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Research: Ecodesign for furniture

Final report January 2024

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Management summary

In order to prepare the Dutch Ministry of Infrastructure and Water Management (I&W) as well as other representatives for the EU-level discussion on ecodesign regulations for furniture this study was performed. The focus of the study is on potentially hazardous chemicals used in furniture (for the readability we sometimes mention 'chemicals' instead of 'potentially hazardous chemicals'), metals used in furniture and the lifespan of furniture.

Potentially hazardous chemicals used in furniture

Types of chemicals in furniture

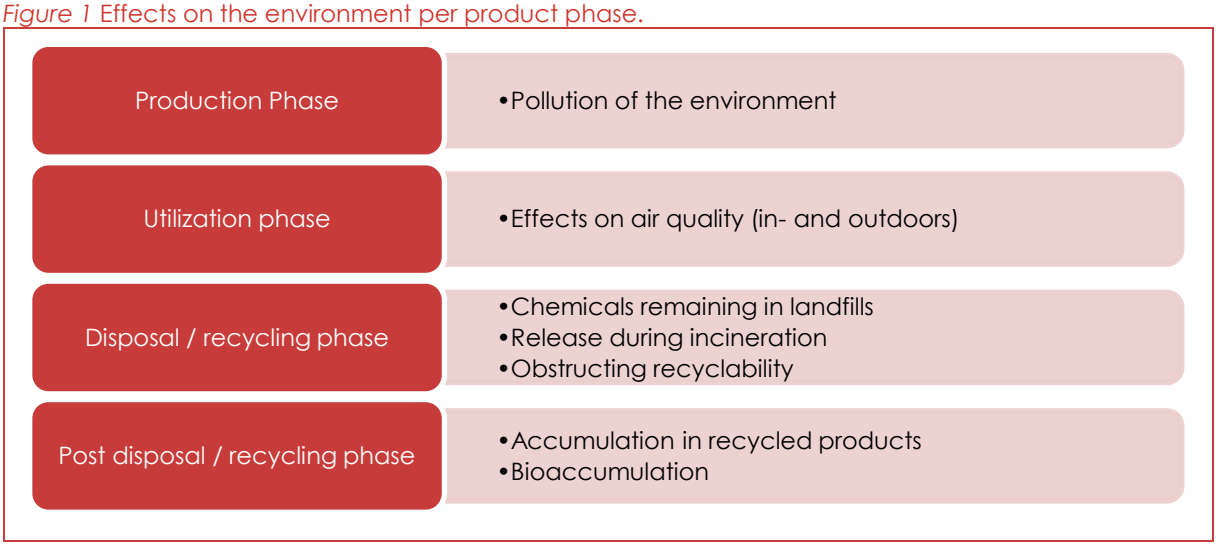
Potentially hazardous chemicals are widely used in manufacturing consumer goods, including furniture. Chemicals and other substances have different uses, purposes and functions, such as protection against rot, mould, decolouration, abrasion and other aspects that reduce longevity, fire retardation, adhesion of different components, coatings, water and oil repellence, anti-microbial effects, anti-allergen effects, and adding certain qualities to the products (such as reducing wrinkling of sheets or increasing the foldability of materials).

Groups of chemicals that are widely used in furniture manufacturing are flame retardants, Volatile Organic Compounds (VOCs), Phtalates, Per- and polyfluoroalkyl substances (PFAS), dyes and pesticides.

Impacts of chemicals used in furniture

Each of these groups includes several different chemicals, each with their own properties and effects on the environment. The effects of these chemical groups on the environment are quite nuanced. Some of the chemical groups have a large impact on the environment and are subject to major restrictions. In other groups, it might be the case that one type of chemicals has a major impact on the environment and others do not (for example flame retardants, where brominated flame retardants have a large impact on the environment, while other types have a lower impact). The following figure lists different effects on the environment, which are categorized in product phases (from production to post-disposal/recycling).

Figure 1 Effects on the environment per product phase.



Source: Technopolis.

It is nearly impossible to estimate the total volume of potentially hazardous chemicals used in furniture. There are many different potentially hazardous chemicals used in furniture production. Information on the use of chemicals is generally lacking, both for consumers and many manufacturers (who get treated materials from suppliers).

Alternatives for potentially hazardous chemicals in furniture

For many applications where potentially hazardous chemicals are used, there are already alternatives that are technically available and used on a small scale by smaller producers. However, challenges remain implementing these alternatives on a large scale – where this would mean that large scale retailers would have to make a switch. A switch to alternatives would mean initial higher production costs, higher consumer prices and large-scale restructuring of international supply chains and manufacturing processes. Based on the gathered information, it seems that not technical aspects limit the switch to alternatives and reduction of potentially hazardous chemicals, but mainly economic aspects are the limiting factor. Furthermore, knowledge of the use and effects of potentially hazardous chemicals on the side of producers and suppliers can be greatly improved.

Ferrous and non-ferrous metals in furniture

Use of metals in the furniture industry

Approximately 12% of the value of EU27 furniture production comes from metal furniture. The highest percentages of metals used can be found in non-padded chairs and outdoor tables (both approximately 40%) and bed frames (approximately 20%).

Especially steel is much used in furniture. Steel is a ferrous metal (ferrous metals are materials, often alloys, in which iron is the main component). There are over 2.000 different types of steel, of which different types of stainless steel are the most used in the furniture industry. Aluminium and copper are also regularly used. These are non-ferrous metals. Non-ferrous metals are not magnetic and do not rust.

