastic) edges on the sides.

For each tabletop a figure illustrates the process that the LCA covers (Figure 4 – 6). Transports are not included in the process diagrams. Each figure is followed by a description of the process.

Composite

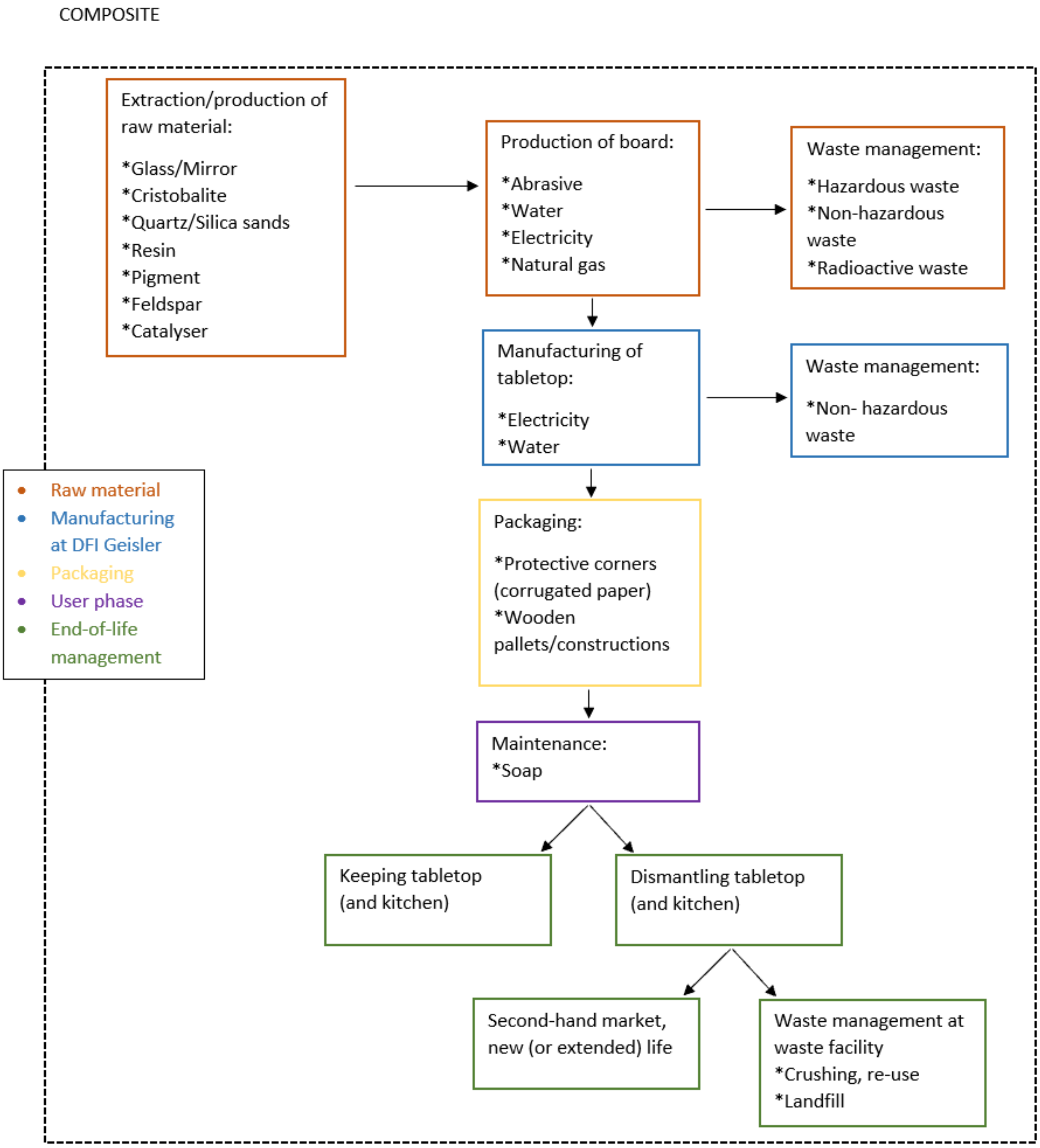

Figure 4: The process diagram for the composite tabletop (cradle to grave). Transports are not illustrated in the diagram.

Raw material: This stage includes the supply of raw material, transport to the production plant in Spain and the production in Spain. The composite tabletops produced are composed of glass/mirror, cristobalite, quartz/silica sands, resin, pigment, feldspar and catalyser.

Transport to DFI Geisler: From the factory (Consentino) located in Spain to DFI Geisler in Nykøbing Mors, Denmark. The transport is by truck with diesel as fuel and the distance the tabletop is transported is 2900 km.

Manufacturing at DFI Geisler: At the factory the tabletops are custom-made. They are cut in specified dimensions and the edges polished. Then corner protectors in corrugated paper are put on the tabletop and they are put on wooden pallets/constructions.

Transport to customer: The transport to the customer is presumed to be a distance from DFI Geisler in Nykøbing Mors, Denmark to Ballingslöv AB in Ballingslöv, Sweden and eventually from Ballingslöv AB to a customer in Stockholm, Sweden. The transport is by truck with diesel as fuel and the transport distance is a total of 1038 km.

User phase: For the user phase it is assumed that there is only an impact from the maintenance of wiping off the tabletop. The tabletop is cleaned with green soap and the assumed yearly consumption is 0.2 kg of soap per m^2.

End-of-life: For a Ballingslöv kitchen there are multiple scenarios in end-of-life which has been taken into consideration since the tabletop is assumed to follow the same path as the rest of the kitchen. Based on a best estimate together with Ballingslöv AB it is assumed that 80% of the tabletops remain installed in the kitchen after 20 years. 12% are sold on a private second-hand market (for example Blocket.se or Citiboard.se) and 8% will be transported to a waste facility where it will be treated (crushed and used as road fill or as cover for landfill). A more detailed explanation of the assumption in end-of-life can be found in Appendix 2.

Solid wood

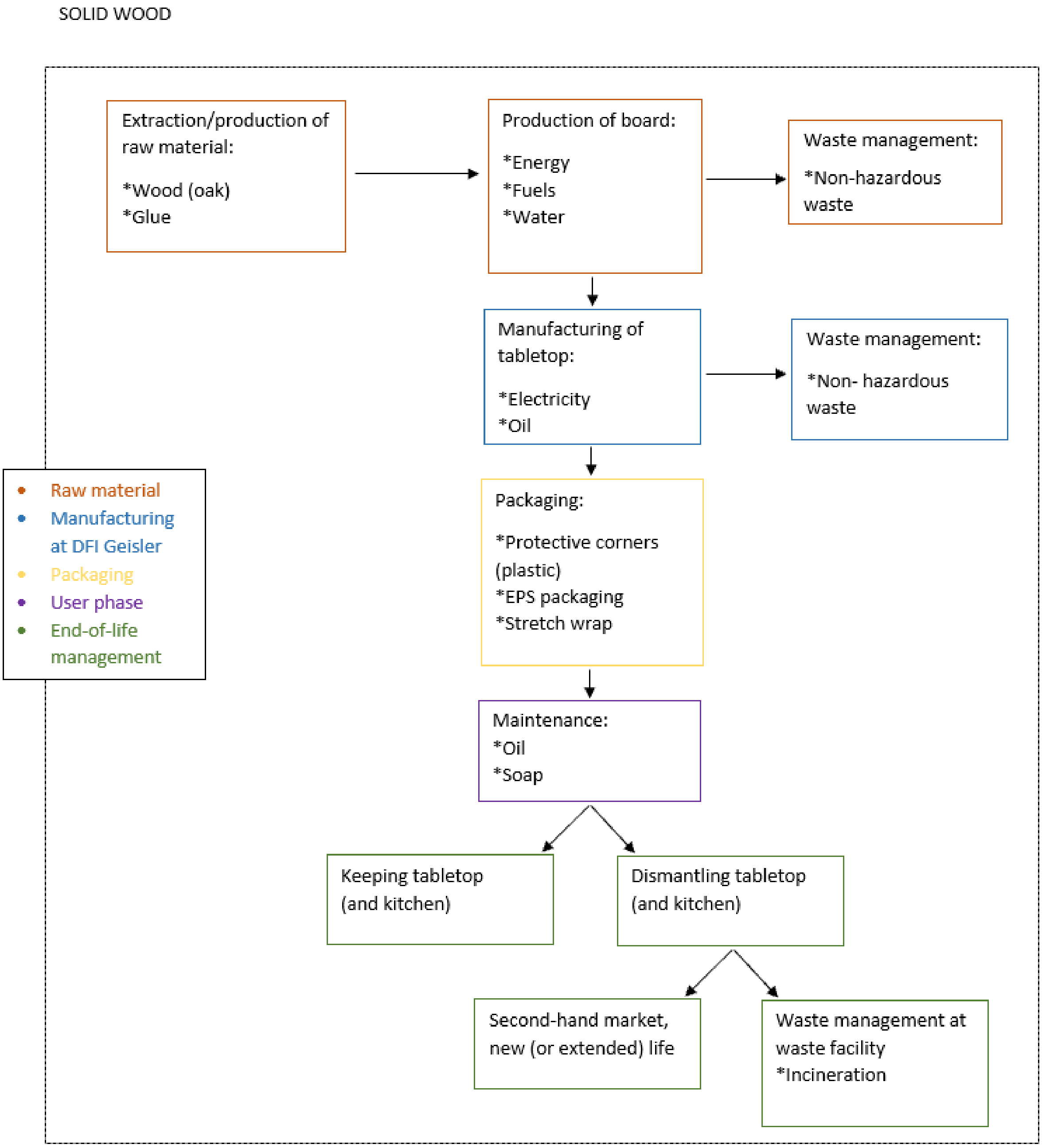

Figure 5: The process diagram for the solid wood tabletop (cradle to grave). Transports are not illustrated in the diagram.

Raw material: This phase includes the supply of raw material (wood from Croatia and glue from USA), transport from the suppliers (Croatia and USA respectively) to the production plant in Denmark (Herning Massivtrae A/S) as well as the production in the factory in Denmark (Herning Massivtrae A/S).

Transport to DFI Geisler: From the factory (Herning Massivtrae A/S) located in Denmark, to DFI Geisler in Nykøbing Mors, Denmark. The solid wood is transported a distance of 100km with truck using diesel as fuel.

Manufacturing at DFI Geisler: At the factory the tabletops are custom-made. They are cut in specified dimensions, and then the surface of tabletop is polished and the edges are polished/shaped. After that the tabletop is oiled and packaged with plastic corner protectors, EPS packaging and stretch wrap.

Transport to customer: The transport to the customer is presumed to be a distance from DFI Geisler in Nykøbing Mors, Denmark to Ballingslöv AB in Ballingslöv, Sweden and eventually from Ballingslöv AB to a customer in Stockholm, Sweden. The transport is by truck with diesel as fuel and the transport distance is a total of 1038 km.

User phase: For the user phase it is assumed that there is only an impact from the maintenance of oiling and wiping off the tabletop. The tabletop is cleaned with green soap and the assumed yearly consumption is 0.2 kg of soap. The solid wood tabletop is also to be oiled 4 times per year and the amount of oil used is 5ml per m^2 each time, which gives a yearly consumption of 20 ml oil per year per m^2.

End-of-life: For a Ballingslöv kitchen there are multiple scenarios in end-of-life which has been taken into consideration since the tabletop is assumed to follow the same path as the rest of the kitchen. Based on a best estimate together with Ballingslöv AB it is assumed that 80% of the tabletops remain installed in the kitchen after 20 years. 12% are sold on a private second-hand market (for example Blocket.se or Citiboard.se) and 8% will be transported to a waste facility where it will be treated (incinerated).

Laminate

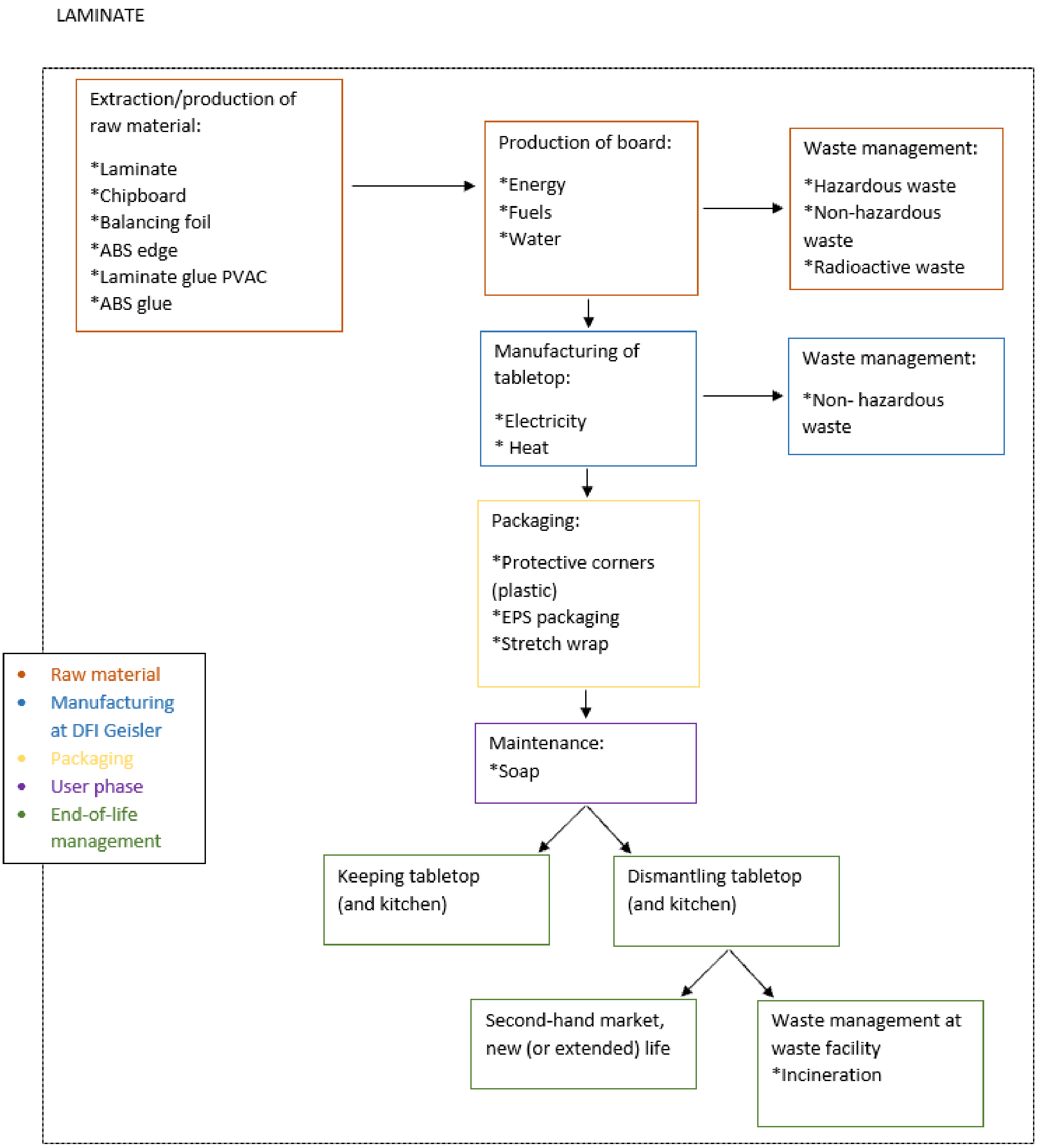

Figure 6: The process diagram for the laminate tabletop (cradle to grave). Transports are not illustrated in the diagram.

Raw material: This phase includes the extraction/production of raw material, the transport to production plant and the manufacturing the raw materials laminate, particle board, ABS edge, balancing foil, PVAC glue and ABS glue.

The laminate is produced by Riisfort in Århus, Denmark. Riisfort is also the supplier of balancing foil. The balancing foil is not produced at Riisfort and therefore an extra transport between sub-supplier and Riisfort is included in this phase of the life cycle. The particle board is produced by Kronospan in Århus, Denmark and the ABS edge is produced in Germany by

REHAU. The PVAC glue and the ABS glue is produced by PKI Industrial Adhesives in Frederica, Denmark.

Transport to DFI Geisler: All transports are by truck using diesel as fuel. The laminate and balancing foil are transported 126 km from Riisfort in Århus to DFI Geisler in Nykøbing Mors. For the particle board the distance of the transport is 140 km (from Kronospan in Århus to DFI Geisler in Nykøbing Mors). The ABS edge is transported 420 km from REHAU, Germany to DFI Geisler in Nykøbing Mors and the PVAC and ABS glue are transported 173km from Frederica, Denmark to DFI Geisler in Nykøbing Mors, Denmark.

Manufacturing at DFI Geisler: The particle board is glued together with laminate on top of it and a balancing foil underneath the particle board in standard dimensions. Then they are cut in custom-made dimensions and an ABS edge is attached with glue. The finished tabletop is packaged with EPS packaging and plastic protecting corners. Finally, the tabletop is wrapped with stretch wrap.

Transport to customer: The transport to the customer is presumed to be a distance from DFI Geisler in Nykøbing Mors, Denmark to Ballingslöv AB in Ballingslöv, Sweden and eventually from Ballingslöv AB to a customer in Stockholm, Sweden. The transport is by truck using diesel as fuel and the transport distance is a total of 1038 km.

User phase: For the user phase it is assumed that there is only an impact from the maintenance of wiping off the tabletop. The tabletop is cleaned with green soap and the assumed yearly consumption is 0.2 kg of soap.

End-of-life: For a Ballingslöv kitchen there are multiple scenarios in end of life which has been taken into consideration since the tabletop is assumed to follow the same path as the rest of the kitchen. Based on a best estimate together with Ballingslöv AB it is assumed that 80% of the tabletops remain installed in the kitchen after 20 years. 12% are sold on a private second-hand market (for example Blocket.se or Citiboard.se) and 8% will be transported to a waste facility where it will be treated (incinerated).

3.1.1.3 LCIA Methodology

SimaPro

The model for the simulations of the environmental impact of the tabletops is set up in the LCA software SimaPro, with the help from Pär Lindman at Miljögiraff AB. SimaPro is connected to different databases that contain methods for evaluating the environmental impact. In this project the results are calculated with the EPD model/method and the midpoint assessment method.

Ecoinvent

Ecoinvent is a large independent database included in SimaPro which can provide generic data where there are gaps in the specific data. The generic data covers environmental impact, including upstream and downstream processes in the life cycle. It is also possible to use generic data from Ecoinvent in combination with specific data.

Impact categories

The impact categories describe the impact caused by emissions and consumption of natural resources along the life cycle. The choice of impact categories in this LCA is based on the categories used in EPDs and are presented in Table 1 below.

Table 1: Impact categories, unit, characterization model and a description of the impact category.

Impact category	Unit	Characterization model*	Description
Climate change (GWP - Global warming potential)	kg CO_2 eq	IPCC (2013)	Indicates the potential of global warming caused by emissions of greenhouse gases
Acidification	kg SO_2 eq	Hauschild & Wenzel (1998)	Indicator of the potential acidification of soil and water as a consequence of the emission of gases such as NO_X and SO_X
Eutrophication	kg PO_4 eq	Heijungs et al. (1992)	Indicator of the increase of nutritional elements in the aquatic ecosystem, caused by the release of compounds containing nitrogen or phosphor
Ozone layer depletion (ODP)	kg CFC-11 eq	WMO (1999)	Indicates emissions (to air) that cause the destruction of the stratospheric ozone layer
Abiotic depletion of fossil resources	MJ	Oers et al. (2002)	Indicates the consumption of natural fossil resources
Abiotic depletion potential of elements (non-fossil resources)	kg Sb eq	Oers et al. (2002)	Indicates the consumption of natural non-fossil resources
Photochemical oxidation	kg NMVOC (Non Methane Volatile Organic Compounds)	Van Zelm et al. (2008), ReCiPe (2008)	Indicator of the release of gases that can react with sunlight and create photochemical ozone in the lower atmosphere (smog).