Although there is no good data available on the type of furniture that uses metals, it is assumed that globally metals are mostly used for beds and sofas, followed by chairs and tables. Furthermore, a French study from 2015 made estimates of the different materials used in different furniture, with input from the French furniture industry. The highest percentages of metals used were found in non-padded chairs (41%), outdoor tables (39%) and bed frames (20%).

Use of recycled metals in furniture

The percentage of recycled metals from metal suppliers can differ over time. European metal suppliers often do not have access to large amounts of recycled content and sometimes they do not know the exact amount of recycled content in their materials, as it differs much over time. They blend the recycled metals and virgin materials and often do not offer 100% recycled material. For furniture producers it is therefore difficult to know the exact percentage of recycled metals and it can also be difficult to get metals with a high recycling percentage.

Approximately 20% of today's steel production comes from recycled steel. For aluminium, 32% of the aluminium production comes from recycled products.[1] As recycled steel and aluminium are often blended with virgin materials, it is estimated that this amount is similar for the furniture industry.

[1] World Aluminium (2020), Aluminium Recycling Factsheet 2020: https://international-aluminium.org/wp-content/uploads/2021/01/wa_factsheet_final.pdf

The potential of recycled metals

The amount of energy needed to produce virgin metals is high compared to other materials. However, the energy needed to produce recycled metals is much lower than the energy needed to produce virgin materials (70% less energy for recycled steel and 95% less energy use for aluminium), and it is technically possible to recycle metals into functionally equivalent products (instead of downcycling). Furthermore, metals have a relatively long lifespan, reducing their environmental impacts.

Approximately 20% of today's EU steel production comes from recycled steel and 32% of the aluminium production comes from recycled products. Furniture producers depend on their metal suppliers for recycled steel or aluminium. Metal suppliers often do not provide metals with a large amount of recycled content and sometimes do not know the exact amount of recycled content in their materials, as it differs much over time, depending on the scrap they can buy on the market.

As much of the metals used still come from virgin materials and the environmental benefits of using recycled metals are large, there is still much potential to gain here. It is technically feasible to use recycled metals instead of virgin metals, especially in furniture where the quality demands for the metals are lower compared to other sectors (like ships). However, the recycling of metals can be difficult and expensive, and recycled metals can be difficult for furniture producers to obtain. The percentage of recycled metals used in Europe can increase, as more metal scraps are available in Europe but are currently exported.

Improving the use of metals in furniture

Besides the potential for using more recycled metals in furniture, there is also still a large potential in increasing reuse and recycling rates for furniture. It is estimated that only 8% of the metal furniture in Europe is currently reused and 8% recycled. These rates are very low compared to other sectors: in general, 85-95% of end-of life steel is recycled back into new steel products, and approximately 76% of end-of life aluminium is recycled. We did not find a study explaining this large difference, but it is expected to come from high recycling rates in the building and automotive sectors, and challenges with furniture recycling in general (because of the composition of multiple different materials).

The lifespan of furniture

The lifespan of different product groups

In general, estimates on the lifespan of furniture are quite broad, estimating a lifespan varying between 5 and 20 years. This broad range is partly due to the lack of research into the lifespan of furniture, but mostly because of the big differences in lifespan between products[2].

In the table below, the estimated lifespan for the different product groups is discussed. We based the distinction of product groups on Smardzewski (2015), as there are no universally agreed upon product groups. The sources for this are mostly blogs on when furniture *should* be replaced. The research into lifespan that is available is based on surveys and expert estimates.

[2] For example: a small and relatively cheap MDF coffee table can break more easily and has a shorter lifespan than a high quality bed

Table 1 Estimated lifespan per product group of furniture.

	Details	Product details	Estimated Lifespan	Source
Seating	For individuals and multiple people, so chairs and couches.	Seating	7 to 15 years	TAUW (2022)[3], Leverette (2019)[4] Mallon (2018)[5]
		Seating	11.7 years	Economic lifespan as maintained by insurance services, according to TAUW (2022)[66]
		Upholstered chair	7 to 10 years	Leverette (2019)[67]
		Leather couches	> 20 years	CE Delft (2019)[6]
		Wooden chair	10 to 15 years	Leverette (2019)[67]
		Couches in the middle segment (between 1000 and 2000 Euros)	15 years	According to experts in TAUW (2022)[66]
		Couches in the high segment (over 2000 Euros)	20 years	According to experts in TAUW (2022)[66]
		Sofa	8.8 years	Wieser et al. (2015)[7]
Sleeping/lying	Such as bed frames, headboards, and loungers. Mattresses are not included[8]	Beds in general	5 to 20 years	Hom Furniture (2020)[9] and Haren de Krant (2020)[10]
		Beds in general	15 to 20 years	Leverette (2019)[67]
Tables	Such as kitchen tables and nightstands	Tables in general	5 to 20 years	Hom Furniture (2020)[72]
		Dining room table	15 to 20 years	Leverette (2019)[67]
		Solid wood tables	15 to 20 years	Hom Furniture (2020)[72]
		Desk	15 years	Leverette (2019)[67]
		Desk	8.8 years	Wieser et al. (2015)[70]
Storage	Such as cupboards, wardrobes, and closets.	Dresser or chest	5 to 20 years	Hom Furniture (2020)[72]
		Dresser or chest	10 to 20 years	Leverette (2019)[67]

[3] Tauw (2022). Grootzitmeubilair: Productstromen en materialen in kaart gebracht. https://www.afvalcirculair.nl/nieuws/afvalnieuws/2022/inzicht-circulariteit-groot-zitmeubilair/

[4] Leverette (2019). When Should You Replace Your Furniture? Source: When Should You Replace Your Furniture? (thespruce.com)

[5] Mallon, B. (2018). 10 HOUSEHOLD ITEMS WITH ACTUAL EXPIRATION DATES. Source: How Often to Replace Furniture — When to Buy New Furniture (elledecor.com)

[6] CE Delft (2019). The environmental benefit of Marktplaats trading. In opdracht van: Marktplaats.