*More detailed information: EPD International AB (n.d. c) and European Union (2011)

3.1.1.4 Data

Data quality requirements

The data quality requirements in this LCA will be set according to:

- *Geographical coverage*: The geographical area covered is Europe and the USA and is based on the location of known suppliers within the areas. Specific sites, transport distances as well as local composition of energy (electricity and heat) are prioritized over generic data.

- *Technological coverage*: To the greatest extent possible specific data for the technology applied in the various production stages is used. Where data for specific sites is missing it is replaced with generic data from Ecoinvent representing sites that fulfil the geographical requirements. Data for the exact products or materials that are studied is prioritized. Alternatively, data for comparable products or materials is used.
- *Time-related coverage*: For all unit processes the data should be as recent as possible after fulfilling the geographical and technological requirements. Data gathered directly from production sites is to be up to date. Where specific data is missing the latest generic data from Ecoinvent is used. The EPDs used for specific or comparable products should not have expired at the time of the data inventory. However, in the case with the particle board the EPD had a validity date that had expired during 2019. It is worth to note that the data used to establish the EPD is most likely gathered up to a few years before the publishing date.

Allocation procedures

Allocations have been made where it is deemed necessary. The transportation has been allocated according to weight. The manufacturing at the factory has been allocated based on statistics of m^2 of tabletops per year. In the end-of-life scenario allocations were made based on the weight of the complete kitchen (Table 2), calculating each tabletop's weight percentage of the complete kitchen (Table 3).

Table 2: Weights of tabletop, kitchen and white goods in kilograms as well as the weight of the complete kitchen for each tabletop. The weight is for 3.2m² of tabletop, which is used in the standard kitchen further ahead.

	Composite	*Laminate*	*Solid wood*
Tabletop	243	71	69
Kitchen[1] *(excluding tabletop and white goods)*	700	700	700
White goods[2]	182	182	182
Total weight of complete kitchen	1125	954	951

Table 3: The percentage of the total weight of the complete kitchen for the tabletop, kitchen and white goods depending on which material the tabletop is made of.

	Composite	*Laminate*	*Solid wood*
Tabletop	25%	9%	9%
Kitchen[1]	47%	57%	58%
White goods[2]	28%	34%	34%

*Due to rounding up or down numbers the total may not correspond to 100%

[1] The kitchen excluding tabletop and white goods consists of 16 frames and cabinets (mixed), estimation of 14.5 standard doors, 25 handles, hinges and 300 screws.

[2] The weight of all white goods is the collected weight of the hob, oven, microwave oven, dishwasher, combined fridge/freezer and hood.

Cut off
A cut off criteria commonly used is that flows smaller than 1% of the total in- or outflow can be cut off, based on mass, if it does not generate a significant impact as long as the sum of the flows excluded does not exceed 5%.

Due to extensive use of specific data in this LCA, most in and out flows in the unit processes have been accounted for. Regarding the specific data in this LCA, it is only oil for moving parts at DFI Geisler that have been cut off according to the criteria. The amount of oil for moving parts (such as engines) is considered to be far less than 1% of the inflows at DFI Geisler and it is therefore excluded from the study.

When using the EPDs for the raw material phases it is noted that the EPDs follow the cut off criteria.

3.1.2 Life cycle inventory analysis (LCI)

The general sources of data and an analysis of time related coverage and geographical coverage is seen in Table 4 below. All data is fulfilling the technological requirements and this requirement is therefore not presented. Detailed data can be found in Appendix 1.

Table 4: Overview of the data types, sources and how it fulfils the data quality requirements.

Material/Process	Description of data	Data source	Time-related coverage	Geographical coverage
Transport to DFI Geisler	Type of transports, distances, allocations	Jens Nedersee, DFI Geisler	2019	Europe
Manufacturing at DFI Geisler	Information about energy, waste, emissions etc.	Jens Nedersee, DFI Geisler	2018/2019	Denmark
Waste management (from DFI Geisler)	Type of waste treatment, and waste treatment company	Jens Nedersee, DFI Geisler	2019	Denmark
Composite tabletop	Extraction/production of raw material, transport to production site and production of tabletop.	EPD Consentino	Valid: 2019 – 2024	Spain
Laminate	Extraction/production of raw material, transport to production site and production	EPD Eggers	Valid: 2014 – 2020	Austria

	of laminate. Production site is modified to Århus.	Jens Nedersee, DFI Geisler	2019	Denmark
Particle board	Extraction/production of raw material, transport to production site and production of particle board. Production site modified to Århus. Energy	EPD Eggers Jens Nedersee, DFI Geisler Henrik Skovbo, Kronospan	Valid: 2013 – 2019 2019	Germany Denmark Denmark
Balancing paper	Energy (at the supplier)	Riisfort	2019	Sweden
ABS-edge	Energy, waste	Jonatan Elnegaard, REHAU	2004	Germany
Laminate glue PVAC & ABS glue	Content	Data sheet, PKI Industrial Adhesives	2018	Denmark
Glue in particle board	Content	Safety data sheet, Dynea	2009	Denmark
Solid wood tabletop	Content, energy and waste	Aleks Olesen, Herning Massivtrae Data sheet, Herning Massivtrae	2019	Denmark
Glue in solid wood tabletop	Content	Safety data sheet, Franklin International	2018	USA
Oil for solid wood tabletop	Content Energy and waste	Safety data sheet, Hesse Lignal Coatings Claus Andersen, Aalborg Farve og Lak	2018 2019	Denmark Germany

3.1.3 Life cycle impact assessment (LCIA)

In this section the results for the tabletops are presented based on the chosen impact categories (see section *3.1.1.3 LCIA Methodology).*

The results of the total amount of CO_2 equivalents (CO_2eq) for each tabletop is illustrated below (Figure 7). For the composite tabletop the total amount of greenhouse gas emissions during the life cycle corresponds to 191 kg CO_2eq. The total impact on climate change for the solid wood tabletop is 25 kg CO_2eq and for the laminate it is 22 kg CO_2eq. The total impact of the composite tabletop is almost 8 times larger than the impact of the solid wood tabletop and 9 times larger than the laminate tabletop. More detailed results in the form of Sankey diagrams can be found in Appendix 3.

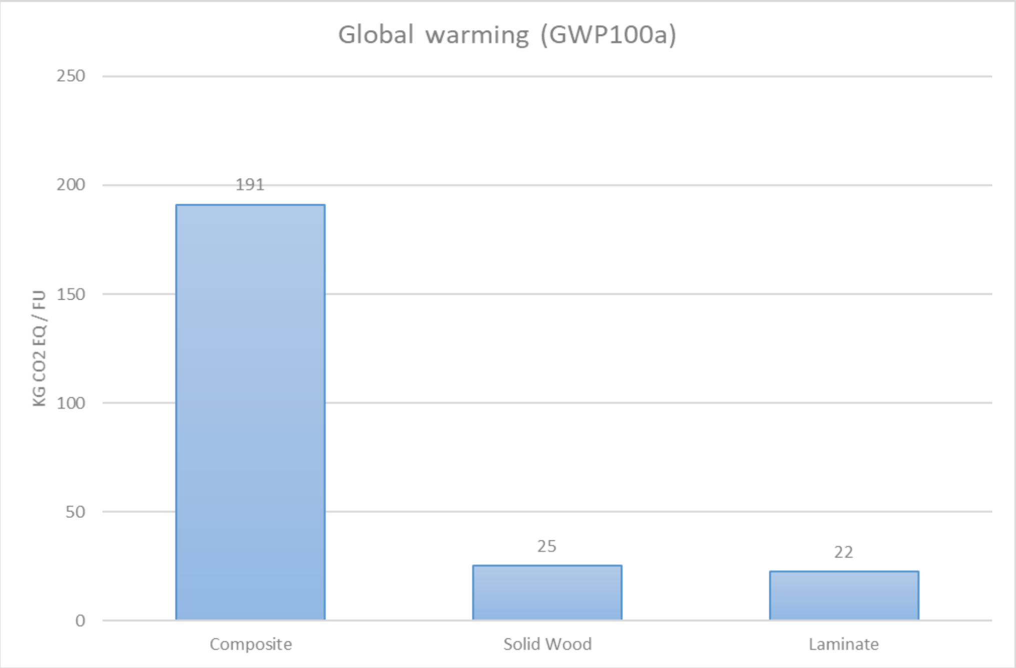

Figure 7: The total amount of CO_2 equivalents (impact on climate change) for the three tabletops composite, solid wood and laminate per functional unit. The composite has the largest impact on climate change. The solid wood and laminate have similar impact on climate change.

The impact for each stage in the life cycle (raw material, transport raw material, manufacturing at DFI Geisler, packaging, transport finished tabletop, maintenance and disposal scenario) as a percentage of the total impact is seen in Figure 8 below. For every tabletop the raw material has the largest impact during the life cycle; composite 64%, solid wood 68% and laminate 63% (Table 5). For the composite tabletop the transport from the factory in Spain to DFI Geisler in Denmark is having the second largest impact, corresponding to 25%. The solid wood tabletop has the second largest impact in the maintenance phase (15%) and the third largest impact in the transport of the finished tabletop to the customer (12%). The laminate tabletop has second largest impact in maintenance phase and third in transport of finished tabletop to the customer, corresponding to 16% and 14% respectively.

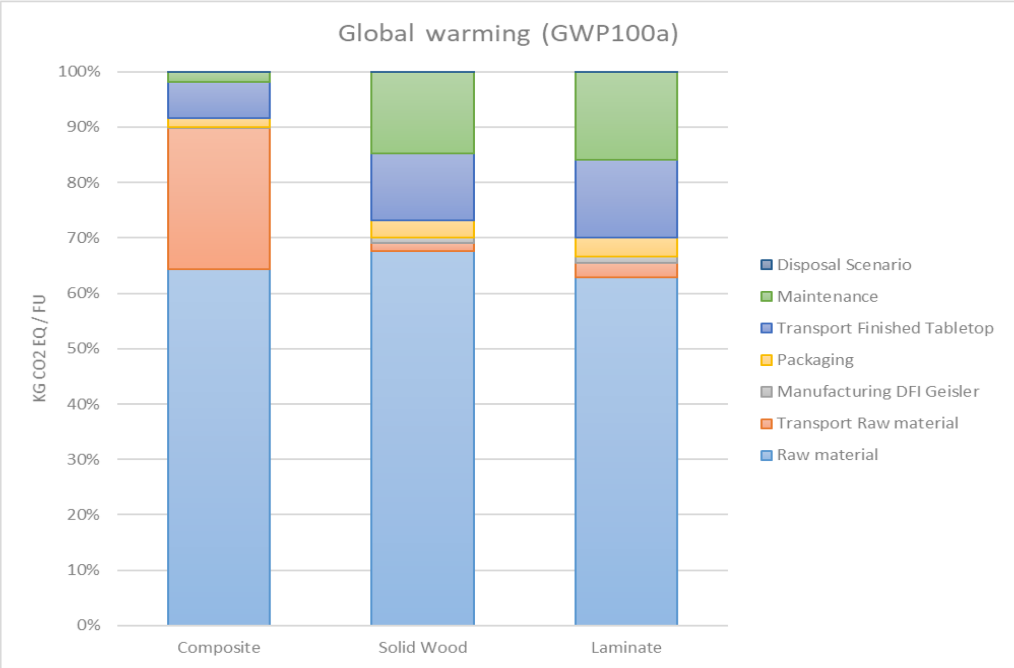

Figure 8: The impact for each stage in the life cycle (raw material, transport raw material, manufacturing at DFI Geisler, packaging, transport finished tabletop, maintenance and disposal scenario) as a percentage of the total impact.

Table 5: The percentage of total impact on climate change for each tabletop divided into the life cycle stages raw material, transport of raw material, manufacturing, packaging, transport of finished tabletop, maintenance and the disposal scenario.

	Composite	*Solid Wood*	*Laminate*
Raw material	64%	68%	63%
Transport raw material	25%	1%	2%
Manufacturing	0%	1%	2%
Packaging	2%	3%	4%
Transport finished tabletop	6%	12%	14%
Maintenance	2%	15%	16%
Disposal scenario	0%	0%	0%

*Due to rounding up or down numbers the total may not correspond to 100%. The impact from the disposal scenario is small compared to the total impact and is therefore approximated to be 0%.

In the diagrams that follow (Figure 9 to 15) the results for each impact category are presented as a total and divided into the life cycle phases of the tabletops.

When comparing the three tabletops the composite has a larger impact in total in all impact categories. In the impact category climate change the composite tabletop has the largest impact in the raw material phase, followed by transports to DFI Geisler and then transports from DFI Geisler. Packaging and maintenance have similar impact and the impact from the manufacturing and disposal scenario is very small (next to zero).

The same trend can be seen in the impact categories acidification, eutrophication, ozone layer depletion and abiotic depletion of fossil fuels (Figure 10 to 13). However, when it comes to photochemical oxidation and abiotic depletion of elements the trend changes (Figures 14 and 15). For photochemical oxidation (Figure 14) the transport of raw material has more impact than the raw material phase. Raw material, transports from DFI Geisler and packaging contribute to the total impact in the specified order. When it comes to abiotic depletion of elements (Figure 15) the largest impact comes from the raw material phase, which contributes with 94%. This is followed by the impact from the packaging and maintenance phases.

Comparing the solid wood and laminate, there is little difference between the two in the impact category global warming (Figure 9). In the impact categories acidification, abiotic depletion of fossil fuels, photochemical oxidation and abiotic depletion of elements (Figure 10, 13, 14 and 15) the laminate tabletop has a larger impact than the solid wood tabletop and the higher impact occurs in the raw material phase of the life cycle. Only in the impact categories eutrophication and ozone layer depletion (Figures 11 and 12) the solid wood has larger impact than the laminate tabletop and it is also in the raw material phase that there is most impact.

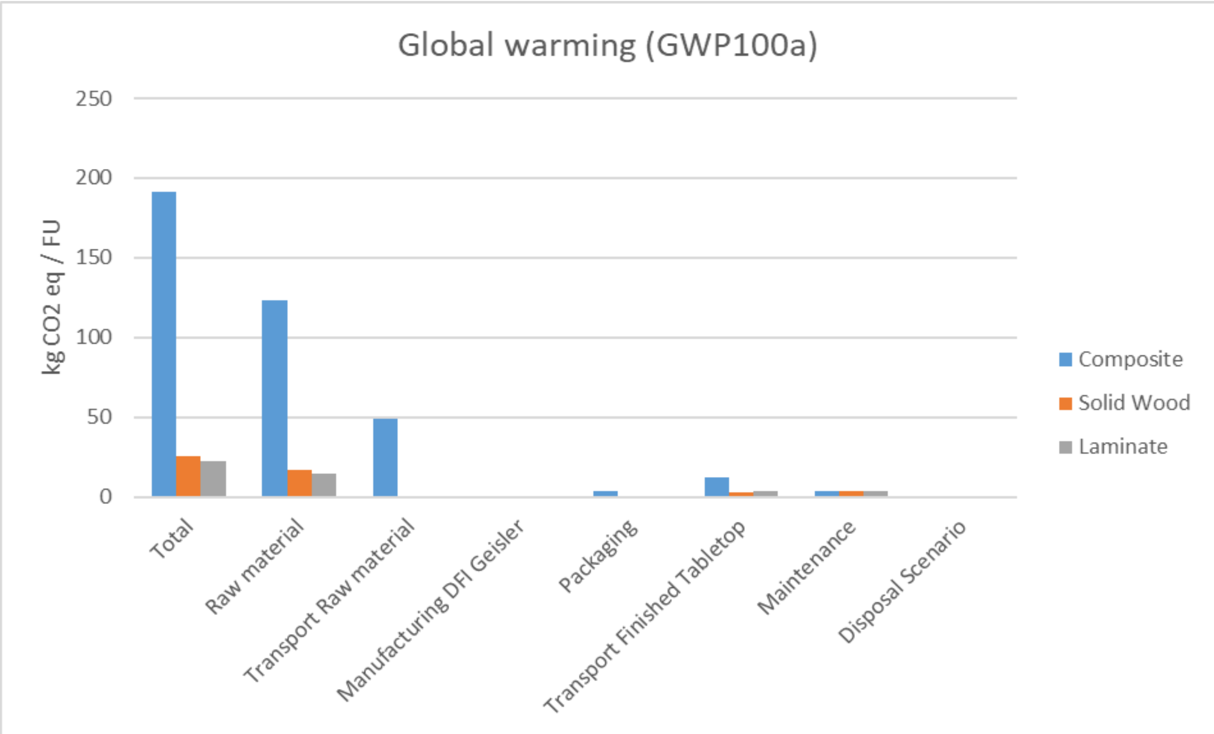

Figure 9: The impact on climate change in each life cycle stage for the three tabletops.

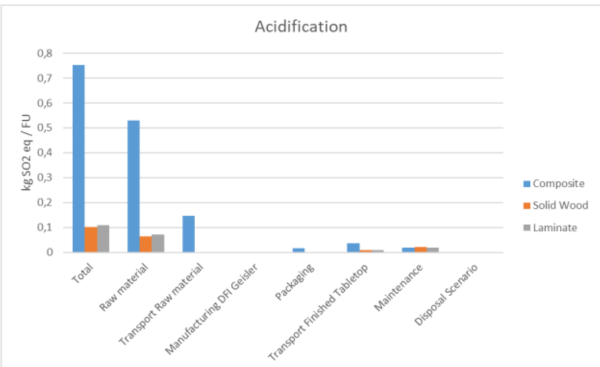

Figure 10: The impact on acidification in each life cycle stage for the three tabletops.

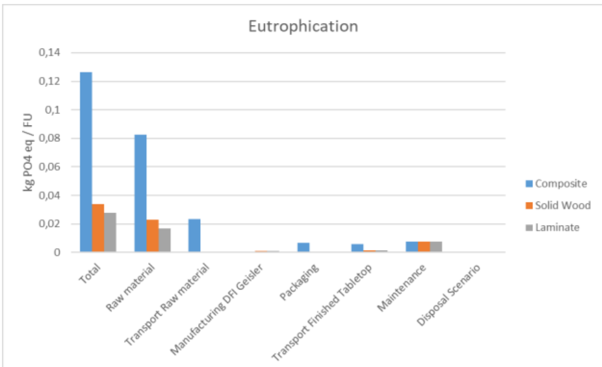

Figure 11: The impact on eutrophication in each life cycle stage for the three tabletops.

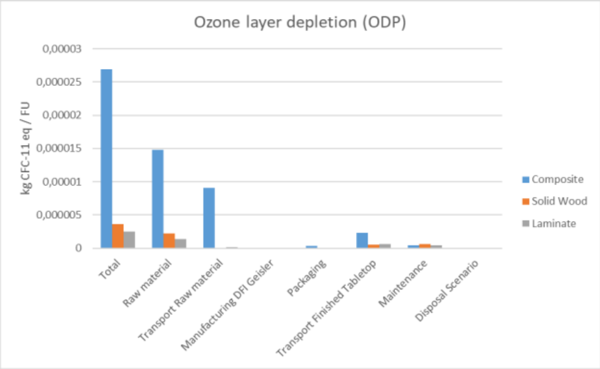

Figure 12: The impact on ozone layer depletion in each life cycle stage for the three tabletops.

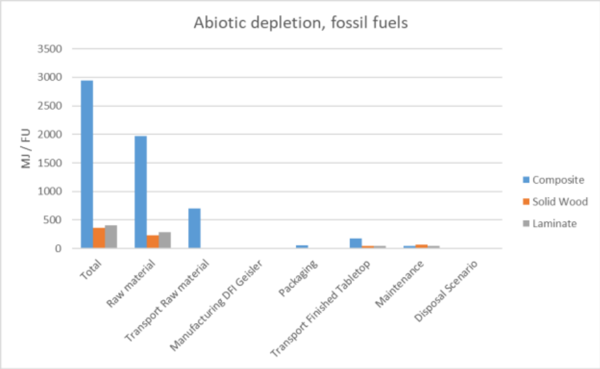

Figure 13: The impact on abiotic depletion of fossil fuels in each life cycle stage for the three tabletops.