[7] Based on a survey where Austrian consumers were asked how long they use their furniture. Wieser, H., Tröger, N., & Hübner, R. (2015). The consumers' desired and expected product lifetimes. Product Lifetimes And The Environment.

[8] Mattresses are not in the scope of this research.

[9] HOM Furniture (2020). FURNITURE LIFESPANS: How long should your furniture last? Source: Furniture Lifespans - design blog by HOM Furniture

[10] It is, however, unsure what this data is based on. Source: Haren de Krant (2020). Algemeen informatief: Hoe lang zouden uw meubels mee moeten gaan. Source: https://www.harendekrant.nl/nieuws/algemeen-informatief-hoe-lang-zouden-uw-meubels-mee-moeten-gaan/

	Details	Product details	Estimated Lifespan	Source
		Bookcases	15 to 20 years	Hom Furniture (2020)[72]
		Wardrobe	10.5 years	Wieser et al. (2015)[70]

Most important factors determining the lifespan of furniture

The estimates on the lifespan are very broad, which is mostly because there are crucial factors, apart from product type, that influence the lifespan. The most important factors determining the lifespan of furniture are:

- Quality of the materials and construction. This is the most important factor for the lifespan. Wooden and metal furniture generally last long, as well as well-maintained leather.
- Cleaning, maintenance, and reparations by the consumer. Consumers are rarely given guidance on how to maintain and repair furniture, in order to prolong and extend the product lifespan. If furniture is regularly cleaned and waxed, it can make a large difference in lifespan and quality. Furthermore, reparations are often expensive compared to new furniture (from the lower segment).
- 'Timelessness' of the furniture. Heirloom furniture emotionally connects with consumers and thus realizes longer lifespans.

Trends in the lifespan of furniture

The consumption of a piece of furniture was once a lifetime purchase. Since around two decades, however, furniture is bought a lot more frequently. This is partly explained by a decrease in quality, at least in the lower price segments. Furthermore, interior design and thus furniture also seem to be increasingly subject to trends. The lifespan of this trendy furniture is generally much lower than 'classic' furniture.

Recommendations regarding ecodesign requirements

Recommended general ecodesign requirements for furniture items

Furniture has a large environmental impact, which is growing in the last decades, as furniture consumption has greatly increased, and the lifespan of furniture declined. Ecodesign requirements can greatly reduce the environmental impact of furniture.

There is not enough information available yet to determine which exact components, materials and potentially hazardous chemicals need to be addressed in these Ecodesign requirements: further investigation into different product groups, components, materials and chemicals is needed to establish effective requirements per group of items or per furniture item. However, there are some general aims, goals and principals for ecodesign requirements that can greatly reduce the environmental impact of furniture, e.g., requiring a digital passport, high(er) quality materials, replaceable components, possibilities for disassembly, and guidelines on user maintenance and repair.

Recommended ecodesign requirements regarding potentially hazardous chemicals

Several of the above listed requirements can be specified for the reduction of potentially hazardous chemicals used in furniture. Most potentially effective requirements are:

- Increasing the transparency and traceability of potentially hazardous chemicals used
  - whereby retailers and manufacturers are required to control and disclose information on the use of potentially hazardous chemicals in furniture items brought to the market, and

requiring suppliers to provide this information in an "information flow" parallel to the material flow. Ideally, producers should be required to list all applied potentially hazardous chemicals (comparable to ingredient listings used in food safety) per component in a furniture item.

- Design requirements – separating components treated with potentially hazardous chemicals from non-treated components:
  - requiring manufacturers to produce furniture items that consist of separate components which are treated with potentially hazardous chemicals (which are deemed necessary) from components that are non-treated, thereby increasing recyclability and separating potentially hazardous chemicals from homogenous and recyclable material streams and preventing them re-entering the production stage and entering the environment.
- Require producers to use potentially hazardous chemicals that have a low(er) environmental impact in the production of furniture items
  - by further building upon existing legislative frameworks such as REACH, POP and waste directives and national legislation, extending the scope of potentially hazardous chemicals which will be (further) limited. Basis of this further limitation is the environmental impact of used chemicals.

Recommendations regarding ecodesign measures and metals used

The amount of energy needed for metal production is high compared to other materials, but much energy can be saved by using recycled metals. Currently, only a small part of metals used in Europe come from recycled materials (20% for steel, 32% for aluminium). Therefore, there is still much potential to gain here.

We recommend further investigating ecodesign requirements:

- Increasing metal recycling rates used (in furniture/ in general)
  - It needs to be further investigated whether it is feasible and relevant to try to improve the metal recycling rate for furniture specifically. On the one hand, there could be opportunities here, as the quality standards for furniture are lower compared to other sectors, making it technically more feasible to use recycled materials. On the other hand, the amount of metals used in furniture is small compared to other sectors and therefore rules regarding recycling rates may not lead to changes on the metal supplier side. This means that furniture producers have to import metal with higher recycling rates from outside the EU. Therefore, increasing the recycling rate of metals in the EU in general may be preferable.
- Increase information provided on recycling rates
  - As metal suppliers often cannot provide furniture producers with recycling rates and do not offer 100% recycled materials, this hinders ambitious producers with increasing recycling rates. There is much to gain here, with current recycling rates used around 20% for steel and 32% for aluminium. However, this problem seems to be more on the supply-side of the materials instead of in the production of furniture.
- Require easy disassembly
  - There is still much potential in increasing reuse and recycling rates for furniture. It is estimated that only 8% of the metal furniture in Europe is currently reused and 8% recycled. This is probably mainly due to the composition of furniture, made from different materials that are difficult and costly to disassembly. Easy disassembly will therefore likely help in higher recycling rates.
- Using common alloys and providing information on alloys(/materials) used

- For ferrous metals (of which steel is by far the most used one in the furniture sector), there are many different alloys that can be used. The different alloys need to be separated for recycling and as detailed product information is often not available, metals need to be tested to see the composition of the alloy. Using common alloys and providing information on the alloy used could therefore increase recycling rates.