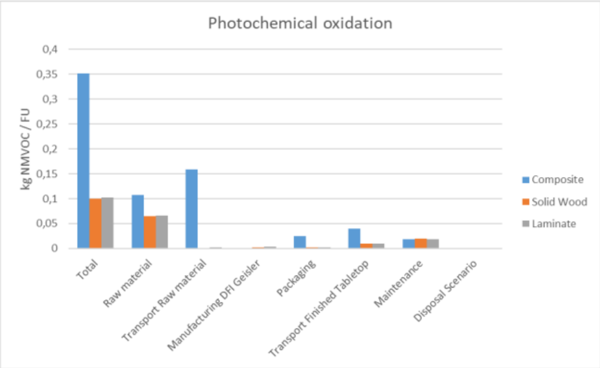

Figure 14: The impact on photochemical oxidation in each life cycle stage for the three tabletops.

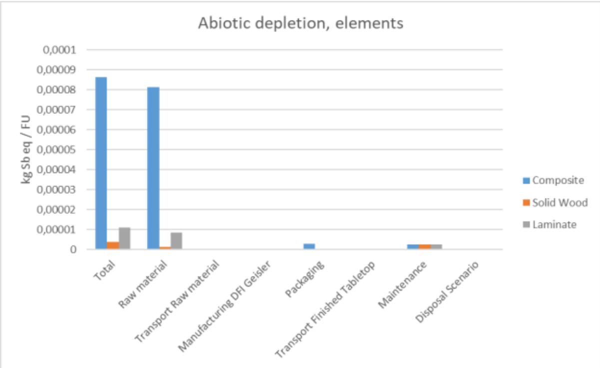

Figure 15: The impact on abiotic depletion of elements in each life cycle stage for the three tabletops.

3.1.4 Life cycle interpretation

3.4.1.1 Identification of hot spots - Tabletops

In this section the identified hotspots from the impact category climate change will be listed. Sensitivity analyses connected to the hot spots will be addressed in the separate section *3.4 Sensitivity analysis*.

For the composite tabletop:

- Most impact, 64%, occur in the raw material phase, including the three steps: generation of raw materials, transport to factory in Spain as well as production of the composite. It is not possible to break out which processes in the raw material phase that contribute most due to the results from EPD being an aggregation of all three steps.

- Second most impact, 25%, comes from the transport to DFI Geisler from Spain. The hot spots for the transport are the weight of the material and the long transport distance. The total weight of the transported tabletop is the combined weight of the finished tabletop (75 kg/m^2) and the waste generated at DFI Geisler (48 kg/m^2).

For the solid wood tabletop:

- Most impact, 68%, occur in the production of raw material. In the raw material phase, the long transport of the wood from the extraction site to the supplier contributes most followed by the impact from the electricity at the supplier. The transport corresponds to 38% of the total impact and the electricity used for production at the supplier 24%. The remaining impact from the raw material phase, 6%, is from the processing of the wood at the extraction site.

For the laminate tabletop:

- Most of the impact, 63%, comes from the raw material phase. Breaking down the raw material phase into the materials that are included in the tabletop, the particle board and laminate are contributing most to the total impact (see Appendix 3).

  The production of the particle board contributes with 40% of the total impact of the tabletop, and the components of the material that cause most impact are considered hot spots. For the particle board the hot spots are the components urea formaldehyde resin, the electricity at the supplier and the melamine formaldehyde resin. Each of the mentioned components of the particle board contribute with 21%, 8% and 4% of the total impact of the tabletop.

  The laminate contributes with 24% of the total impact of the tabletop. For the laminate an EPD has been used (with aggregated data for production, transport and manufacturing of the laminate) to model the material and therefore it is not possible to break down the material further.

3.2 LCA of door and frame

This section contains the LCA for door and frame summarised in a description of the door and frame, the previous work and method, the results as well as identification of hotspots for the impact category climate change. A sensitivity analysis is presented in a separate section after section *3.3 LCA for a standard kitchen*.

3.2.1 Description of door and frame

The cabinet door investigated in this LCA is a white painted MDF door. For the door the raw material is produced in Poland and the manufacturing (cutting, polishing and painting) of the door is done at Ballingslöv AB in Ballingslöv. The frame is a melamine coated particle board that is produced in Poland and cut into correct dimensions and assembled at Ballingslöv. The complete cabinet (door and frame) is transported with the rest of entire kitchen to a customer in Stockholm, as described for the tabletops.

3.2.2 Previous work & method

The results from a previous LCA screening for the door and frame indicated that there was need for more data regarding the raw materials and that the end-of-life scenario had to be changed.

By completing the previous work with more specific data on particle board, MDF and the paint used for painting the door an improved and complete LCA was made for the door and frame following the same work process as described for the tabletops. The model in SimaPro was updated with new data and simulations were run. The functional unit used in this LCA study is one door with a lifetime of 20 years and one frame with a lifetime of 20 years. An important assumption is that the impact in the user phase is assumed to be zero (due to such low level of maintenance required). As for the tabletops, allocations have been made when required and below is an example of the allocation used for the end-of-life scenario. Based on the weights presented in Appendix 2 the weight percentage of the door and frame are calculated (Table 6).

Table 6: The weight percentage of the door and frame depending on the type of tabletop used in the kitchen.

	Composite	*Laminate*	*Solid wood*
Door	0.5%	0.6%	0.6%
Frame	2.2%	2.6%	2.6%

3.2.3 Results – door and frame

For the cabinet door the total amount of greenhouse gas emissions during the life cycle corresponds to 7 kg CO_2 equivalents, see Figure 16. The total amount of greenhouse gas emissions during the lifecycle of the frame equals to 21 kg CO_2eq, which is 3 times the impact of the door.

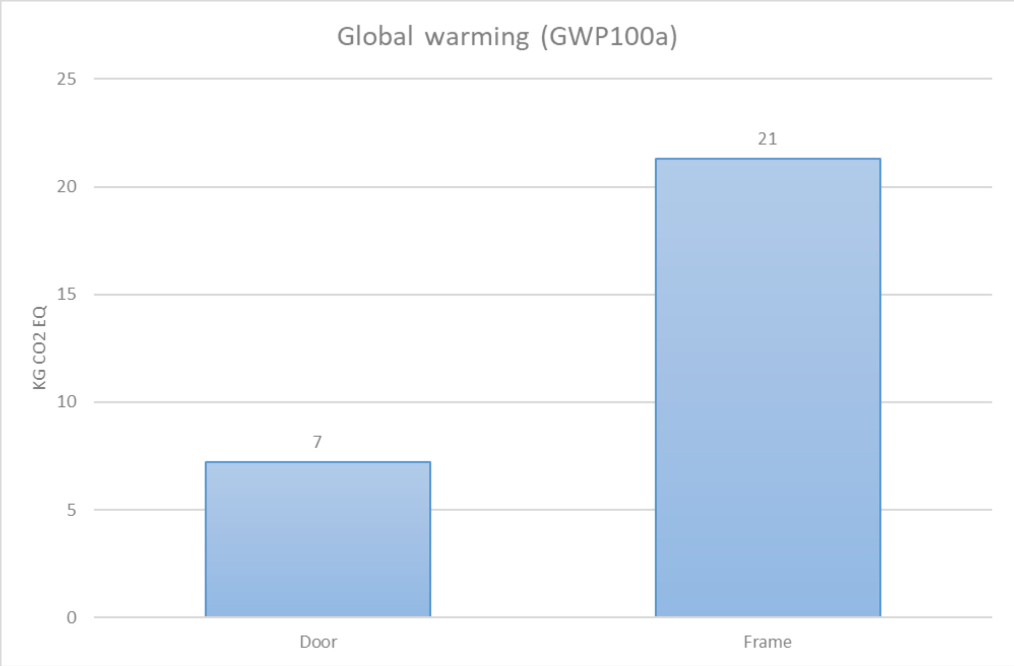

Figure 16: The total amount of CO_2eq (impact on climate change) for the door and the frame.

As illustrated in Figure 17 most of the emissions of greenhouse gases (CO_2eq) during the lifecycle of door originates from the raw material stage, 71%. The manufacturing at Ballingslöv is the second most impacting phase in the lifecycle, corresponding to 15% of the total impact (Table 7). The two phases with most impact for the frame are the raw material phase and the transport of the raw material to Ballingslöv. 74% of the impact occur in the production of the raw material, and 14 % of the CO_2eq emissions from the transport of the raw material.

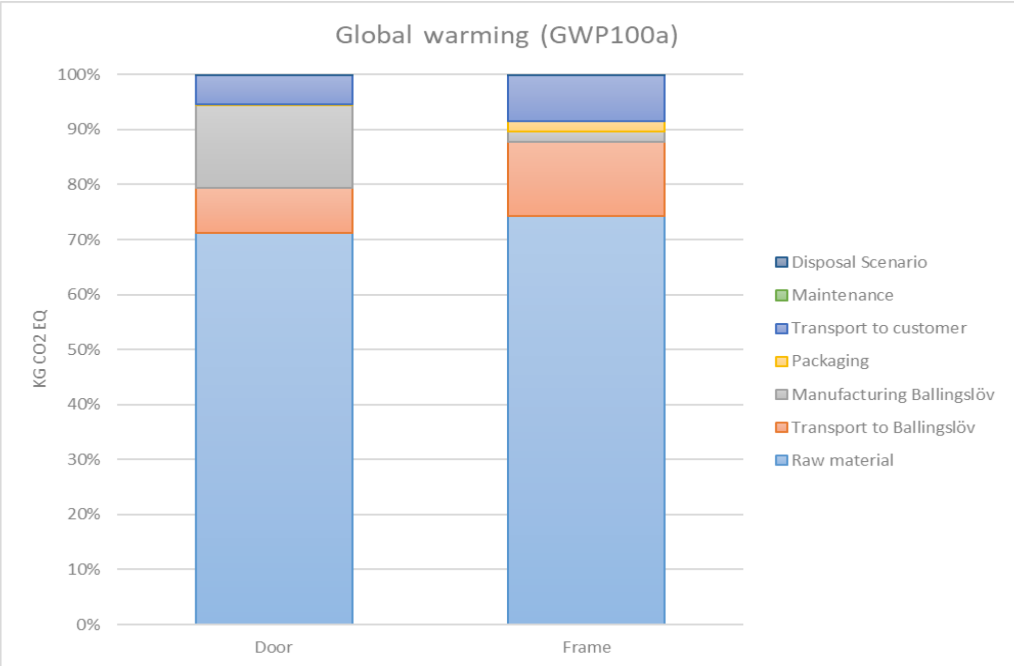

Figure 17: Diagram illustrating the impact for the different phases of the life cycle for the white MDF door and the frame.

Table 7: The percentages of the total impact of greenhouse gas emissions during the life cycle, assigned to each phase of the life cycle for the door and frame (IPCC 2013, GWP 100a).

	Door	**Frame**
Raw material	71%	74%
Transport to Ballingslöv	8%	14%
Manufacturing Ballingslöv	15%	2%
Packaging	0%	2%
Transport from Ballingslöv	5%	8%
User phase	0%	0%
End-of-life	0%	0%

*Due to rounding up or down numbers the total does not exactly correspond to 100%. The impact from the user phase and disposal scenario is small compared to the total impact and they are therefore approximated to be 0%.

In the diagrams that follow (Figure 18 to 24) the results for each impact category are presented as a total and divided into the life cycle phases of the tabletops (raw materials, transport in, manufacturing, transport out, user phase and end-of-life).

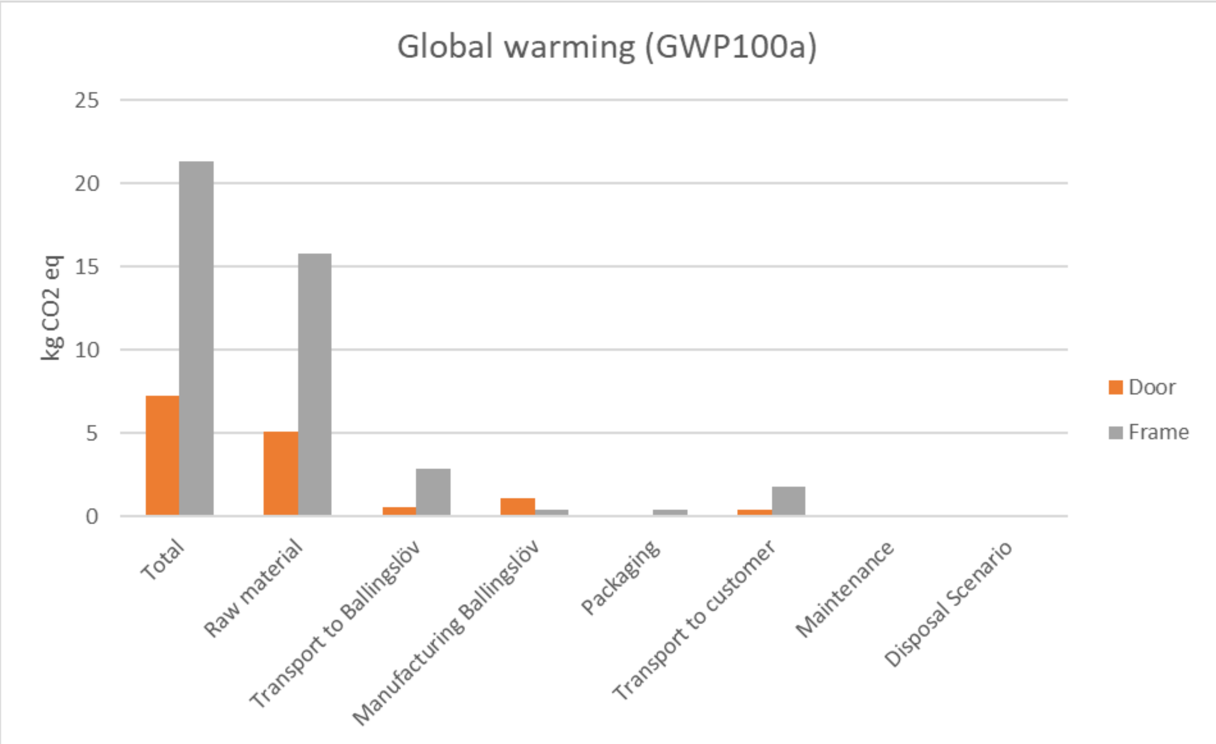

Figure 18: The impact on climate change in each life cycle stage for the door and frame.

In almost all impact categories shown in Figure 18 to 24 below, the trend for the door is that the raw material gives the highest impact followed by the manufacturing at Ballingslöv and then the transport of raw material to Ballingslöv. The exception is the impact category abiotic depletion of elements where nearly all impact (96%) comes from the raw material phase.

When it comes to the frame, the trend for the impact category global warming (Figure 18) is that the largest impact comes from the raw material phase. The second largest impact comes from the transport of raw material to Ballingslöv and the third most impacting life cycle phase is the transport of the finished frame from Ballingslöv to the customer. The same trend can be seen in the impact categories acidification, eutrophication, and photochemical oxidation

(Figure 19 to 21). For the impact categories abiotic depletion of fossil fuels and ozone layer depletion the trend is slightly different (Figure 22 and 23). Raw material contributes most to the total impact followed by the transport of the raw material to Ballingslöv, but the third most impacting phase is the manufacturing at Ballingslöv for these impact categories. The difference between the manufacturing phase and the transport to customer is so small that they are almost equal. Abiotic depletion of elements in an impact category that has a significantly different trend with 99% of the impact coming from the raw material phase (Figure 24).

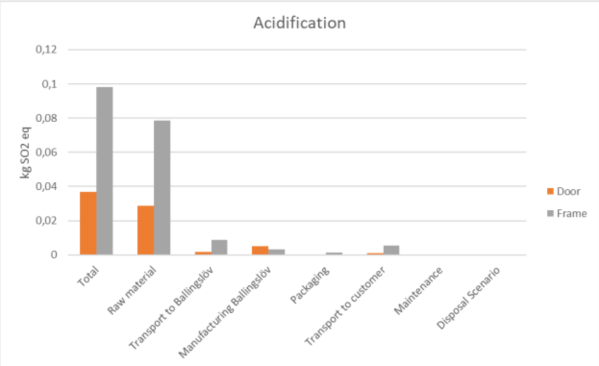

Figure 19: The impact on acidification in each life cycle stage for the door and frame.

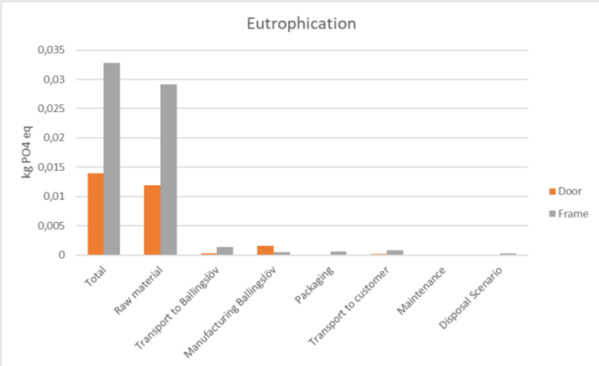

Figure 20: The impact on climate eutrophication in each life cycle stage for the door and frame.

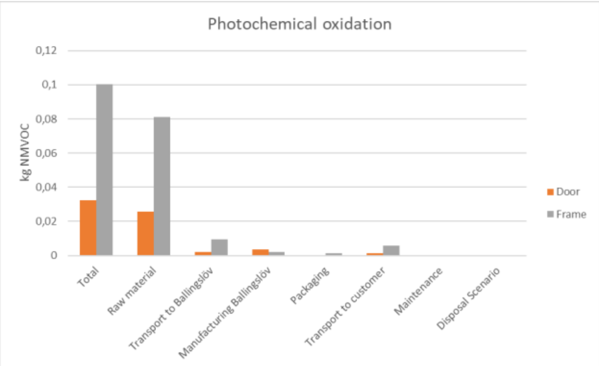

Figure 21: The impact on photochemical oxidation in each life cycle stage for the door and frame.

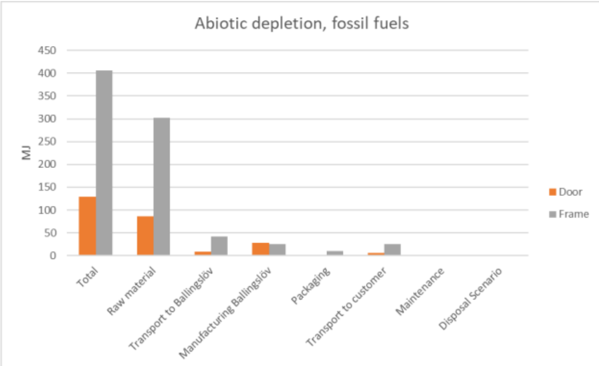

Figure 22: The impact on abiotic depletion of fossil fuels in each life cycle stage for the door and frame.

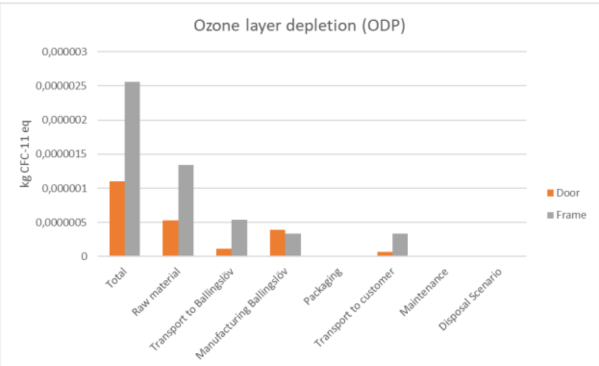

Figure 23: The impact on ozone layer depletion in each life cycle stage for the door and frame.