Interesting product groups to start could be outdoor tables, bed frames and non-padded chairs, as relatively high percentages of metals are used for these product groups.

Recommendations regarding ecodesign measures and increasing the lifespan

In general, estimates on the lifespan of furniture show great variation. Most estimates vary between 5 and 20 years. This broad range is partly due to the lack of research into the lifespan of furniture, but mostly because of the big differences in lifespan between products. The quality of materials and construction is the most important factor for the lifespan. Another factor is the maintenance by the consumer. Finally, the ' timelessness' of the furniture is an important factor. Heirloom furniture emotionally connects with consumers and thus realizes longer lifespans.

We recommend further investigating ecodesign requirements:

- Increasing durability
  - There is a trend of weaker design and cheaper materials that are of lesser quality. For example, we see a shift from solid wood and metal (durable, high-quality materials) to cheaper materials such as plywood. We therefore recommend investigating possibilities of increasing the durability, to increase the lifespan of furniture.
- Increasing repairability (and disassembly)
  - The lifespan can probably also increase by increasing repairability. Repairing furniture is currently difficult, as most furniture is difficult to disassemble, and spare parts are not easily available. Ecodesign measures could help improving the repairability. Providing spare parts and enabling third party professional repairers' possibilities to repair (via design requirements) are fruitful strategies.
- Information provided on product care
  - Consumers are rarely given guidance on how to maintain and repair furniture, in order to prolong and extend the product lifespan. If furniture is regularly cleaned and waxed, it can make a large difference in lifespan and quality. Measures on information for product care could therefore possibly increase the lifespan of products.

In general, low-quality furniture with a short lifespan and a large market share are interesting to start with. Furniture with low quality materials present in fundamental parts of their structure (especially items that consist of combinations of wood processed materials such as MDF and polyurethane foam), such as sofas and couches and 'MDF or plywood' type closets and cupboards could be a good start. Furthermore, composite wood items that are heavily processed with chemical substances could be interesting to look at as well. Finally, furniture with electronics embedded and 'smart furniture' could be an interesting category to start, as replacement of parts and disassembly of the item are expected to be more important in this (growing) category.

1. Introduction

This research is executed by Technopolis, on behalf of the Dutch Ministry of Infrastructure and Water Management (I&W) and Rijkswaterstaat (the executive agency of the Ministry I&W). They represent the Netherlands in the EU negotiations regarding Ecodesign measures. The Ecodesign for Sustainable Products Regulation[11], which was presented by the European Commission in March 2022, allows for setting design and information requirements (Ecodesign requirements) for specific product groups. The European Commission will present an Ecodesign Working plan which contains the product groups for which Ecodesign requirements will be set in the next years. The Ecodesign working plan will be presented in 2024. Goal of the research

It is expected that furniture will be one of the priority products for which ecodesign requirements will be developed in the next years. For this reason, this research was commissioned by the Ministry of Infrastructure and Water Management to gain more insight in furniture production in the EU and in potential Ecodesign requirements. The aim of this research is to provide information that prepares the Dutch Ministry of Infrastructure and Water Management (I&W) as well as other representatives for a discussion on Ecodesign requirements for furniture. This regulation will include Ecodesign requirements which make the product more circular e.g. by extending the lifecycle, the reusability and recyclability.

1.1 Focus of the research

The research is focused around three topics:

- Potentially hazardous chemicals used in furniture: which potentially hazardous chemicals are used, for what purposes, the impacts (e.g., on the lifespan, recyclability, health and environment), and possible alternatives.
- Metals used in furniture: how much (ferrous and non-ferrous) metals are used, how much is recycled, what is the impact and how can the impacts be improved.
- Lifespan of furniture: what is the lifespan of different types of furniture, what is the trend in the lifespan and which factors are most important for the lifespan of furniture.

We focus on the European market. We use the following definition for furniture:

> *'Free-standing or built-in units whose primary function is to be used for the storage, placement or hanging of items and/or to provide surfaces where users can rest, sit, eat, study or work, whether for indoor or outdoor use. Bed frames, legs, bases and headboards are included in the scope. Not included are: bed mattresses, streetlights, railings and fences, ladders, clocks, playground equipment, stand-alone or wall-hung mirrors, electrical conduits, road bollards and building products such as steps, doors, windows, floor coverings and cladding'*

1.2 Research methodology

We analysed European and Dutch research, statistics, and other documentation. We complemented this with 11 interviews with different stakeholders (experts, producers, policy makers and industry representatives etc.) from different countries. The organisations we interviewed are listed in Appendix A. Finally, we did a short case study, where we compared two chairs with each other, to illustrate the potential differences in impacts the furniture can have.

[11] Ecodesign for sustainable products (europa.eu)

1.3 Set-up of the report

We start with giving some background information on the production and recycling of furniture in the EU, in chapter 2. We then present results for the different topics in the following chapters: potentially hazardous chemicals used in chapter 3, metals used in chapter 4 and the lifespan of furniture in chapter 5. Chapter 6 presents the case study, where we compare the impacts of two different chairs. Finally, the conclusions and recommendations are presented in chapter 7.