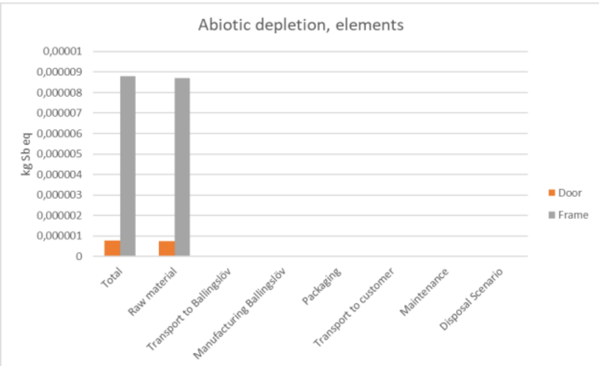

Figure 24: The impact on abiotic depletion of elements in each life cycle stage for the door and frame.

3.2.4 Identification of hot spots – Door and Frame

In this section the identified hotspots from the impact category climate change will be listed. Sensitivity analyses connected to the hot spots will be addressed in the separate section *3.4 Sensitivity analysis*.

For the door:

- Most impact occur in the raw material phase, 71%. In this phase it is the MDF material that generates most impact of the door, 64%. The two hot spots that generate the most impact in the production of MDF is the urea formaldehyde (25% of total impact) and electricity at the supplier in Poland (24% of total impact).

- The manufacturing phase (at Ballingslöv AB) generates 15% of the total impact of the door. The hot spot for the manufacturing are the emissions and waste that occur in the painting process.

For the frame

- The raw material phase generates most impact, 74%. Breaking down the raw material phase into the materials that are included in the frame, it is the particle board and the laminate that contribute most to the total impact.

  The particle board causes 49% of the total impact for the frame. The components of the particle board that generate most impact are considered hot spots. For the particle board the hot spots are the urea formaldehyde (19% of total impact) and the electricity used for production at the supplier (14% of total impact).

  The laminate contributes with 17% of the total impact of the frame. For the laminate an EPD has been used (with aggregated data for production, transport and manufacturing of the laminate) to model the material and therefore it is not possible to break down the material further.

- The transport from the supplier to Ballingslöv AB contributes with 14% of the total impact of the frame.

3.3 LCA of standard kitchen

3.3.1 Description of a standard kitchen

The standard kitchen from Ballingslöv investigated in this report (Figure 25) consists of:

- 10 low cabinets[3] + 3 tall cabinets
- 3.2 m^2 composite tabletop
- White goods
    - Hob
    - Oven
    - Microwave oven
    - Dishwasher
    - Combined Fridge/Freezer
    - Hood
- Sink, hinges, handles, drawers, screws and legs

Figure 25: The standard kitchen from Ballingslöv.

[3] A cabinet consists of a frame and a door.

3.3.2 Method – standard kitchen

The model for the standard kitchen was built using the results from the LCA of the tabletops, the door and the frame combined with information for the white goods and electronics made by Electrolux[4] and making additional LCAs for the drawers, hinges, handles, plastic legs and screws. The functional unit was a standard kitchen with a lifetime of 20 years. The simulations were run in SimaPro to see what the impact of a standard kitchen was during the life cycle.

Regarding the white goods, it was assumed that they would have to be exchanged once in 20 years. The old ones are assumed to be worn out and disposed of at a waste management facility. The new ones follow the same assumption as the rest of the kitchen after 20 years with 80% remaining installed, 12% are sold second hand and 8% are going to waste management with the rest of the kitchen.

3.3.3 Results – standard kitchen

In this section the results of the standard kitchen in the impact category climate change are presented.

A standard kitchen has a total impact of 3810 kg CO_2eq during its entire lifetime. Most impact occurs in the manufacturing of the kitchen (3190 kg CO_2eq), followed by 603 kg CO_2eq from the use of electricity for white goods in the user phase.

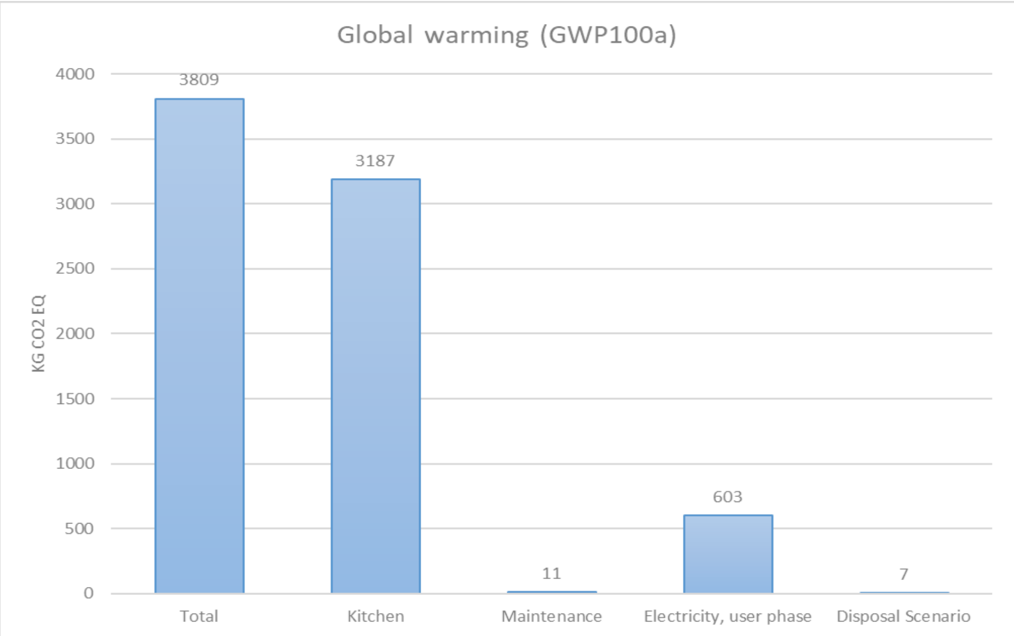

Figure 26: The impact on climate change for a standard kitchen. "Kitchen" covers production of all components for the kitchen as well as all transports of raw material and the transport to the customer.

Separating the bar "kitchen" in Figure 26 above into the components of the kitchen gives an increased understanding of which parts that contribute most to the total impact. It is evident

[4] Data on the impact on climate change was provided for the hob, combined fridge/freezer, dishwasher and oven. The data covered the life cycle phases raw material, production and user phase (except for the hob where data for production was missing and therefore excluded). Due to lack of data for the hood and microwave they were excluded from the study.

that white goods have most impact, corresponding to 42% of the total impact from the standard kitchen (Figure 27). The second most impacting posts are the composite tabletop and the electricity in user phase, which contributes with 16% of the total impact each (Table 8). Other kitchen parts correspond to 14% and the drawers have by far the most impact due to the large amount of steel used in them.

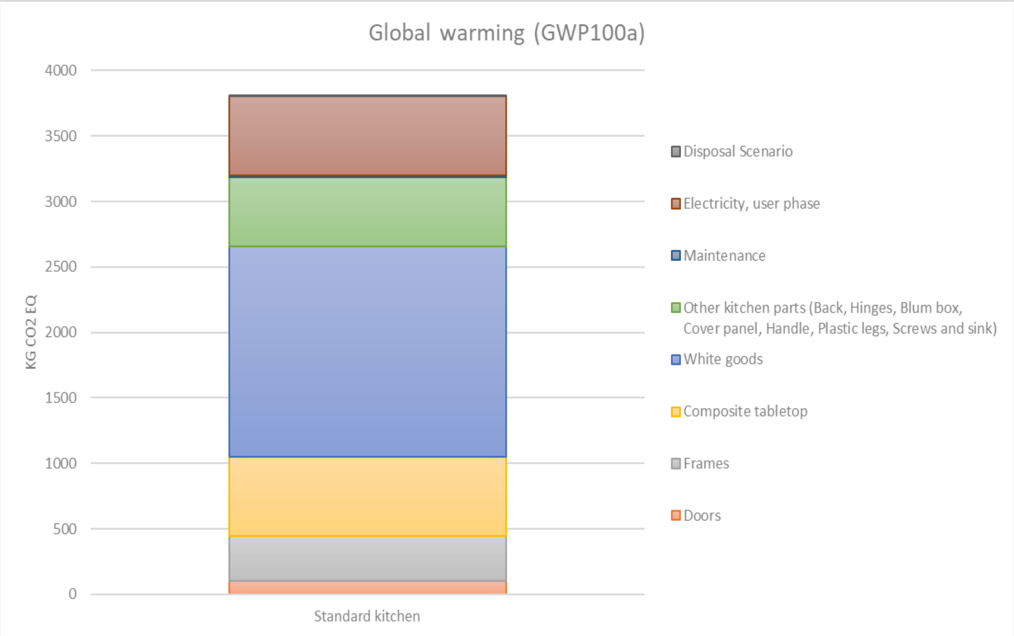

Figure 27: A more detailed image of the impact from the standard kitchen, where the impact from the components in the kitchen are accounted for separately.

Table 8: The percentage of the total impact on climate change for the different components and life cycle phases of the standard kitchen (IPCC 2013, GWP 100a).

Kitchen part	Percentage
Doors	3%
Frames	9%
Composite tabletop	16%
White goods	42%
Other kitchen parts	14%
Maintenance	0%
Electricity, use phase	16%
Disposal scenario	0%

In a report by IVA and Sveriges Byggindustrier (2014) the results from an LCA of the multifamily houses in the block Blå Jungfrun in Stockholm are presented. Upstream processes and the user phase are investigated and the results for a multifamily house is approximately 3000 ton CO_2eq. The same phases of the standard kitchen correspond to 3.8 ton CO_2eq. The multifamily house has a lifetime of 50 years and contains 24 apartments. Correcting for the difference in lifetime and number of kitchens installed, the total impact from all standard kitchens in the multifamily house is 228 ton CO_2eq. Comparing the kitchens to the building, the impact from all standard kitchens corresponds to 7.6% of the impact from a multifamily house.

3.3.4 Identification of hot spots – Standard kitchen

In this section the identified hotspots from the impact category climate change will be presented. Sensitivity analyses connected to the hot spots will be addressed in the separate section *3.4 Sensitivity analysis*.

A hot spot for the standard kitchen is the white goods. The white goods have most impact on climate change, corresponding to 42% of the total impact for the standard kitchen (in raw material and production phase). The data for the raw material and production phase is aggregated and it is therefore not possible to determine exactly which processes in these phases that causes most impact. However, it is possible to determine that the raw material phase causes more impact than the production phase.

Another hot spot is the electricity consumed by the white goods in the user phase, which contributes with 16% of the total impact of the standard kitchen.

A third hot spot is the composite tabletop. The impact of composite tabletop on climate change corresponds to 16% of the total impact for the standard kitchen. In chapter *3.1 LCA for tabletops* it can be found that 64% of the impact from the composite comes from the raw material phase and 25% occurs in the transport of the composite from the supplier.

3.4 Sensitivity analysis

In this section several different sensitivity analyses will be performed based on the hot spots that were detected in the results for the tabletops, the door and frame as well as the standard kitchen. Some assumptions regarding the standard kitchen will also be investigated.

3.4.1 Tabletops

Composite

The raw material phase of the composite tabletop is contributing most to the total impact. It is not possible to break out which processes in the raw material phase that contribute most since the data collected from the EPD is an aggregation of extraction/production of raw material, transporting to factory in Spain and manufacturing at the factory in Spain. Therefore, it is more reasonable to put focus on improving the transport from Spain to Denmark. Transporting the raw material by train would reduce the impact from 50 kg CO_2eq to 12 kg CO_2eq, which is a reduction of 76% (Table 9). Changing the fuel from diesel to HVO100 reduces the impact to 17 kg CO_2eq (see section *3.4.3 Standard kitchen* for further explanation of HVO).

The high impact from the transport of raw material is due to a long transport distance and that composite is a heavy material. The weight of the material transported is the sum of the finished tabletop and the waste that occurs at DFI Geisler. The waste adds on an extra 48 kg to the 1m^2 of finished tabletop (weighing 75kg) and the total weight transported from Spain per m^2 is 123 kg. If it is possible to reduce the waste that occurs per m^2 at DFI Geisler, it would decrease the impact from the transport of raw material.

Table 9: The impact from different types of transports for the composite tabletop. The functional unit (FU) is 1 m^2 of tabletop with a lifetime of 20 years. Conversion factors are explained in section 3.4.3 Standard Kitchen.

Type of transport	***Conversion factor [kg CO_2eq/tkm]***	***Impact [kg CO_2eq / FU]***
Truck, diesel (base case)	0.139	50
Train	0.0347	12
HVO100	70% less than diesel	15

Solid wood

The raw material phase is contributing most to the total impact on climate change, corresponding to 19.5 kg CO_2eq. The largest impact in the raw material phase comes from the transport of wood (oak) from the extraction site in Croatia to the supplier in Denmark, which contributes with 11kg CO_2eq (see Appendix 3). Transporting the wood by train or use HVO100 as fuel instead of diesel reduces the impact of the transport to approximately 3 kg CO_2eq (Table 10). This is a reduction of 73%.

A contributing factor to the impact from the transport of wood is that the supplier in Denmark have a high percentage of waste per m^2 solid wood tabletop, 66%. By reducing the amount of waste at the supplier the weight of the transported material is decreased and in turn the impact of the transport from Croatia to Denmark is reduced. The combination of sustainable transports and reducing the amount of waste per m^2 solid wood tabletop at the Danish supplier has a potential to reduce the impact from the transports to less than 3 kg CO_2eq.

Another big post in the production of raw material is the electricity at the Danish supplier which has a total impact of 6.3 kg CO_2eq. This is due to the use of non-renewable electricity in the production. Using renewable electricity would reduce the impact to next to 0 (see example in sensitivity analysis for the standard kitchen).

Use of sustainable transports and renewable electricity at the supplier can reduce the impact on climate change with 73%, from 19.5 kg CO_2eq to 5.2 kg CO_2eq. A reduction of waste at the supplier can reduce the impact more. Alternatively, the impact from the transport of wood can be reduced if the wood comes from a supplier closer to Denmark.

Table 10: The impact from different types of transport for the solid wood tabletop. The functional unit (FU) is 1 m^2 of tabletop with a lifetime of 20 years. Conversion factors are explained in section 3.4.3 Standard Kitchen.

Type of transport	Conversion factor [kg CO_2eq/tkm]	Impact [kg CO_2eq]
Truck, diesel (base case)	0.139	11
Train	0.0347	3
HVO100	70% less than diesel	3

Laminate
The largest impact on climate change occur in the raw material phase for the laminate tabletop. The production of the particle board contributes most with 40% of the total impact and the hot spots in the production are the urea formaldehyde resin, the electricity at the supplier of particle board and the melamine formaldehyde resin.

The content of the particle board is modelled based on an EPD from Eggers. To make a sensitivity analysis regarding the formaldehyde resin the content of a particle board with less formaldehyde resin would have to be available, since the substances are most likely substituted with something else and not just reduced.

The electricity at the supplier can be substituted with renewable electricity, generating an impact next to 0 kg CO_2eq (see example in sensitivity analysis for the standard kitchen). The total impact from the particle board could be reduced from 9.1 kg CO_2eq to 7.3 kg CO_2eq if renewable electricity is used in the production of the particle board.

3.4.2 Door and frame

Door
Most impact occur in the raw material phase, where the MDF material generates most impact. The identified hot spots for the MDF were the urea formaldehyde and the electricity at the Polish supplier. If electricity from renewable sources is used in the production of MDF the impact from the MDF can be reduced with 37%.

Frame
Most impact occur in the raw material phase where the production of the particle board and the laminate contributes most. The electricity used in the production of the particle board at the supplier is a hot spot. If the supplier switches from conventional electricity to electricity from renewable sources it is possible to reduce the impact from the production of the particle board with 14% (3 kg CO_2eq).

Apart from the raw material phase, there is a hot spot in the transport of the raw material from the supplier to Ballingslöv AB. The transports of raw material to Ballingslöv AB contributes with 14% of the total impact on climate change for the frame. A sensitivity analysis comparing the impact from different types of transports in this phase is made to detect how much the transports can be affected. Transports of raw material corresponds to 21tkm and in the base case with diesel the impact generated is 2.9 kg CO_2eq (Table 11). Transports by train generate an impact of 0.7 kg CO2eq, reducing the impact from the transports of raw material to 3% instead of 14%. Using HVO100 as fuel instead of diesel generates an impact of 0.9 kg CO2eq, corresponding to 4% of the total impact of the frame. There is a potential to accomplish a reduction of the total impact from the frame by using sustainable transports.

Table 11: The impact from different types of transport for the frame. Conversion factors are explained in section 3.4.3 Standard Kitchen.

Type of transport	*Conversion factor [kg CO_2eq/tkm]*	*Impact [kg CO_2eq]*
Truck, diesel (base case)	0.139	2.9
Train	0.0347	0.7
HVO100	70% less than diesel	0.9

3.4.3 Standard kitchen

The main hot spots in the standard kitchen are the white goods, the electricity in the user phase and the composite tabletop. Additionally, it is of interest to see how much the assumptions made in the end-of-life phase affects the total impact, to compare the impact of having suppliers using electricity from renewable sources in their production and investigating the potential to affect the total impact from transports in the supply chain and to the customer.

White goods

The white goods have the highest impact of the components in the standard kitchen (42%). Due to the lack of data for the white goods there are still quite a lot of uncertainties. There is no data for production of the hob, and the hood as well as the microwave had to be excluded because there was no data at all for them. There is potential to improve collaboration with suppliers of white goods to get more specific data on white goods.

If the white goods had a lifetime of 20 years and an energy efficiency that is not reduced too much over those years, the white goods would not have to be changed during the lifetime of the kitchen. Consequently, there is potential to reduce the impact from the production of the white goods with 50%.

The impact of Swedish electricity vs European mix

In the base case a Swedish electricity mix is used to assess the total impact from the standard kitchen. Changing the electricity in the user phase for the standard kitchen from Swedish electricity mix to a European electricity mix gives a significant impact on the results (Figure 28). The 603 kg CO_2eq generated in the user phase with a Swedish electricity mix is instead 6670 kg CO_2eq with a European electricity mix. The impact in the user phase is 11 times larger with a European electricity mix compared to a Swedish electricity mix.

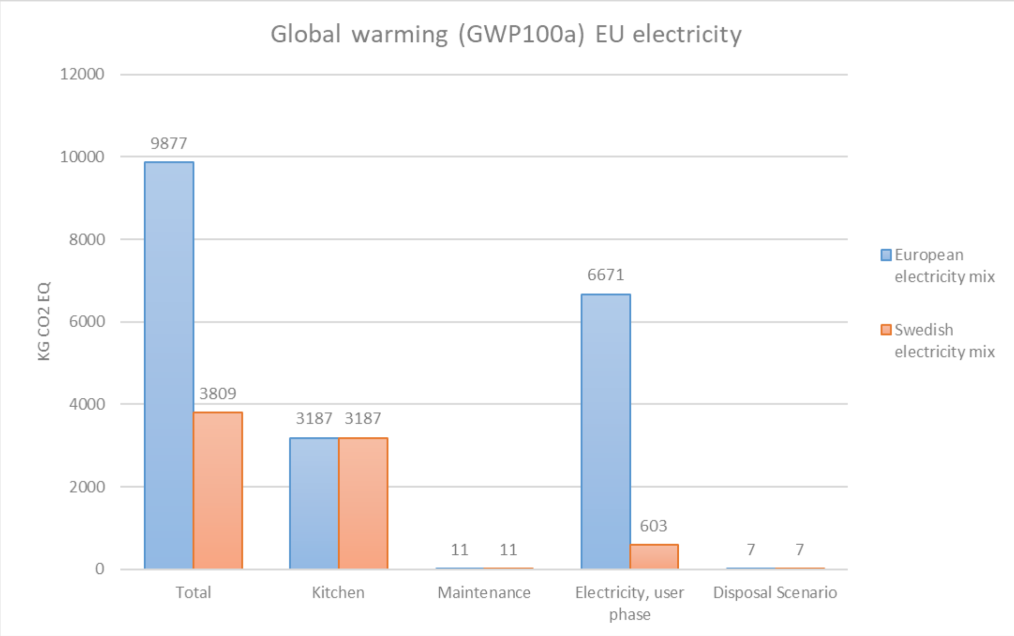

Figure 28: The base case using Swedish electricity mix in the user phase compared to the use of European electricity mix in the user phase.

Choice of tabletop

A composite tabletop is used in the standard kitchen in the base case. When investigating 1m^2 of tabletop separately the composite had an impact on climate change equal to 191 kg CO_2eq, the solid wood 25 kg CO_2eq and the laminate 22 kg CO_2eq. In 20 years the composite tabletop has 8 times larger impact than the solid wood tabletop and 9 times larger impact than the laminate tabletop. To compensate for this, the composite tabletop would have to remain installed for 160 years to have an impact that is equal to the solid wood tabletop and 180 years when compared to the laminate tabletop. The probability that a tabletop remains installed for 160 or 180 years is small, making the composite tabletop the least favourable choice from a life cycle perspective.

However, when investigating the total impact of the kitchen the impact from the individual tabletop is smaller. In the base case of the standard kitchen a composite tabletop is used, generating a total impact on climate change of 3810 kg CO_2eq (Figure 29). If a tabletop of solid wood is used in the standard kitchen the total impact from the kitchen is equal to 3270 kg CO_2eq. With a laminate tabletop the total impact is 3260 kg CO2eq. The total impact from the composite tabletop in the complete standard kitchen is approximately 1.2 times the solid wood tabletop (and the laminate tabletop). To compensate for the higher total impact the kitchen with a composite tabletop would have to be installed for 24 years instead of 20 years. To keep the kitchen installed for 24 years is not unrealistic.

Choosing a solid wood tabletop instead of a composite tabletop reduces the total impact on climate change with 537 kg CO_2eq. A laminate tabletop reduces the impact with 545 kg CO2eq. The environmental performance of the standard kitchen can be improved with 14% by choosing solid wood or laminate instead of composite.

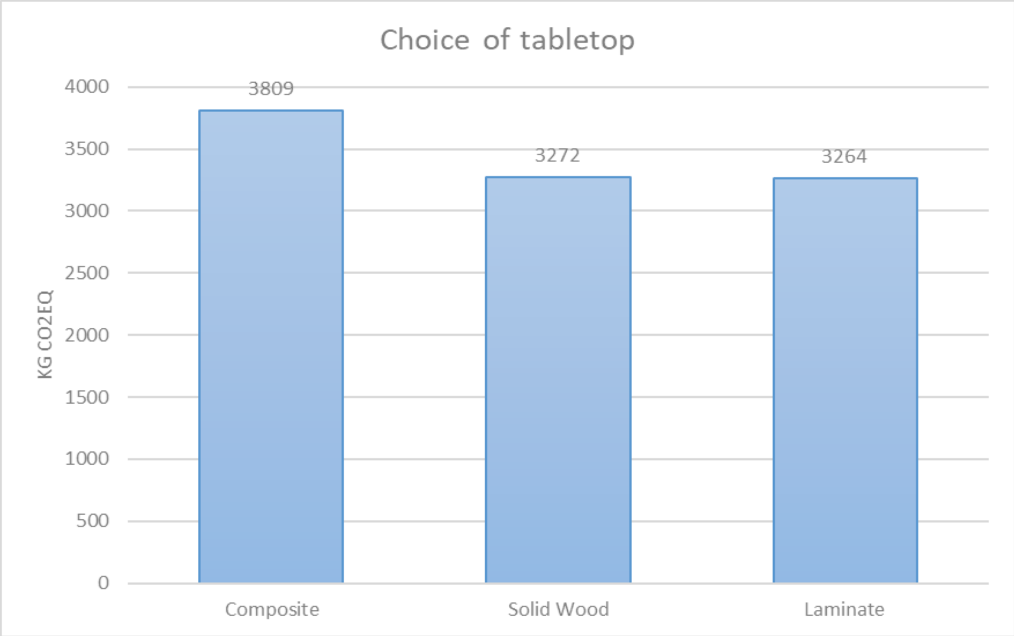

Figure 29: The impact on global warming for a standard kitchen in three cases with tabletops of the materials composite, solid wood and laminate.

Changed end-of-life scenario

In the base case the kitchen is assumed to be transported to a waste management facility in 8% of the cases. It is of interest to investigate how much impact a change of the assumption in the end-of-life phase has on the total impact of the standard kitchen. A comparison of the base case to a scenario with 100% disposal (no prolonged life in the end-of-life phase) can be seen in Figure 30. In the base case scenario the impact from the disposal scenario is 7 kg CO_2eq and in the case with 100% disposal of the kitchen after 20 years the impact is 121 kg CO_2eq. The total impact from the standard kitchen is 3920 kg CO_2eq instead of 3810 kg CO_2eq in the base case, which is an increase of 114 kg CO_2eq. The assumption in the disposal scenario affects the total impact of the kitchen, but only with 3% which is less than expected.

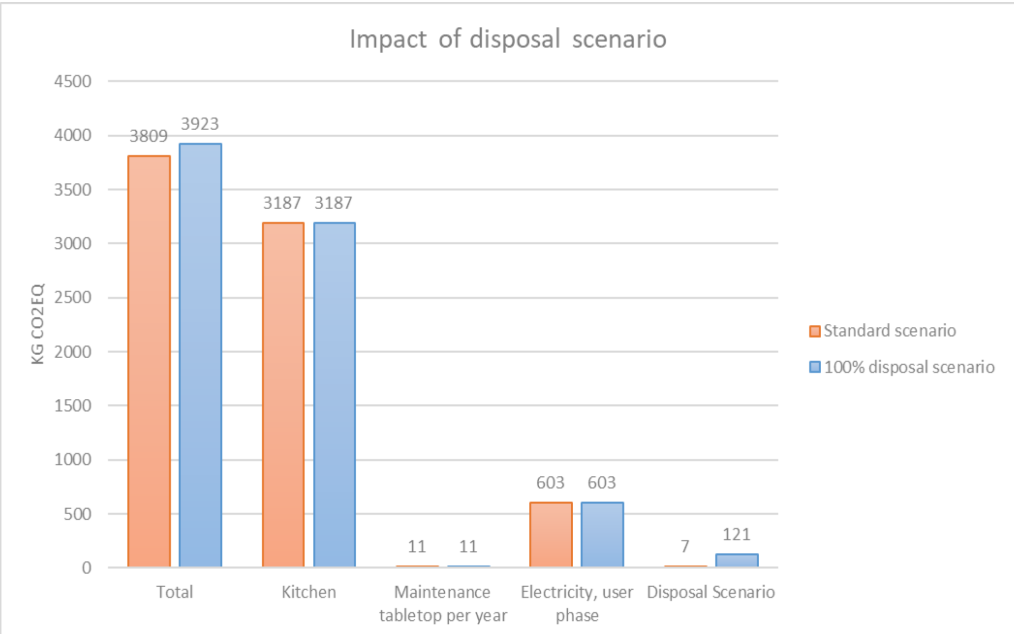

Figure 30: The impact of changing the disposal scenario to 100% disposal in the end-of-life phase instead of a prolonged life for the kitchen in 92% of the cases.

Renewable electricity – suppliers

The electricity used at the suppliers in Poland and Germany is 487 MJ (147MJ in Poland and 340MJ in Germany). This energy consumption corresponds to an impact that is equal to 99.7 kg CO_2eq (Table 12). If the electricity used in the base case is substituted with electricity from renewable sources the impact from electricity in the supply chain becomes very small. Wind power would generate an impact on climate change equal to 0.02 kg CO_2eq, solar power installed on roof 0.4 g CO_2eq and solar power from a large solar park 0.002 g CO_2eq. This means that there is a potential to reduce the total impact of the kitchen with 3% in the supplier chain if suppliers use renewable electricity.

Table 12: The impact from different types of electricity sources.

Type of source	*Impact [kg CO_2eq]*
Polish and German electricity mix (base case)	99.7
Wind power	0.02
Solar power installed on roof	0.0004
Solar power from large solar park	0.000002

Sustainable transports

The sum of the transports in the supplier chain, to the manufacturing sites (DFI Geisler and Ballingslöv AB) as well as from the manufacturing sites to the customer equal to 2490 tkm. In the base case a truck with diesel is used and this generates a total impact of about 346 kg CO_2eq in total for these transports (Table 13). Changing means of transport to transportation by train reduces the impact on climate change to 86 kg CO_2eq. It is not logistically possible to change all transports to train but considering the reduction of the impact on climate change it could be of interest to investigate the possibilities to use trains for longer distances. For example, it would be beneficial to change the long transport from Spain from truck to train.

Switching fuel to HVO, short for Hydrogenated Vegetable Oil, is another alternative that is interesting to investigate. HVO is a relatively new fuel and therefore not included in either of the calculation tools SimaPro or NTMcalc. According to Network for Transport Measures (NTM) using HVO100 (pure HVO) as fuel instead of diesel has a potential to reduce the impact on climate change with 70% (NTM, n.d.). Based on this information there is a potential to reduce the total impact from the transports in the supplier chain to 104 kg CO_2eq instead of 346 kg CO_2eq.

Table 13: Impact from different types of transports for the standard kitchen.

Type of transport	*Conversion factor [kg CO_2eq/tkm]*	*Impact [kg CO_2eq]*
Truck, diesel (base case)	0.139	346
Train	0.0347	86
HVO100	70% less than diesel	104

4. Literature study

The resulting hits from the literature study, presented in table 14, indicate that there are articles connected to the search words, but very few were relevant for the specific topic of this literature study. When broadening the perspective to find more general information it was discovered that many references are old, from the 80s or 90s.

Table 14: A summary of the search words, combinations and hits in the database LubSearch.

Search words	Number of hits	Relevant hits
Customer behaviour		
Customer behaviour + Furniture	138	2
Customer behaviour + Environmental impact+ Furniture	3	1
Furniture + Customer behvio* + Environm*	18	3
Kitchen		
Kitchen + Life cycle assessment	125	2
Kitchen + LCA	34	2
Kitchen + Market + Consumer behaviour	105	2
Kitchen + Market + Consumer attitudes	26	0
Life cycle assessment or LCA		
Kitchen cabinet + Life cycle assessment	3	2
Kitchen cabinet + LCA	3	1
Tabletop + Life cycle assessment	3	0
Tabletop + LCA	0	-
Other combinations		
Trends + Furniture industry + Europe	14	0
Trends + Kitchen industry + Europe	8	0
Trend* + Consumer + Sustainab*	284	6
Green marketing + Influence + Behaviour	841	3
Green marketing + Influence + Customer behav*	223	9
Furniture + Customer attitude	35	0

4.1 Lack of information

About 40 articles have been thoroughly reviewed and there is none that specifically addresses customer behaviour in connection to the kitchen market. There is a lack of information not only on customer behaviour, but also on environmental performance of kitchens in general. The search did only generate one article about life cycle assessment directly linked to kitchens and that was about specially designed kitchens for elderly or physically disabled people. Otherwise there is no information about LCAs for kitchens or parts of kitchens other than white goods and electronics. Most of the articles are addressing other subjects involving the kitchen such as food waste.

Looking into the furniture industry for the same kind of information to be able to compare to the kitchen industry, the results were much the same. It was difficult to find information within the furniture market that could be used as a comparison and be assumed to reflect the kitchen market as well.

Due to the lack of information directly linked to the kitchen market the perspective had to be broadened to general trends and drivers, as well as customer behaviour and values in general. Based on the information that was considered relevant for the study it had to be assumed that if there is a general trend on the market regarding for example increased sustainability requirements from customers, it may be an indication that the kitchen industry will experience this as well.

It was discovered that there is significantly more information about so called green marketing and its effect on customer behaviour in a general, broader perspective. The following parts will explain some general trends and drivers as well as customer behaviour in general and try to connect them to the kitchen market/industry.

4.2 Customer behaviour

Firstly, some trends/drivers and the effects of these regarding the customer behaviour will be addressed. This section takes up some trends in customer behaviour such as increased awareness of environmental issues and environmental performance of products as well as the request for counselling at the time of the purchase. Further on some effects of customer behaviour connected to the increased interest for sustainability and environmental performance of products will be presented. The effects that will be addressed are positive attitude towards companies that have good knowledge on sustainability, that there is an increase in buying environmentally adapted (“green”) products and more requests for specific information on the environmental performance of products.

There is an increased concern for environmental issues and environmental issues are contributors to consumer decision-making (Cummins *et al.*, 2014). However, the environmentally friendly aspect of products and services is a relatively new need from consumers, and companies that address this need may gain a competitive advantage (Richey *et al.*, 2014). The importance of and the market for green products and sustainable consumption is growing. In terms with that, companies face the challenge of presenting solutions to the growing concern while remaining profitable. When introducing green initiatives or programs timing is an important factor. Customer scepticism that prevents the desired effects of the initiative or program can simply be a result of timing. Therefore, Richey *et al.* (2014) means that it is of essence to make sure that the green initiatives/programs are thoroughly developed to be able to meet scepticism instead of producing something of less quality just to be first. A well worked out program or initiative that may not be the first launched on the market can have a higher impact on performance, than a premature less developed program/initiative that is first on the market. The challenge when designing and launching green initiatives is that consumers want to know the specifics of green initiatives and how their actions and purchases impacts the planet.

Bednárik and Kováts (2010) studied customer behaviour on the furniture market in Hungary. They emphasise that the customers in the study valued counselling from experts when making decisions on what to buy. Counselling is important and customers entrust some decisions to experts when they feel they have little knowledge of subject. The study the authors made also shows that durability and functionality are the most important factors for all types of customers. The trend with eco-chic products and the importance of communication to customers can to some extent be seen as an effect of CSR activities in companies. The overall trend indicates that customers request transparency and would like to have an overview of the production process.

There are several effects of the customer behaviours regarding sustainability. Customers are more positively inclined towards companies that can prove their ecological perceptiveness (Papadopoulos, Karagouni & Trigkas, 2018). The results of the report indicate that 68% of the sampled customers are willing to pay an additional amount of money for what the authors refer to as eco-smart furniture.

As the environmental consciousness among customers increase they tend to buy products that are more environmentally friendly (Boztepe, 2012). Boztepe states that previously there has been a negative correlation between “green price” and customer purchasing behaviour, but now the trend has changed, and customers are willing to pay more for environmentally friendly products. The study also contains an interesting result in the difference between genders when it comes to what affects each genders purchasing behaviour. Male customers’ green purchasing behaviour is affected by green promotion, environment awareness, green price and green product features. Female customers’ green purchasing behaviour is only affected by green promotion.

A study by Hartmann, Apaolaza and D’Souza (2018) indicates that the psychological factor of empowerment as a motivational factor for pro-environmental consumption is important to consider when investigating the consumer purchasing behaviour. The authors could show that psychological empowerment was an outcome from pro-environmental actions among customers, and that this effect in turn motivates the customer to make more green choices. This is therefore a driver and an outcome of pro-environmental behaviour. By using the concept of psychological empowerment in the marketing strategy and enhance the feeling of empowerment, the customer can feel that their decisions and consumption choices actually make a difference on global environmental problems.

Customers that are environmentally conscious are aware of a company’s reputation, advertising, labels on product or clues on the packaging when deciding to buy products (Smith & Brower, 2012). Customers are requesting specific information on how the company or product affects the environment.

The increased awareness among customers lead to new demands on businesses and products, and the kitchen industry is no exception to this. Environmental aspects can be an important factor in the customers’ decision making and the importance of presenting products and solutions that fulfil this need is important. Considering this, when it comes to the timing of launching green initiatives it seems to be the right time now. For the kitchen market it could be publishing the environmental performance of kitchens. To prevent that customer scepticism has the opposite effect the green initiative has to be well worked through to the point where it can sufficiently meet questions regarding specifics and prove the company's awareness of environmental impact.

Counselling is important also on the kitchen market and when it comes to sustainability this information can be woven into the counselling so that customer can make well informed decisions. Through counselling it is easier to give information to the customer on the environmental performance of the product as well as being able to motivate the customer to choose more environmentally friendly or eco-smart solutions. Durability is very much connected to sustainability in the way that it prevents over production, and counselling is an opportunity for kitchen producers to emphasise the importance of maintaining and keeping the kitchen for as long as possible.

The report made by Papadopoulos, Karagouni and Trigkas (2018) is from Greece and was published after the financial crisis, which the authors think may have affected the answers. But this makes it interesting because there is such a high percentage of the sampled participants in the study that are willing to pay more for an eco-smart furniture. In a kitchen there are many ways of creating innovative eco-smart solutions and functions, which can make the customer pay extra for added value.

The studies indicate that customers are buying "green" products and that they may be willing to pay more for them. For the kitchen industry it is a matter of finding good ways to communicate the environmental performance of their products, since this could generate higher profitability.

Again, to be able to motivate customers to pay more for green products it is necessary to comply with the request for more information. Having knowledge about the environmental performance of the kitchen in detail and what kind of impact and where in the life cycle this occur is important to be able to communicate this to customers and meet the need for more detailed information. Having a good reputation is essential and being able to advertise the environmental performance in a good, trustworthy way is a means of competition for the customers that are environmentally conscious.

4.3 Communication

This section will cover some trends on communication connected to sustainability and green marketing as well as some impacts of communication.

Sustainability has become one of the biggest challenges for companies, especially within the marketing area (Diez-Martin, Blanco-Gonzalez & Prado-Roman, 2019). During the 21st century, digital marketing has transformed the way companies communicate with their customers. However, digital marketing can also be a tool to influence the attitudes and beliefs within the society. There is still a gap between the behaviour and beliefs of customers and the society and businesses ability to address this trend. Knowing what the customer values, how to market this and connect it to sustainability is important to meet the trend.

The increasing interest in green marketing can partially be attributed to social movements among consumers and the growing concern for the environment (Cummins *et al.*, 2014). A driver that is changing the demands for value creation in products is the technological development, especially the rapid development within the field of information technology (Papadopoulos, Karagouni & Trigkas, 2018).

According to Gabler, Butler and Adams (2013) it is important for businesses to provide more information to customers, and when doing so businesses should clearly state exactly how their projects or initiatives affect the environment. Vague claims create confusion for the customer and may be perceived as greenwashing. Communication without greenwashing means that except from green marketing the company must show that practices and policies across all functional areas of the business are green.

More available information is a way of strengthening the link between the consumer's beliefs and behaviour (Gabler, Butler & Adams, 2013). The authors say that if consumers had more information that enhance their sense of contribution, their behaviour can be altered. Another result in the study is that mainstream consumers will not buy products that offer no additional benefit apart from the environmentally friendly aspect. A large part of the sample group felt that the problem will go away by itself or that it was not their responsibility. Therefore, the authors claim that the "green" aspect of the product should be marketed as an added value, meaning that product is more than "just" green. Few consumers buy a product only because it is environmentally friendly, it must be an added value.

Incorporating green benefits into the promotion of products may enhance the perceived behavioural control of customers and also increase the intention to purchase green products. "This would be especially true in cases where information about the green nature of both the firm's products and processes are readily available. Such efforts to communicate not only the "green-ness" of the product, but how choosing that product will positively and tangibly impact the environment, could be effective for both consumables and durables." (Gabler, Butler & Adams 2013, p. 169)

Grönlund Krantz and Petersson (2019) states that communication is a key for companies/corporations to be successful. The results from the study shows that businesses with a good reputation are less sensitive to fluctuations on the stock market. A good reputation is also an advantage in the communication with for example customers and investors. Grönlund Krantz and Petersson mentions Swedbank as an example where a bad reputation caused their stock to fall 45 million SEK in a couple of days. The article concludes that in order for a company to be successful, communication should be prioritized.

How companies communicate sustainability affect the credibility of the sustainability message (Cummins *et al.*, 2014). Long term commitments seem to be received well by the judges in the study and is perceived as qualifying the message as sustainable. Companies that seemed honest in their communication by admitting shortcomings and for example defining the sustainability work as "being a start" were also well received among the judges in the study, since the judges meant that the statements implied a continuing effort. An interesting finding was that no sustainability claims that were part of the study were deemed a lie by the judges, and the reason was that the judges felt that they lacked the knowledge to evaluate the message due to complex technical terms being used in the advertisement (Cummins *et al.*, 2014). This means that when communicating sustainability, it is important to keep the communication clear and at a technical level where customers will understand it.