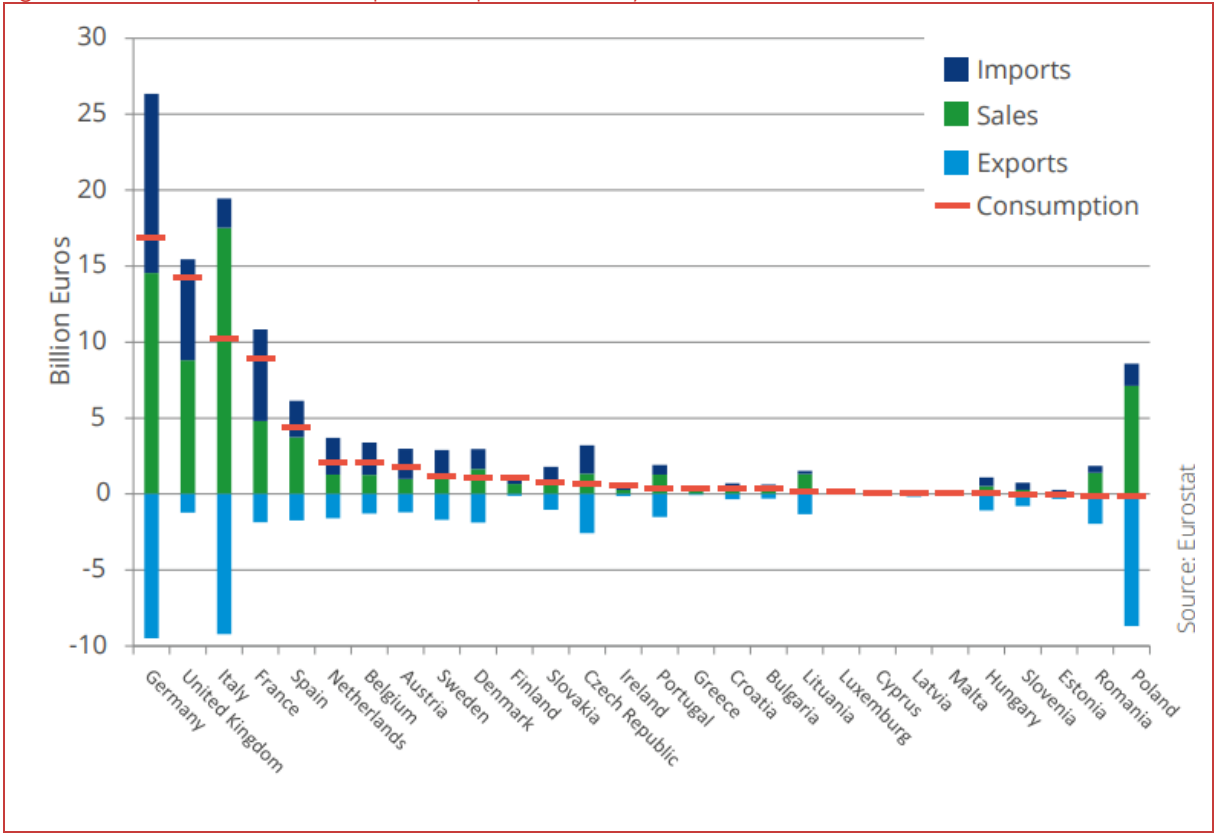
2 Background information – production and recycling of furniture

This chapter briefly covers production and recycling of furniture in the EU. This chapter serves as background information, which we will refer to in later chapters.

2.1 Production in the EU

Furniture production is an important industry in the EU. EU Member states manufacture 28% of the furniture sold worldwide[12]. This represents a €84 billion market, employing approximately 1 million European workers[13]. Italy, Germany and Poland are the most significant furniture producers and exporters.

Figure 2 Furniture Production, Import & Export Values by Member State.



Source: EU Furniture Market Situation Report, CEPS, 2014. Based on Eurostat data.

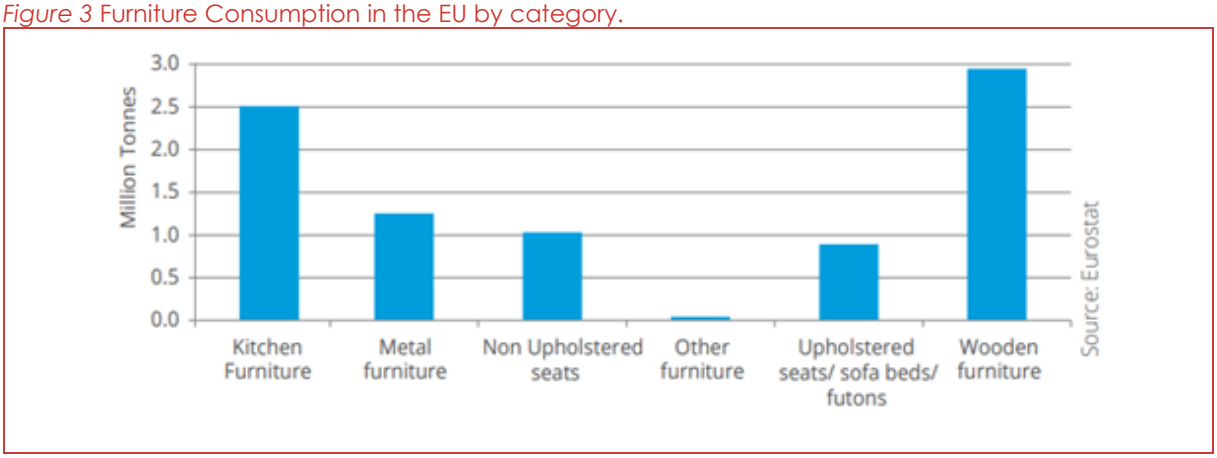
[12] Data used in this chapter is (except when a different source is provided) gathered from the most recent and comprehensive study on the EU Furniture Market, called the 'EU Furniture Market Situation Report by CEPS.' This report was published in 2014 and is Pre-Brexit, therefore including Great Britain as a part of the EU.

[13] Centre for European Policy Studies (CEPS) (2014). EU Furniture Market Situation Report. https://www.ceps.eu/ceps-publications/eu-furniture-market-situation-and-possible-furniture-products-initiative/

2.2 Consumption

The annual consumption of furniture in the EU is estimated to be around € 68 billion[14]. Types of furniture that are consumed the most are wooden furniture and kitchen furniture[15]. It is estimated[16] that the domestic sector (i.e. households) accounts for around 82% of the furniture consumption, and 18% is associated with consumption by businesses (mostly office furniture).

Figure 3 Furniture Consumption in the EU by category.



Source : EU Furniture Market Situation Report, CEPS, 2014. Based on Eurostat data.

2.3 Waste collection and recycling

According to European Federation of Furniture Manufacturers (UEA) statistics, 80% to 90% of the EU furniture waste in municipal solid waste is incinerated or sent to landfill, with ~10% recycled[17].

Based on this data[18], it is estimated that 2% to 5% of household waste in the EU consists of furniture. This means that the total annual EU28 furniture waste equates to 8 to 12 million tonnes, reflecting a yearly substitution of new versus discarded furniture.

Low recycling rates depend on the fact that furniture is mostly treated as "bulky waste" and not always collected separately for recycling from other waste streams.[19] This has several causes: most importantly, disassembly is needed for recycling (separating the different materials in furniture), which is costly and often not possible due to glue and composite components consisting of mixed materials.

Reuse activity in the sector (reselling of furniture) is also relatively low (see chapter 5 and 6 on lifespan and causes of the low reuse rate). Where reuse does occur, it is mostly through commercial second-hand shops, social enterprise companies or charities.

[14] European Environment Bureau (2017). Circular economy opportunities in the furniture sector. https://eeb.org/wp-content/uploads/2019/05/Report-on-the-Circular-Economy-in-the-Furniture-Sector.pdf

[15] Idem.

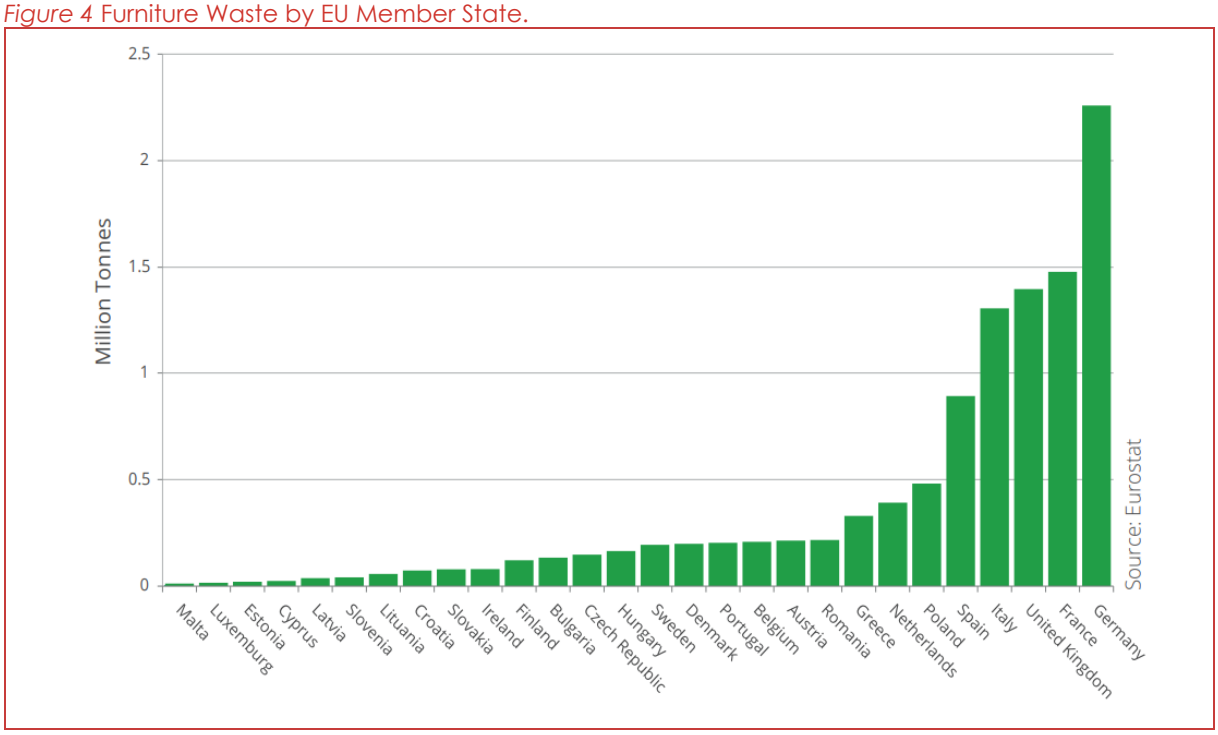
[16] Centre for European Policy Studies (CEPS) (2014). EU Furniture Market Situation Report. https://www.ceps.eu/ceps-publications/eu-furniture-market-situation-and-possible-furniture-products-initiative/

[17] European Environment Bureau (2017). Circular economy opportunities in the furniture sector. https://eeb.org/wp-content/uploads/2019/05/Report-on-the-Circular-Economy-in-the-Furniture-Sector.pdf

[18] Idem.