There is an increased interest for sustainability information, and since the technological development has changed the marketing channels the kitchen industry as all other industries have to adapt to this. This is an opportunity to quickly spread information, but also a challenge when it comes to communicating without greenwashing.

The results from the literature study indicate that a trend with more focus on sustainability and highlights the importance and close connection between communication and a good reputation. When customers become more aware and/or interested in the sustainability aspects of products, this will further increase the importance of a good and valid sustainability communication to keep up a good reputation. The lack of information on products environmental performance on the kitchen market is an opportunity to increase the positive attitude for a kitchen brand by providing this information to the customer.

Based on the results from the literature study it may be possible to draw the conclusion that companies that are communicating on sustainability are perceived more positively in the eyes of the customer. An important factor is how the sustainability information is communicated, since it affects the credibility of the information. It needs to be honest, realistic and on a level of knowledge that is adapted to the audience. Providing this information to customers may influence their behaviour in choosing the more sustainable alternative.

What is important is to be able to create a common language when it comes to sustainability. To be able to work internally and communicate the results/efforts externally. The kitchen industry can work with this by involving customers and educate them through marketed information.

4.4 Trends and drivers on the market

Finally, some trends and drivers on the kitchen market will be identified. This section addresses the existing second-hand market, some building rules and guidelines as well as certifications and sustainability reporting.

Although there is no specific actor specialized in trading second-hand kitchens, it is evident that a private second-hand market for kitchens exists. Kitchens or parts of kitchens are sold privately via webpages such as Blocket and Citiboard (Blocket (n.d.); Citiboard (n.d.)). Browsing through these webpages, it can be concluded that the second-hand market for kitchens includes tiles, tabletops, faucets and also complete kitchens (or almost complete except from white goods). Some of the difficulties seem to be that many kitchens are custom-made. There are no “standard measurements” for kitchens since it differs depending on the layout of the specific room where the kitchen is to be installed. Another difficulty seems to be the dismantling process, where you would not want to break anything.

Building rules and guideline are affecting the kitchen industry in various ways due to the contractors demands on interior design. The kitchen industry is affected by demands from the building industry. One such demand is reporting to BREEAM. The BREEAM certification is an international scheme that provides independent third-party certification of the assessment of the sustainability performance of buildings communities and infrastructure (BREEAM, 2019). The rating that is generated by the assessment reflects the environmental performance of a building and can range from Pass to Good, Very Good, Excellent and Outstanding.

The rating is based on 10 different categories where each is divided into different assessment issues with its own aim, target and benchmarks (BREEAM, 2019). Each target or benchmark is assessed and scored by the assessor and is weighed in when the overall score for the category is calculated. The final performance rating is determined by the weighted category scores. The 10 categories are: Energy, Health and Wellbeing, Innovation, Land Use, Materials, Management, Pollution, Transport, Waste and Water.

Another tool for providing information on the environmental performance of products is Environmental Product Declarations (EPDs). The building industry is currently working a lot with producing EPDs for different products and materials. An EPD is a document that conveys a products' environmental impact during the lifecycle (EPD International AB, n.d. a). It is a voluntary document that is independently verified and made according to ISO 14025:2006. The document can be used for individual product or for assessment schemes, green procurements or business-to-business communication. The last years the building industry has significantly increased the use of EPDs and created a lot of them for different products and materials.

There are no EPDs for kitchens, or parts of kitchens such as cabinets or counters in the database (EPD International AB, n.d. b). However, there are a lot of EPDs for furniture and construction products. Many types of material, everything from paint and coatings to wood and asphalt have EPDs.

The sustainability work within companies can be managed and certified according to ISO 14001 or EMAS (or both). Certifiering.nu (2019) gathers information about different certifications. In figure 31 the number of accumulated certifications of ISO 14001:2015 and EMAS are illustrated. Companies that have at least one of the certifications are included. Old versions of ISO 14001 that have been updated to the newest version are included, and the date of the first certification of ISO is still valid after updates to a new version. This is why there are certifications from 1989 although the newest version did not exist then.

The trend shows that during the 21st century the number of certifications of businesses in Sweden has gone from 380 certifications in year 2000 to 4008 certifications in year 2019. However, not all certification bodies are connected to the website Certifiering.nu and therefore the statistics in the illustration are not a 100% accurate.

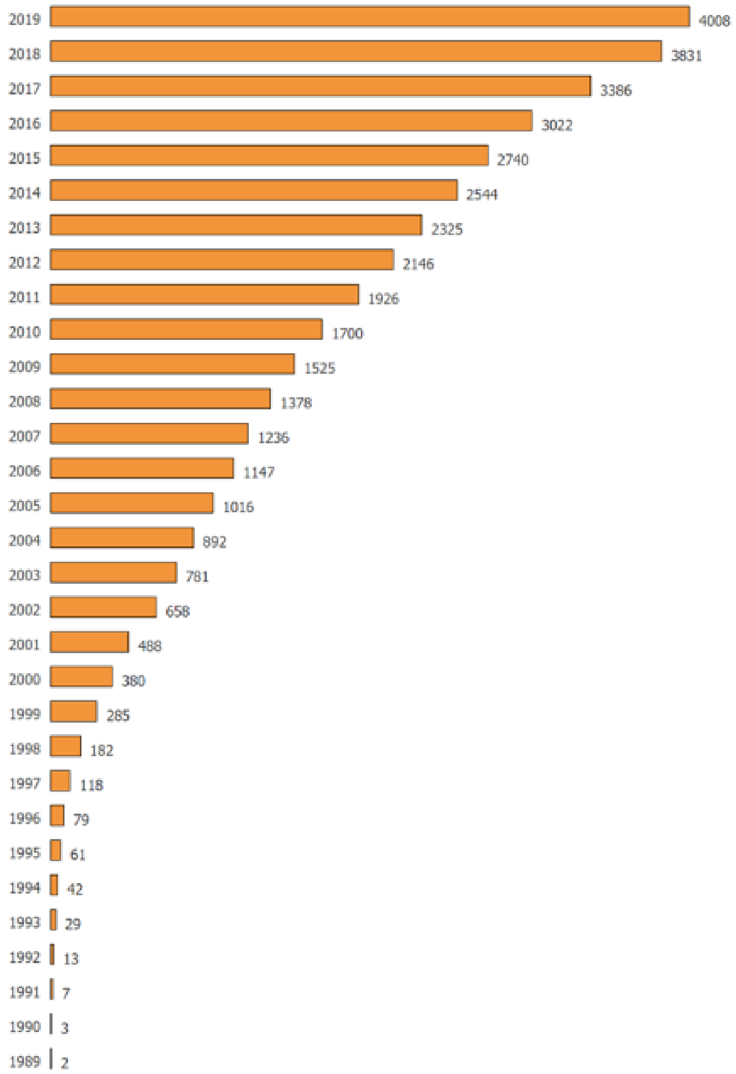

Figure 31: The number of companies in Sweden that have at least one certification of ISO14000 or EMAS. Illustration from certifiering.nu.

A way to communicate the sustainability work and progress is through sustainability reporting. In Sweden companies that fulfil at least two of the three following conditions are to create a sustainability report (Bolagsverket, 2019). The conditions are:

- The average number of employees have been more than 250 people
- The balance sheet total is more than 175 million SEK.
- The accounted net sales are more than 350 million SEK.

More and more companies are reporting on their sustainability work, and in larger businesses sustainability reporting has gone from being a trend to being the norm (Hadjipetri Glantz, 2018). Global Reporting Initiative (GRI) is an organisation that has developed global standards for sustainability reporting (GRI, n.d.). The standards provide a framework which an increasing amount of companies worldwide uses as a tool in developing their sustainability reports.

Most big companies both in Sweden and globally are working with sustainability and to communicate it in the form of a sustainability report (Wennerstrand & Berheim, 2018). There are many reasons to do this, among others strengthening the brand, inspiring others and have a constant development in the sustainability work. Many companies are also reporting on the increase in profitability as an effect of an effective sustainability work.

A study by Liu, Kasturiratne and Moizer (2012) investigates a new model for integration of green marketing in supply chain management and the drivers for embarking on a green journey for the companies participating in the study. The external driver that ranked highest was governmental regulations just before customer demand. The internal driver that ranked highest in the study was to improve the sustainability in the supply chain to meet environmentally conscious customer's expectations and demands in order to achieve best possible business performance.

It seems that the general trend on the market is that customers are more aware of environmental problems and request "green products", which is a major driver for companies. The increased interest for sustainability is causing companies to report on sustainability and be able to provide "green products". Sustainability and "green marketing" have also become a means of competition.

On the market there are several external demands in the form of building rules and guidelines do affects the kitchen industry when it comes to business to business markets. BREEAM can be used in project to create buildings with a high environmental performance. Many kitchen manufacturers/companies also report to BREEAM, since the kitchen contributes to the overall rating of the building. The requirement to report to BREEAM is an external driver for the kitchen industry to work with sustainability.

While there are no or very few EPDs for kitchens or parts of kitchens today it can be assumed that an external driver to produce more EPDS is the increased use of EPDs in the building industry. To a large extent furniture use the same type of materials as kitchens and it is in the same business category, and it can be assumed that EPDs for kitchen parts can be found in the database soon too. The increased use of EPDs in the building industry could mean that contractors may request EPDs for kitchens (or parts of kitchens) in a not so distant future.

Being certified according to ISO 14001 or EMAS is a way to show a continuous effort to work with sustainability. Certifiering.nu does not cover all certifications but nonetheless, the trend indicates that the interest in sustainability issues among businesses is growing, and the number of companies working with sustainability is increasing. It can be assumed that this trend is important to keep up with to have an advantage on the market. In the most recent update of ISO 14001 there is a much greater focus on having a life cycle perspective, and to work with LCAs on products is a way to learn what this perspective really means, the hard work that is required, the complexity but also the opportunities that arise.

Sustainability reporting may not be a tool for communicating to private customers, since they most likely do not use that for gathering environmental information. However, business-to-business customers and investors may use the sustainability reporting as a way to gather information about a company and in those cases they are useful. Therefore, LCA is a useful tool when it comes to providing specific information to private customers.

4.5 Need for more research

The lack of information about customer behaviour as well as trends and drivers on the kitchen market indicates that there is a need for more information within this area. More research is needed regarding the customer behaviour on the kitchen market, and how the customer behaviour can be influenced by information on environmental performance. There is also a need for more research on the environmental performance on kitchens, since most information on environmental performance on the kitchen market is about food waste.

There is not only need for more information on environmental performance, customer behaviour and trends and drivers on the kitchen market, but also within other industries. Looking to other industries, for example the furniture industry, for literature to be used as comparison there is no such information available either. Due to the extensive similarity in materials it could be beneficial for both the kitchen and furniture industry to conduct more research within this area. There might even be possibilities to have joint projects on some materials.

Additionally, a lot of the existing research on customer behaviour is old, from the 1990s or older. This means that although it might still be possible to draw general conclusions on customer behaviour and marketing, there is a lack of new information on this topic. The technological development during the 21st century has affected the communication significantly, and it would be interesting to conduct more research on the impact of this change connected to customer behaviour on the kitchen market.

5. Discussion

This chapter addresses the results from the LCA studies as well as the literature study to connect the results and try to provide some suggestions on how to improve the environmental performance of the components investigated (tabletops, door and frame) as well as the complete standard kitchen.

5.1 Improvements in supply chain

The LCA studies show that the raw material phase is the most impacting phase in a life cycle perspective for the standard kitchen as well as the components investigated. To improve the environmental performance of the kitchen and its components from a production perspective it is in the raw material phase that actions will have most effect in reducing the overall impact.

Tabletops

From a life cycle perspective, the composite is the least favourable alternative when investigating the tabletops separately. The composite tabletop has the most impact with 191 kg CO_2eq. The solid wood has 87% less impact and the laminate has 88% less impact. The common denominator for all tabletops is that most impact occur in the raw material phase.

For the composite tabletop the data used for the LCA is aggregated for the processes of extraction of material, transport to production site and production of the tabletop which makes it difficult to assess where in the raw material phase that the most impact occur. In the EPD the supplier mentions that they work with finding more sustainable solutions by for example using electricity from renewable sources in their own production and use recycled material in the product. Identifying the possibilities for improvements of the environmental performance in the raw material phase can only be done in close collaboration with the supplier or by the suppler since they have information on which processes that contribute most. Another way to improve the environmental performance of the composite tabletop is to investigate the possibilities to reduce the impact from the transport to DFI Geisler from the supplier. Out of the total weight of material transported from the supplier 39% becomes waste in the manufacturing at DFI Geisler. Actions that can reduce the generation of waste from the composite tabletop can reduce the overall impact from the tabletop significantly.

To improve the environmental performance of the solid wood tabletop reducing the impact from the transport from the extraction site to the supplier as well as the electricity at the supplier is important. To a large extent the impact from the transport is caused by the high percentage of waste, 66%, (see Appendix 3) that occurs at the supplier in the production of the tabletop. Reducing the waste in the production decreases the amount of extra weight per m^2 tabletop transported and improves the environmental performance of the product significantly. Furthermore, it can be assumed there is an economic incentive for the supplier to reduce the waste, and indirectly for DFI Geisler since a reduced production cost could mean a reduced purchasing cost. Another alternative is to find a supplier of wood closer to Denmark that can provide the same material, since this would reduce the transport distance. Communicating the importance of these improvements down the supply chain and engaging the supply chain in becoming more sustainable has a large potential to improve the overall environmental performance of the tabletop.

The laminate tabletop has most impact in the raw material phase and specifically from the materials particle board and laminate. The particle board contains urea formaldehyde which contributes with 40% of the total impact on climate change for the laminate tabletop. Reducing the amount of urea formaldehyde in fibre boards is discussed within the industry. However, EPDs were used to model the materials and further investigations on the content, for example the effects of reducing the urea formaldehyde in the particle board, demands information on content from suppliers which has not been possible to retrieve in this study. Reducing the impact from the electricity used in the production of the particle board by using renewable electricity can improve the environmental performance of the tabletop with 8%. Increasing the interest in sustainability among suppliers and highlighting the possibilities with making their own LCAs generates more specific data and possibly actions that could improve the overall environmental performance of the tabletop.

The laminate is modelled based on an EPD from Eggers with production in Germany which can be assumed generate more impact than if this was produced in Denmark, since the electricity mix contains a larger share of non-renewable sources. Due to the aggregated data in the EPD it is difficult to assess which processes covered by the EPD that contribute most to the total impact of the material. In order to identify the possibilities for reducing the impact from the laminate there is need for more specific data.

Door and frame

Like the tabletops the door and frame also have most impact in the raw material phase. For the door it is the production of the MDF that causes most impact. More specifically it is the urea formaldehyde and the electricity at the supplier that contribute most. As mentioned before the formaldehyde is a hot topic and already there are products with less formaldehyde in them on the market, indicating a switch in the content of the MDF. To be able to assess the improved environmental performance of changing MDF board a new LCA has to be made since it is not certain that one could just reduce the impact from the formaldehyde and be done with it. There might be some other chemical instead that has to be evaluated and added to the total impact. However, there is certainly room for improving the environmental impact of the door. Encouraging the supplier of MDF to switch to renewable electricity could improve the total environmental performance of the door with 24%.

The most impacting material in the raw material phase for the frame is the particle board, and similar to the particle board in the laminate tabletop it is the urea formaldehyde that generate most impact. As discussed previously there are changes within the industry that reduces the amount of formaldehyde used in the particle boards. The second most impact in the particle board comes from the electricity used at the supplier in Germany. The environmental performance of the frame can be improved with 14% if the supplier switches to renewable electricity. Laminate is also a material that causes a significant impact of 17% of the total impact. However, as mentioned previously it is based on the EPD from Eggers and not possible to identify where improvements can be made.

Standard kitchen

The results from the LCA of the standard kitchen shows that the white goods by far have the most impact on the standard kitchen, followed by the electricity consumed by the white goods in the user phase and the composite tabletop. The assumption for the white goods was that they would have to be exchanged once in 20 years. If they would have a lifetime of 20 years, the impact from the white goods would be reduced to half of the impact that they have in the base case. To analyse how to improve the environmental performance of the white goods the suppliers have to be involved so that they can take responsibility for their supply chain.

Ballingslöv AB can focus on collaborating with suppliers that are working with sustainability along their supply chain in order to reduce the impact from the white goods.

5.2 Approach to customer

To truly have the life cycle perspective it is necessary to see how the environmental performance can be improved all the way along the life cycle. Apart from recommendations to the producers on how to improve the environmental performance of the kitchen and individual components the customers are important to focus on since they are the ones that make the demands regarding the type of kitchen they want. Their behaviour and requests can impact the overall design of the kitchen and being able to communicate the specifics for the overall environmental performance of the kitchen is of great value.

Literature study

The results from the literature study are indicating that there is need for more information about how to affect the customer behaviour and decisions on the kitchen and furniture markets. However, in general there are several different trends and drivers that can be identified, from building rules and guidelines to certifications and customer behaviour. An increase in the work with the sustainability issues in companies and a steady increase in certifications indicate that sustainability is getting more and more attention. In general customer behaviour connected to sustainability can be assumed to follow the trend that companies with a good reputation, transparent communication and honest sustainability claims are more positively perceived. Sustainability can be marketed as added value to appeal to a wider range of customers than just the environmentally conscious and increase the profit of the kitchen industry.

A trend among customers is that they want to know exactly how the product affect or impact the environment and that companies should be transparent, open and honest in the sustainability communication. To adhere to this trend LCA can be a good tool to get an understanding of the environmental impact of products internally within the company, and then be able to communicate how and why the product impacts the environment externally. By communicating the environmental impact of different parts of a kitchen the customer can feel comfortable in making well informed decisions.

To do this it is important that the company and customer have a common language when it comes to sustainability. During the work with LCA there have been many discussions around the complexity and the time it takes to understand results and how to interpret information. If this is so complex already when creating the LCA, how it is possible to easily explain to customers? This is a challenge with creating transparent information. Sustainability marketing is complex, and it is important not to greenwash, but not to reveal corporate secrets either. At the same time sustainability is to be communicated effectively to the customers.

Alternatives

Providing customers with alternatives on how they can improve the environmental performance of their kitchen is a way to make good use of the results presented in this LCA. Below two alternatives are described.

Alternative one is for the customer to keep the kitchen for more than 20 years. Environmentally aware customers can be assumed to know that good quality and a long lifetime is the best from a sustainability perspective. The high quality of a Ballingslöv kitchen means that the technical lifetime exceeds 20 years. The longer a kitchen remains installed, the better from a life cycle perspective.

The second alternative is that if the customer wants to change kitchens it is important to make sure that the old kitchen gets a second life, for example through second-hand market. The importance of this can be seen in the sensitivity analysis where the end-of-life scenario changes from one where kitchens go to waste management in 8% of the cases after 20 years to a scenario with 100% disposal after 20 years. The customer behaviour in the end-of-life phase can be impacted through communication when buying a new kitchen. Informing the customer about this could also be perceived as an additional service and expertise from the customer perspective.

A third alternative would be to investigate the possibility to change the doors of the cabinets and see how it would affect the impact of the kitchen from a life cycle perspective. However, when investigating the possibility to do this in this particular master thesis it turned out that this was a far more complex scenario than first assumed. It is not only the doors themselves that would have to be changed, but also cover boards and other parts that are of the same colour or design as the doors. Therefore, this scenario is not investigated in the scope of this master thesis. It would be interesting to have more research of how this impacts the overall environmental performance of the kitchen.

Customer behaviour and information when designing a kitchen

Apart from working with improving the overall environmental performance of the kitchen in a production perspective with a large focus on the raw material production and transports, the customers can be a part of improving the environmental performance of their specific kitchen in the design and choice of products.