[19] Eurostat (2020). Guidance for the compilation and reporting of data on municipal waste according to Commission Implementing Decisions 2019/1004/EC and 2019/1885/EC, and the Joint Questionnaire of Eurostat and OECD. https://ec.europa.eu/eurostat/documents/342366/351811/Guidance+on+municipal+waste+data+collection/

Figure 4 Furniture Waste by EU Member State.



Source: EU Furniture Market Situation Report, CEPS, 2014. Based on Eurostat data.

Some furniture items are also exchanged via free and paid exchange platforms, such as eBay and Freecycle, though the number of items traded in this way is difficult to quantify. In the UK, data from the Furniture Reuse Network (FRN) indicates that its members delivered 120,000 tonnes of reuse[4], which means that in the UK 6% of collected furniture items are resold in stead of being processed as waste[20].

With respect to remanufacturing, the size of the European sector is estimated to be €300 million turnover, employing 3,400 European workers (less than 0.1% of the total furniture industry).

[20] European Environment Bureau (2017). Circular economy opportunities in the furniture sector. https://eeb.org/wp-content/uploads/2019/05/Report-on-the-Circular-Economy-in-the-Furniture-Sector.pdf

3 Results - 1 Potentially hazardous chemicals used in furniture

In this chapter we show the types of potentially hazardous chemicals used in furniture and why they are used. Then we provide an overview of the impacts of the potentially hazardous chemicals used in the different product phases. Finally, we show the alternatives for the potentially hazardous chemicals used and the effects of the application of the alternatives on the industry. For the readability we sometimes mention 'chemicals' instead of 'potentially hazardous chemicals'.

3.1 Types of potentially hazardous chemicals used in furniture

3.1.1 Applications of potentially hazardous chemicals used in furniture

Potentially hazardous chemicals are widely used in manufacturing consumer goods, including furniture. Chemicals and other substances have different uses, purposes and functions[21], such as:

- Protection against rot, mould, decolouration, abrasion and other aspects that reduce longevity
- Fire retardation
- Adhesion of different components
- Coatings
- Dyes
- Water and oil repellence
- Anti-microbial effects
- Anti-allergen effects
- Adding certain qualities to the products (such as reducing wrinkling of sheets or increasing the foldability of materials).

Furniture containing potentially hazardous chemicals sold in the EU are subject to chemical regulation and legislation, such as the REACH framework (see paragraph 3.2.2 for a detailed explanation on REACH and the so called 'substances of very high concern'). EU chemical legislation is implemented by ECHA (The European Chemicals Agency), which also coordinate research and continuously evaluate the impacts of chemicals on health and environment. REACH however, does not account for accumulation of substances in the recycling stream.

3.1.2 Types of potentially hazardous chemicals in furniture

The following figure gives a main overview of different groups of chemicals which are used in furniture. These will be further described in the table below[22].

[21] Waar zit wat in? (Dutch informative website by the RIVM/Ministry of Health/Ministry of Infrastructure). https://waarzitwatin.nl/

[22] This table is based on data provided online by the RIVM (the Dutch National Institute for Public Health and the Environment) and information provided on the website of ECHA, using the 'Substance Information Database' and press releases. The table also describes DMF and formaldehyde as they are a chemicals that were/are widely used in furniture manufacturing, which will be covered separately in the table.

Figure 5 Types of chemical substances used in furniture.

Source: Technopolis.

Table 2 Overview of chemicals used in furniture, their use and their environmental impact

Substance	
Flame retardants	**Description and uses** Flame retardants are used in furniture to reduce the risk of fire and slow down the spread of flames in case of an ignition. They serve as a safety measure to enhance the fire resistance of furniture and prevent it from rapidly catching fire. Flame retardants work by either inhibiting combustion, forming a protective barrier, or releasing fire-extinguishing gases when exposed to heat or flames. They are essential in meeting fire safety regulations and standards for furniture. Some commonly used flame retardants in furniture include: • Polybrominated diphenyl ethers (PBDEs): These were once widely used but are now being phased out due to concerns about environmental and health effects. • Chlorinated flame retardants: Compounds like tris(2-chloroethyl) phosphate (TCEP) and tris(1-chloro-2-propyl) phosphate (TCPP). • Phosphorus-based flame retardants: Substances like ammonium polyphosphate and red phosphorus are increasingly utilized as more environmentally friendly alternatives. • Halogen-free flame retardants: These include aluminium hydroxide and magnesium hydroxide, which are considered less harmful to health and the environment. • Antimony trioxide: This flame retardant is sometimes used in combination with other compounds to enhance fire resistance in furniture. **Effect on environment** Efforts are ongoing to develop and adopt flame retardants that are effective in fire prevention while minimizing potential risks to health and the environment, as some traditional flame retardants have raised concerns about their persistence in the environment and their potential health effects. ECHA is currently[23] (as of October 2023) reviewing certain brominated flame retardants as candidates for restriction. Among others, there are concerns regarding bio accumulation. The review also mentions an assessment of the waste stage to find out if hazardous substances are released when products containing flame retardants are dismantled, recycled, or disposed of. It could also include an assessment of the availability of suitable alternative substances or materials.
Volatile organic compounds (VOCs)	**Description and uses** Volatile Organic Compounds (VOCs) are byproducts or components found in materials and finishes used in furniture production. VOCs are organic chemicals that readily evaporate into the air. They can be present in adhesives, paints, varnishes, and finishes applied to furniture. VOCs can serve various purposes in furniture materials, like contributing to the performance of adhesives, enhancing the durability and aesthetics of finishes, or improving the application properties of coatings. VOCs can be released from products such as mattresses, carpets and glue. VOCs can be smelled when taking a