The goal is to develop the results in this report and expand to all products within the collection at Ballingslöv and use this when designing the kitchen. That way the customer can see how their choices of components and details impact the environmental performance of their kitchen. Doing this would fulfil the requests and general trends on providing more specific information on environmental impact of kitchens.

An example is the comparison of the tabletops that was made with LCA in this report. If the kitchen has a lifetime of 20 years, the composite tabletop will have a higher impact than the solid wood or laminate. The environmentally conscious customer that would think that a composite tabletop with a long lifetime would have less impact in the long run, would have to be informed that they need to keep the entire kitchen for at least 24 years to compensate for the significantly larger impact that occurs in the production of the tabletop and transport to the customer. To ensure this the house that the kitchen is installed in would have to be kept by the owner for the same amount of time, to prevent that new owners would like a new kitchen. In this example it is clear that LCA can be a tool used for making these types of comparisons and communicate the results to the customer.

Connecting to alternative one described above with keeping the kitchen for more than 20 years it is important to inform the customer that when they choose a composite tabletop in their kitchen it is necessary to keep the kitchen longer than 20 years than if they choose a solid wood or laminate tabletop (from a life cycle perspective).

White goods & electricity
Another important aspect of designing the kitchen is the impact from the white goods. When the kitchen is installed in a Swedish household and the white goods use a Swedish electricity mix the impact is almost 11 times lower than if a European electricity mix with more fossil fuels in the mix is used. This means that it can be important to communicate the impact of the white goods to the customer in order to make the customer aware of that they can reduce their impact on the global warming potential by using renewable electricity and use their white goods wisely to not waste an unnecessary amount of energy. Buying white goods of high quality and with a good energy efficiency can greatly impact the overall environmental performance of the kitchen in a life cycle perspective.

It would also be useful to do more research on the white goods, since the data used in this report was not very specific to separate materials used in the white goods and to get further knowledge on which materials in the raw material phase that has most impact it is necessary to make LCAs on white goods too.

Lifetime
High quality and a long lifetime are two important factors for a kitchen. Informing the customer about the importance of keeping their kitchen is a way to increase the lifetime of kitchens. If the customer wants to change their kitchen, there is an opportunity to inform the customer to try to prolong the lifetime of the kitchen by selling it second-hand. High quality of a kitchen increases the lifetime since it will look good for a longer time and remain functional longer than a low-quality kitchen. Combined, this leads to a higher probability that customers keep their kitchen longer.

To summarise, a kitchen consists of many components and each have an impact that contributes to the overall environmental performance. The environmental performance depends on the design and components the customer chooses to include in their kitchen, for example type of tabletop. Providing information about environmental performance of different components to customers is a way to fulfil the need for more specific information in a selling phase. Working with own production and the supply chain to improve the environmental performance of each component will impact the total environmental performance of the kitchen. It is also a way to improve supplier relations and gain increased knowledge of the products and the challenges that remain from a life cycle perspective. Being able to tell the customer about the work in progress increases transparency and as seen in the results from the literature study this increases the trust for the brand. Informing the customer about the importance of keeping the kitchen is a way to try to impact the end-of-life phase of the kitchen that is to be bought but also for the kitchen that the customer replaces.

6. Conclusions

In this chapter the main conclusions are summarised.

- Comparing the three types of tabletops the composite tabletop has most impact from a life cycle perspective. This is mostly due to high impact in the raw material phase. Since the information on the different processes in the raw material phase is aggregated it is not possible to deduce which process contributes most. A large impact also comes from the transport of the raw material to Denmark. This is due to the high weight and long distance. Reducing the waste at DFI Geisler is an opportunity to reduce the impact from the transport. Another option is using sustainable transportation alternatives.

- The common denominator for the components investigated through LCA (tabletops, door and frame) is that most impact occur in the raw material phase. Use of EPDs for many materials makes it impossible to investigate which process in the production of the material that contributes most. However, in many cases the impact from the electricity used in the production and the transports contribute a lot and there are possibilities to improve these.

- The environmental impact of a standard kitchen is approximately 3.8 ton CO_2eq. Compared to a multifamily house (with 24 apartments and a lifetime of 50 years), the impact from all standard kitchens installed corresponds to 7.6% of the impact from the multifamily house itself. The components of a standard kitchen that contribute most to the total impact on climate change are the white goods, the solid wood tabletop and the electricity in the user phase.

- To improve the environmental performance of a standard kitchen a solid wood or laminate tabletop can be chosen instead of a composite tabletop. Another way to improve the environmental performance is to use renewable electricity in the production at the suppliers instead of conventional electricity. Also, choosing sustainable transportation methods where it is possible improves the total impact.

- There is a lack of studies that specifically addresses customer behaviour in connection to the kitchen market and there is a need for more research within this area. However, the general trend on the market is that the use of EPDs increase as well as different sustainability certifications. Customers request more transparent communication on sustainability and are motivated to buy environmentally adapted (“green”) products if they have information on how their choices have an impact. LCA studies are a tool to be able to provide such information.

- Communicating the impact of choosing for example one type of tabletop instead of another can make the customer aware of the impact their choices have. Informing on the importance to keep the kitchen for at least 20 years or make sure that the kitchen has an extended life through second-hand trade if the customer wants to change kitchen after 20 years is a way to reduce the impact, involve the customer and be able to highlight the positive effects of a high quality kitchen.

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Appendix 1 - Data collection/inventory

Appendix 1 contains the data from the LCI in detail for the three tabletops.

Raw material – Composite tabletop

The data for the raw material phase of the composite tabletop is retrieved from an EPD made by Consentino. In and outflows are stated per 1000kg of composite for the processes in raw material supply, transport to factory and manufacturing of the composite tabletop.

Table A1: Data for the raw material phase of the composite tabletop.

Environmental Behaviour per 1000 kg composite		**Unit**
Depletion of abiotic resources (elements)	0.00066	kg Sb eq
Depletion of abiotic resources (fossil fuels)	16 000	MJ
Global warming	1000	kg CO2 eq
Ozone depletion	0.00012	kg CFC eq
Photochemical oxidation	0.31	kg C2H4 eq
Acidification	4.3	kg SO2 eq
Eutrophication	0.67	kg PO4 eq
Use of resources per 1000 kg composite		**Unit**
Use of renewable primary energy as energy	1640	MJ
Use of renewable primary energy as raw material	0	MJ
Total use of renewable *primary energy*	*1640*	*MJ*
Use of non-renewable primary energy as energy	17 700	MJ
Use of non-renewable primary energy as material	0	MJ
Total use of non-renewable primary energy	*17 700*	*MJ*
Use of recycled materials	53	kg
Use of secondary renewable fuels	0	MJ
Use of secondary non-renewable fuels	0	MJ
Net use of running water resources	800	m3
Waste generation and waste management per 1000 kg composite		**Unit**
Hazardous waste discharged	0.0106	kg
Non-hazardous waste discharged	41.4	kg
Radioactive waste discharges	0.0302	kg
Components for its reuse	0	kg
Materials for recycling	0	kg
Materials for energy recovery	0	kg
Exported energy	0	MJ

Raw material – Solid Wood tabletop

Raw material – Solid wood

Table A2: Data for the raw material phase for the solid wood tabletop.

Inflows	
Energy (conventional)	9.088 kWh/m^2
Outflows	
Waste	56% (+ 10 to15%) /kg solid wood

Raw material- Oil.

Table A3: In and outflows per kg of oil.

Inflows	
Energy (conventional)	6.234
Energy (green)	4.156
Outflows	
Waste	14% (0,14kg)

Raw material – Laminate tabletop

Raw material – Laminate.

Table A4: In and outflows per 1m^2 of laminate (1.08kg/m^2) for raw material supply, transport to factory and manufacturing of the laminate.

Environmental impact per 1 m^2 of laminate (1.08 kg/m^2)		**Unit**
Global warming potential	2.29	kg CO2 eq
Depletion of the stratospheric ozone layer	1.16E-09	kg CFC11 eq
Acidification potential of land and water	0.00849	kg SO2 eq
Eutrophication potential	0.00147	kg (PO4)3 eq
Formation potential of tropospheric ozone photochemical oxidants	0.00137	kg Ethen eq (C2H4)
Abiotic depletion potential for non-fossil resources	0.00000398	kg Sb eq
Abiotic depletion for fossil resources	61.9	MJ
Resource use per 1 m2 of laminate (1.08 kg/m^2)		**Unit**
Renewable primary energy as energy carrier	12.6	MJ
Renewable primary energy resources as material utilization	7.02	MJ
Total use of renewable primary energy resources	*19.6*	MJ
Non-renewable primary energy as energy carrier	55	MJ
Non-renewable primary energy resources as material utilization	10.2	MJ
Total use of non-renewable primary energy resources	*65.2*	MJ
Use of secondary material	0	kg
Use of renewable secondary fuels	0.00128	MJ
Use of non-renewable secondary fuels	0.0134	MJ
Use of net fresh water	0.0145	m3
Output flows and waste categories per 1 m^2 of laminate (1.08 kg/m^2)		**Unit**
Hazardous waste disposed	0.0168	kg
Non-hazardous waste disposed	0.034	kg
Radioactive waste disposed	0.00136	kg
Components for re-use	IND	kg
Material for recycling	IND	kg
Material for energy recovery	IND	kg
Exported electrical energy	IND	MJ
Exported thermal energy	IND	MJ

Raw material – Particle board.

Table A5: In and outflows per 1m^3 of particle board. For raw material supply, transport to factory and manufacturing of the laminate.

Environmental impact per 1 m^3 of particle board, raw	**Raw material supply**	**Transport**	**Manufacturing**	**Unit**
Global warming potential	-858	4.06	85.6	kg CO2 eq
Depletion of the stratospheric ozone layer	0.000007	8.11E-09	0.0000173	kg CFC11 eq
Acidification potential of land and water	0.256	0.0174	0.225	kg SO2 eq
Eutrophication potential	0.106	0.00404	0.0418	kg (PO4)3 eq
Formation potential of tropospheric ozone photochemical oxidants	0.0285	0.00189	0.217	kg Ethen eq (C2H4)
Abiotic depletion potential for non-fossil resources	0.0000387	8.56E-08	0.000176	kg Sb eq
Abiotic depletion for fossil resources	2620	57.2	983	MJ
Resource use per 1 m^3 of particle board, raw	**Raw material supply**	**Transport**	**Manufacturing**	**Unit**
Use of renewable primary energy (excluding those used as raw materials)	31.3	0.0758	533	MJ
Use of renewable primary energy resources as raw materials	8250	0	43.4	MJ
Total use of renewable primary energy resources	*8280*	0.0758	577	MJ
Use of non-renewable primary energy(excl those used as raw materials)	2290	57.5	1580	MJ
Use of non-renewable primary energy resources as raw materials	580	0	0	MJ

Total use of non-renewable primary energy resources	*2870*	57.5	1580	MJ
Use of secondary material	110	0	0	kg
Use of renewable secondary fuels	0	0	1150	MJ
Use of non-renewable secondary fuels	0	0	0	MJ
Use of net fresh water	1610	1.08	911	m3
Output flows and waste categories per 1 m^3 of particle board, raw				**Unit**
Hazardous waste disposed	0.282	0	0.0556	kg
Non-hazardous waste disposed	0.0151	0	0.0111	kg
Radioactive waste disposed	0.0844	0.000101	0.214	kg
Components for re-use	0	0	0	kg
Material for recycling	0	0	0	kg
Material for energy recovery	0	0	0	kg
Exported electrical energy	0	0	0	MJ
Exported thermal energy	0	0	0	MJ

Additional data
Energy: 0.9 kWh/kg (16kWh/m^2) mixed energy sources biomass, oil and electricity.
All waste is incinerated.

Raw material – Balancing foil.
Energy: Use electricity 1.013 kWh/kg where supplied electricity is 50% water and wind power and the in-house production has 95% renewable resources.

Raw material – ABS edge

Table A6: In and outflows per kg of ABS edge.

Inflows	
Energy (conventional)	60.336 MJ/kg
Energy (green)	40.224 MJ/kg
Outflows	
Waste	122 g/kg

Transports (ingoing)

All information about distances and the allocations are based on a best estimate from Jens Nedersee, DFI Geisler. The time-related coverage is 2019 and the geographical coverage is Europe.

Table A7: Information on the transports of the different materials.

Which product	From	Distance	Type of transport (fuel)	Allocation
Composite tabletop	Consentino,Spain	2900 km	Truck (diesel)	500 m^2/truck
Laminate	Riisfort, Århus, Denmark	126 km	Truck (diesel)	2665 m^2/truck, 30% of space
Particle board	Kronospan, Århus, Denmark	140 km	Truck (diesel)	1964 m^2/truck
Balancing foil	Riisfort, Århus, Denmark	126 km	Truck (diesel)	4752 m^2/truck, 10% of space
Laminate glue PVAC (& ABS glue)	PKI Industrial Adhesives, Frederica, Denmark	173 km	Truck (diesel)	1135 kg/truck
ABS edge	REHAU, Germany	420 km	Truck (diesel)	8400 m/truck
Solid wood tabletop	Herning Massivtrae, Herning, Denmark	100 km	Truck (diesel)	784 m^2/truck
Oil for solid wood tabletop	Aalborg Farve og Lak A/S, Aalborg, Denmark	116 km	Truck (diesel)	200 l/truck, 1/30 of space

Manufacturing at DFI Geisler – Composite

Table A8: In and outflows per m^2 of composite tabletop (finished).

Inflows	
Composite (material)	75 kg
Corner protectors, corrugated paper (packaging)	0.584 kg
Wood for pallets (packaging)	11.86 kg
Electricity (green)	7.92 MJ
Heat (incineration on site)	6.217 MJ
Heat (natural gas)	0.0159 m^3
Water	0.0627 m^3
Fuel for trucks on site (gas)	0.02 kg
Outflows	
Waste (composite)	47.95 kg

Manufacturing at DFI Geisler – Solid wood

Table A9: In and outflows per m^2 of slid wood tabletop (finished).

Inflows	
Solid wood (material)	21.3 kg
Glue (material)	0.000128 kg
Oil	0.0429 kg
Sandpaper	0.107 m^2
Stretch wrap (packaging)	0.105 kg
Plastic protective corners (packaging)	0.0295 kg
EPS packaging (packaging)	0.2 kg
Electricity (green)	9.75 MJ
Heat (incineration on site)	6.217 MJ
Heat (natural gas)	0.0159 m^3
Fuel for trucks on site (gas)	0.02kg
Outflows	
Waste (solid wood)	5.33 kg
Waste (glue)	0.000032 kg
Waste (oil)	0.0871 kg

Manufacturing at DFI Geisler – Laminate

Table A10: In and outflows per m^2 of laminate tabletop (finished).

Inflows	
Laminate (material)	1 m^2
Particle board (material)	1 m^2
Balancing foil (material)	1 m^2
PVAC glue (material)	0.22 kg
ABS edge (material)	2.75 m
Abs glue (material)	0.0132 kg
Corner protectors, plastic (packaging)	0.547 kg
EPS edges/packaging (packaging)	0.2 kg
Stretch wrap (packaging)	0.105 kg
Electricity (green)	9.75 MJ
Heat (incineration on site)	6.217 MJ
Heat (natural gas)	0.0159 m^3
Fuel for trucks on site (gas)	0.02kg
Outflows	
Laminate (waste)	0.33 m^2
Particle board (waste)	0.33 m^2
Balancing foil (waste)	0.33 m^2
PVAC glue (waste)	0.0132 kg

Waste management at DFI Geisler

Table A11: Fate of different materials in waste management processes.

	Who?	What?	Other
Composite tabletop	Filtenborg	Recycled road material/landfill	
Wood (packaging)	Filtenborg / Bio Supply	Recycled	
Corrugated paper(packaging)	Filtenborg / Nomi 4S	Recycled	
Sand paper	Filtenborg / Thisted Forbraending	Incineration / Energy recovery	
Laminate tabletop (laminate + particle board + balancing foil)	Kronospan	Recycling into new boards	
Glue	Kronospan	Recycling	
ABS edge	Kronospan	Recycling	
Stretch wrap (packaging)	Filtenborg / Nomi 4S	Recycled	
Plastic protective corners			No waste
EPS packaging	Filtenborg / Thisted Forbraending	Incineration / energy recovery	
Solid wood tabletop (wood + glue)	DFI Geisler	Recycled in own production and incineration	
Oil	Filtenborg / Thisted Forbraending	Incineration	

Appendix 2 - Assumptions

End-of-Life
The assumptions regarding the scenarios in the end-of-life phase are based on a best estimate together with Ballingslöv AB.

In the end-of -life phase it is assumed that:

- 80% keep their kitchen for 20 years or more (due to high quality, economic incentive etc)
- 20% change or renew kitchen once within 20 years (due to trends etc)

Of the 20% that change kitchens:

- 60% sells their kitchen second-hand (for example online via blocket.se)
- 40% transports their kitchen to a waste management facility

Of the 40% that transport their kitchen to a waste management facility:

- 60% transports their kitchen by themselves and has to make the trip twice to transport everything
- 40% use a professional service where a larger truck comes and picks up the kitchen

When the transport to the waste management facility is done by the individual owner of the kitchen, it is assumed that they wold have to make the trip to the waste facility twice to dispose of the entire kitchen. In the cases when a larger truck/lorry will be picking up the kitchen and transport it to the waste management facility the trip is done once. The distance of the return trip is estimated to be 25km.

The solid wood tabletop and the laminate tabletop are incinerated in the disposal scenario, while the composite tabletop is crushed and used as road fill material or as landfill cover.

Table A 12: The weights in kilograms of the components door and frame as well as the complete kitchen depending on the type of tabletop installed in the kitchen.

	Composite	*Laminate*	*Solid wood*
Door	5.5	5.5	5.5
Frame	25	25	25
Total weight of kitchen	1125	954	951

Appendix 3 - Results

The results are illustrated as Sankey diagrams for each tabletop. A thinker arrow represents more impact.

Composite

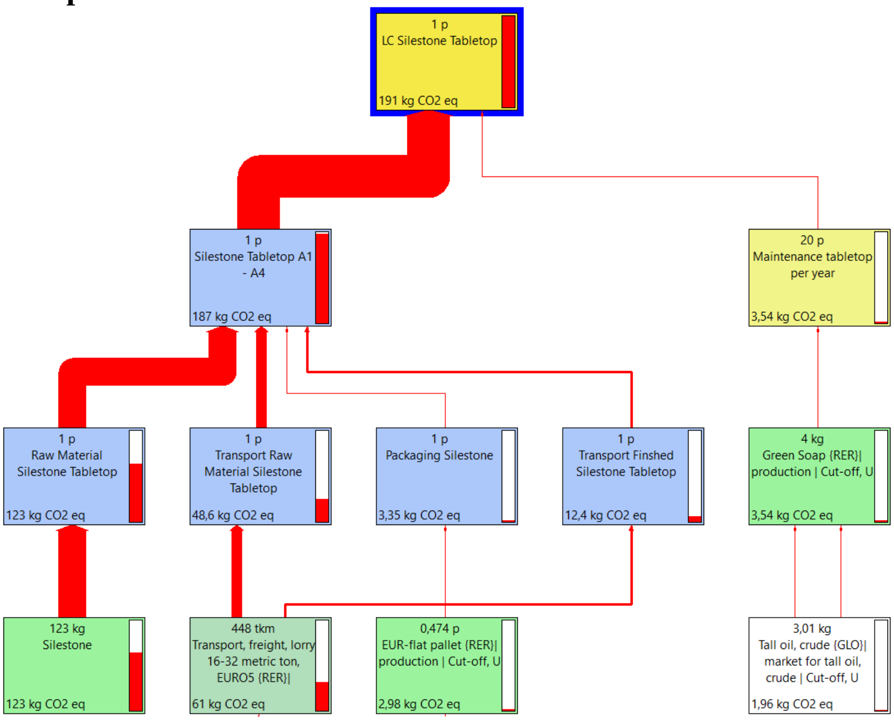

Figure A1: Sankey diagram for the life cycle of 1m² of composite tabletop.

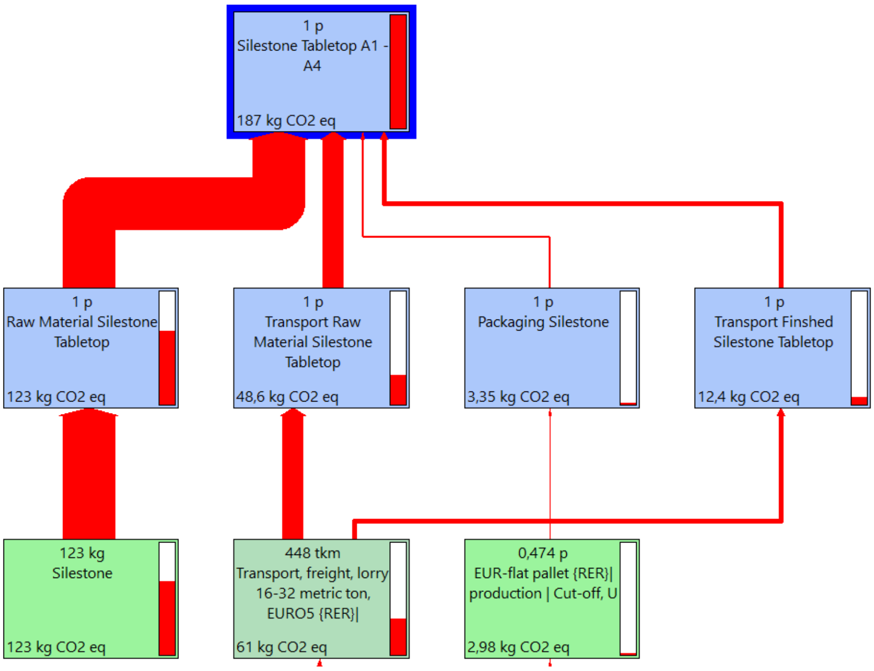

Figure A2: Sankey diagram for the life cycle phases raw material, transport to DFI Geisler, manufacturing and transport from DFI Geisler to the customer.

Solid Wood

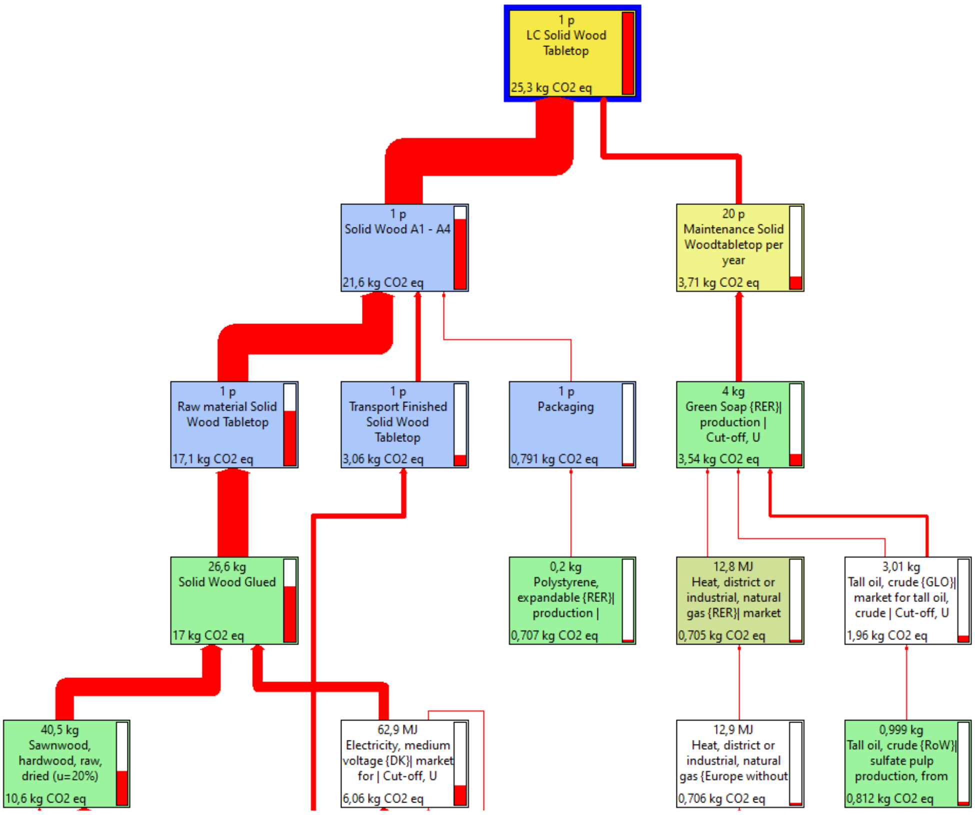

Figure A3: Sankey diagram for the life cycle of 1m² of solid wood tabletop.

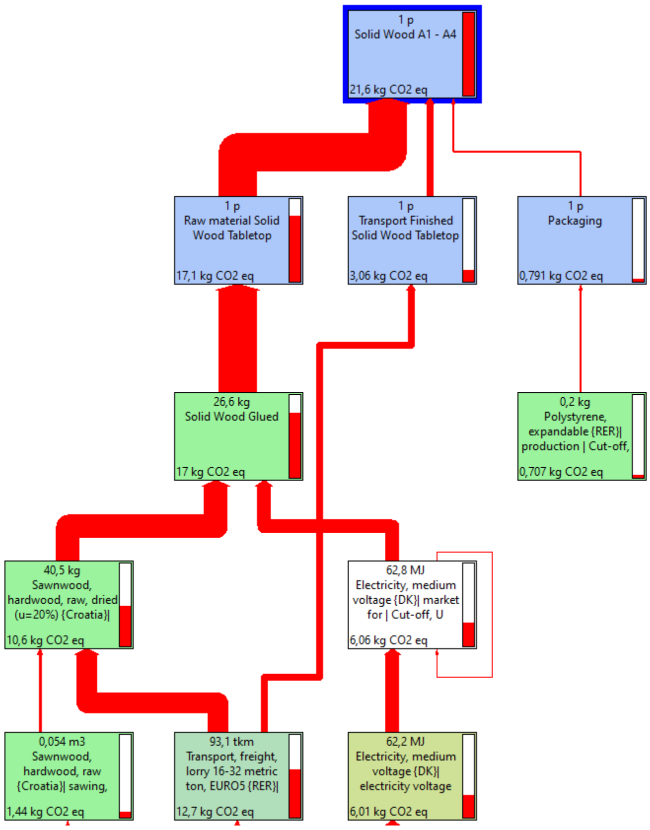

Figure A4: Sankey diagram for the life cycle phases raw material, transport to DFI Geisler, manufacturing and transport from DFI Geisler to the customer.

Laminate

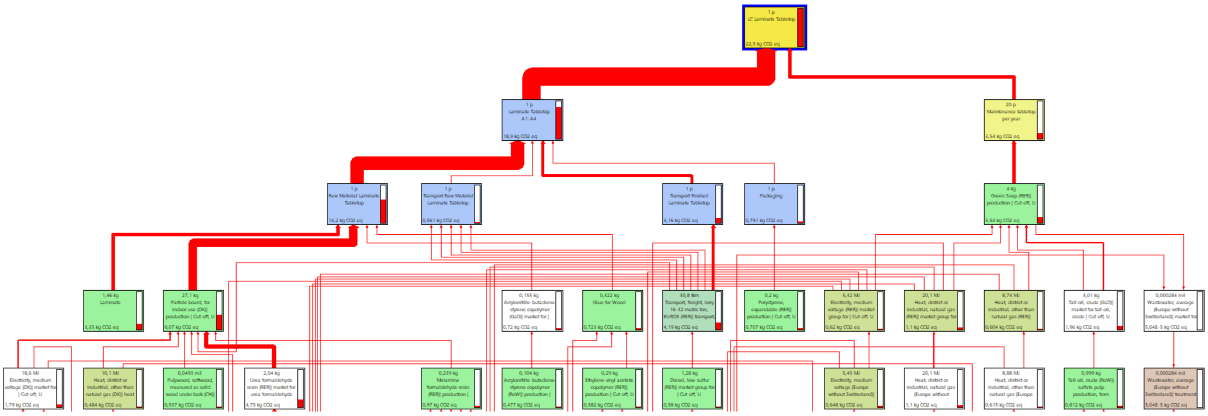

Figure A5: Sankey diagram for the life cycle of 1m² of laminate tabletop.

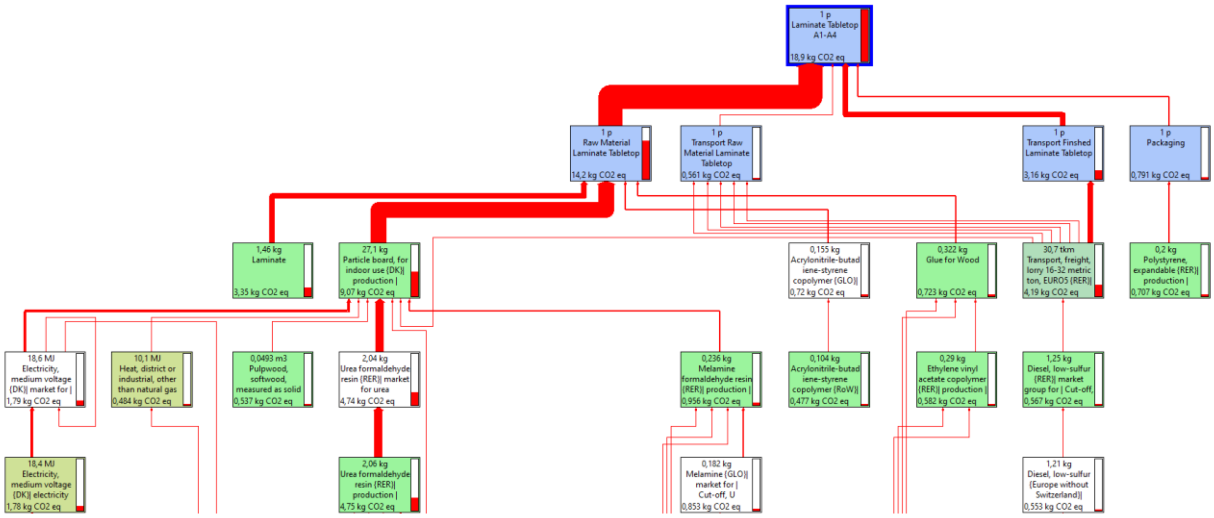

Figure A6: Sankey diagram for the life cycle phases raw material, transport to DFI Geisler, manufacturing and transport from DFI Geisler to the customer.

Door

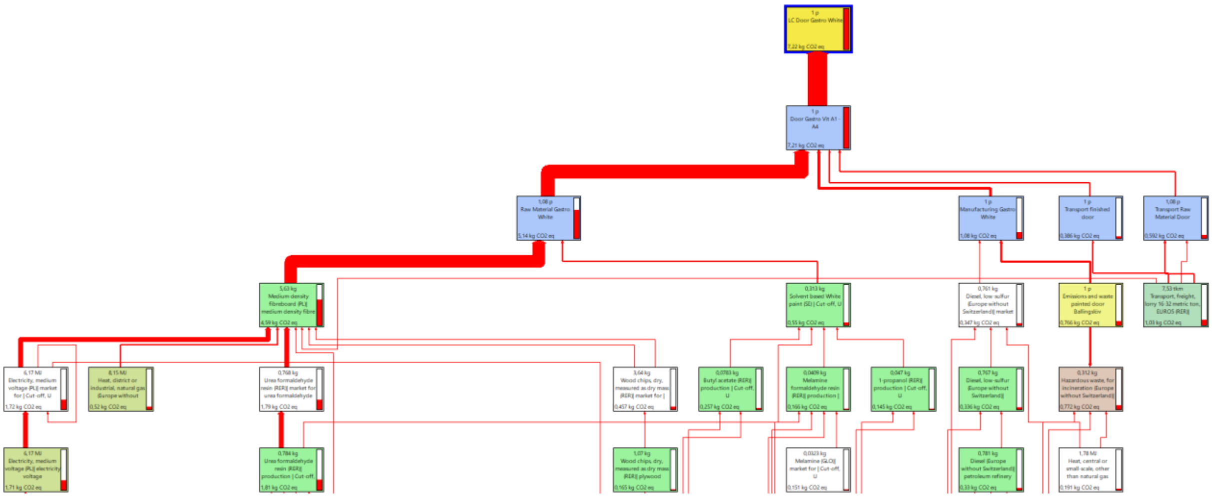

Figure A7: Sankey diagram for the life cycle of the door.

Frame

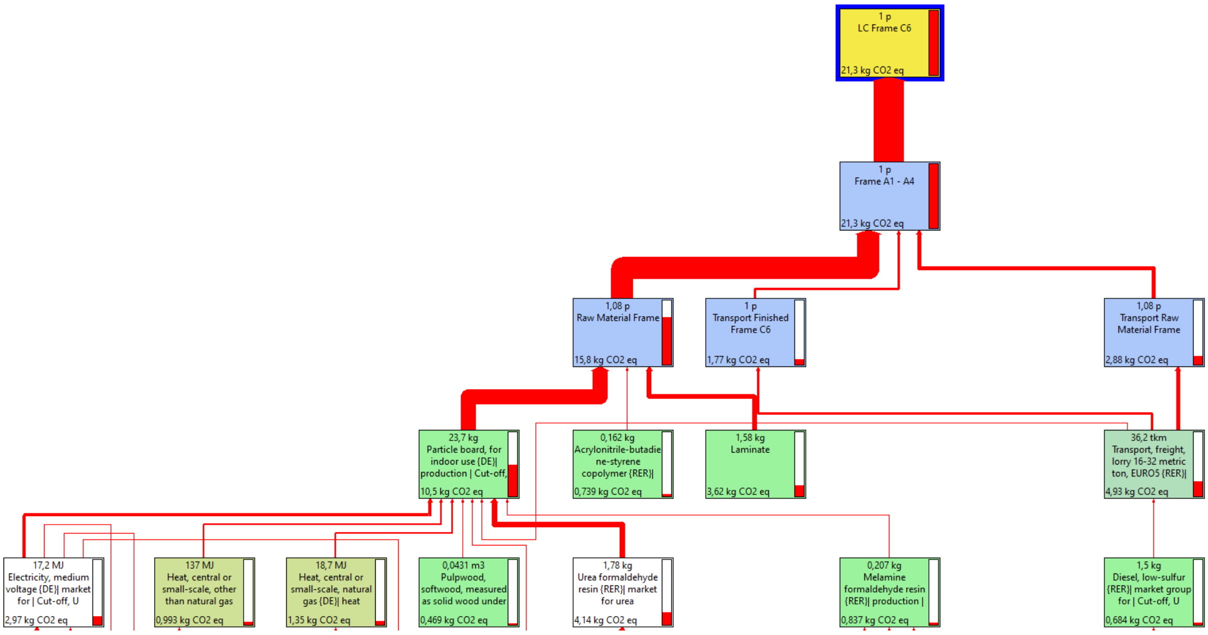

Figure A8: Sankey diagram for the life cycle of the frame.

Standard kitchen – SE electricity mix

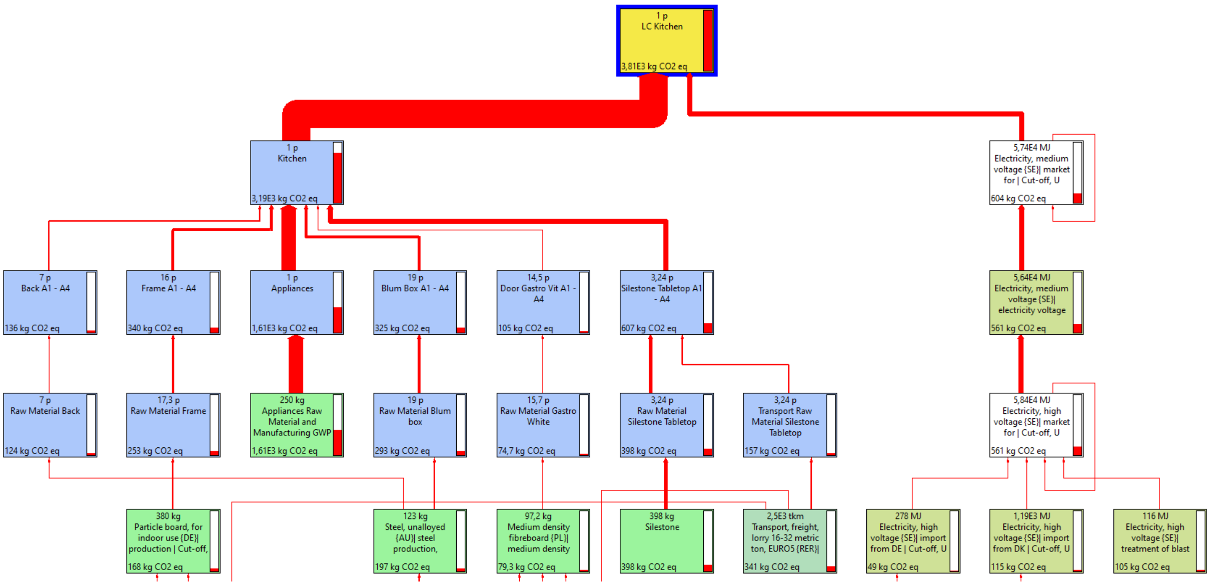

Figure A9: Sankey diagram for the life cycle of the standard kitchen.

Standard kitchen – 100% disposal, SE electricity mix

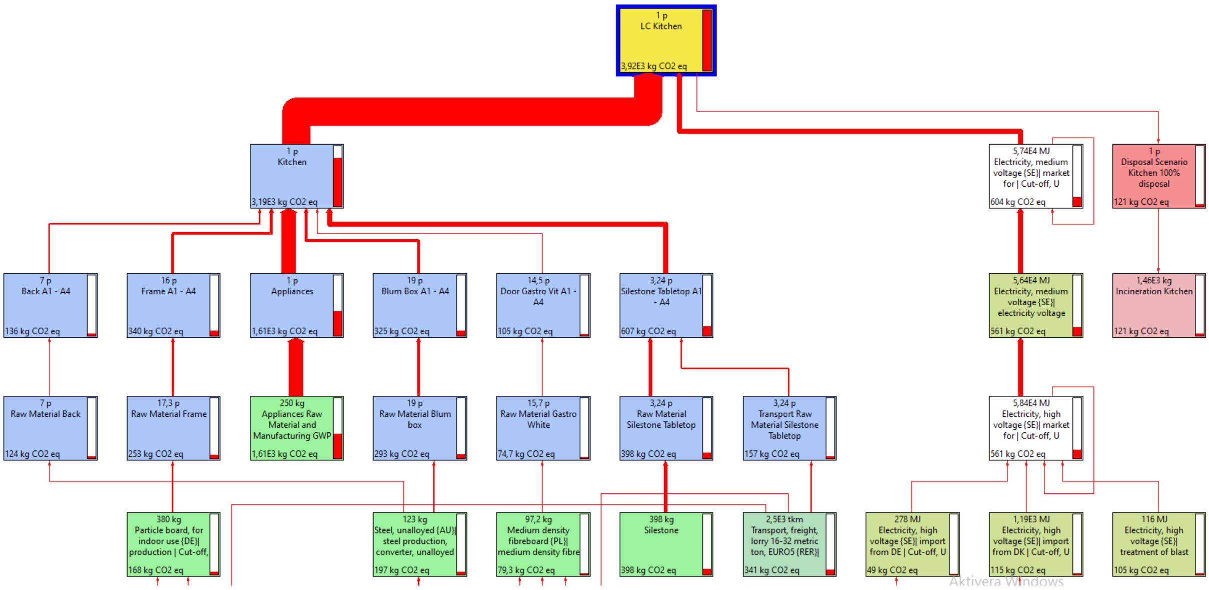

Figure A10: Sankey diagram for the life cycle of the standard kitchen with an altered end-of-life scenario to 100% disposal.