[23] ECHA (2017). ECHA identifies certain brominated flame retardants as candidates for restriction https://echa.europa.eu/-/echa-identifies-certain-brominated-flame-retardants-as-candidates-for-restriction. This research might result in proposed alternatives for these flame retardants.

	new mattress or carpet out of its packaging. VOCs are used in wooden and wood-composite based furniture units. Burning candles and incense also releases VOCs. Typical VOCs consist of aldehydes and benzene derivatives such as toluene and benzene. **Effect on the Environment** VOCs are naturally occurring in the environment; however, average annual emissions of man-made volatile organic compounds have increased dramatically in recent decades. When exposed to the environment, VOCs evaporate quickly into the air, where they can form different chemical bonds. Most VOCs have a short atmospheric lifetime and are decomposed, thus diminishing their effect. The chemical transformation of VOCs leads to the production of reactive volatile substances and contributes to atmospheric ozone formation, acid deposition, organic aerosol formation and photochemical smog formation in the atmosphere. Certain VOCs were identified as greenhouse gases, which are able to absorb radiated energy from Earth, their concentrations increase in the atmosphere been correlated with the global warming. Furthermore, VOCs in wastewaters decrease the possibility of water reuse, such as in irrigation, thereby placing a higher demand on the limited existing primary water resources. VOCs are linked to several health issues. Short term effects of exposure to high doses are irritation in eyes, mouth, nose and skin and dizziness and headaches. Recent studies show furniture emitting VOCs have a negative impact on indoor air quality. Long term exposure to VOCs is associated with raspatory, cardiovascular, neurological and carcinogenic health effects, where effects may differ per type of VOC, exposure time and concentration of VOCs.
Phtalates	**Description and uses** Phthalates form a family of synthetic chemicals with a wide variety of uses, ranging from consumer to industrial products. There are different kind of phthalates and they are commonly used as softeners to make plastics, such as PVC, more flexible and durable. Although phthalates are mostly used as plasticisers, they can also be found in, adhesives, sealants, paints, rubber materials, wires and cables and packaging. The most known phthalates are ortho-phthalates, such as bis(2-ethylhexyl) phthalate (DEHP) and di-"isononyl" phthalate (DINP). Ortho-phthalates are broadly divided into two main distinct groups: LMW ("low molecular weight") and HMW ("high molecular weight") ortho-phthalates with very different applications, toxicological properties, classification and legal requirements. **Effect on the environment** As phthalates are not chemically bound in the materials they are added to, they can easily leach out or evaporate. Several ortho-phthalates, for example DEHP, dibutyl phthalate (DBP), diisobutyl phthalate (DIBP) and benzyl butyl phthalate (BBP) may damage fertility or the unborn baby and interfere with our hormonal system. In particular, they affect the sexual development of boys which can lead to infertility in adults. Some ortho-phthalates, such as DBP, BBP, and DEHP, are harmful to the environment and can interfere with endocrine system function, reproduction and development of wildlife.
PFAS	**Description and uses** Per- and polyfluoroalkyl substances (PFAS) is a collective name for more than 6,000 different fluorine compounds. They all contain carbon-fluorine bonds, which are one of the strongest chemical bonds in organic chemistry. This means that they resist degradation when used and also in the environment. Most PFAS are also easily transported in the environment covering long distances away from the source of their release. PFAS are known as 'forever chemicals' as they do not degrade in natural environments; some PFAS tend to accumulate in water, soil and organisms. PFAS are used as stain repellents and in polishes, paints and coatings in furniture manufacturing. Currently, PFAS are subject of regulatory clampdown and it is expected they will be banned from production in large groups of consumer products.

	Effect on the environment PFAS have been frequently observed to contaminate groundwater, surface water and soil. Cleaning up polluted sites is technically difficult and costly. If releases continue, they will continue to accumulate in the environment, drinking water and food. Human health effects from exposure to low environmental levels of PFAS are uncertain. Studies of laboratory animals given large amounts of PFAS indicate that some PFAS may affect growth and development. In addition, these animal studies indicate PFAS may affect reproduction, thyroid function, the immune system, and injure the liver. Due to the bio accumulating aspect, it is feared PFAS continue to affect the environment and have adverse effects on wildlife and enter the food chain.
Dyes	**Description and uses** Chemicals are heavily used in the dying of furniture, especially textiles. The dying of textiles exists of different steps, each step including different chemicals. In general, textiles are processed with, caustic soda (helping absorb colouring agents), peroxide, stabilizers, detergents, anti-creasing agents, sequestering and wetting agents, softeners and fixing agents. Chemicals such as sulphuric acid (H2SO4), hydrochloric acid (HCL), acetic acids (CH2COOH), alkali, sodium chloride (NaCl) are widely used. Next to this, a group of very varied colourants are used (for different colours), some of which are considered highly impactful on health and the environment. **Effect on environment** The use of chemicals in the colouring of furniture has a very large impact on the environment, mainly in the production phase. Chemicals used in the colouring of textiles pollutes water bodies and further enters the environment such as soul and drinking water. The textile dyes significantly compromise the aesthetic quality of water bodies, increase biochemical and chemical oxygen demand (BOD and COD), impair photosynthesis, inhibit plant growth, enter the food chain, provide recalcitrance and bioaccumulation, and may promote toxicity, mutagenicity and carcinogenicity[24]. Besides chemicals entering the environment, colouring has other effects such as lowering air quality, using large amounts of drinking water and energy.
Pesticides & biocides	**Description and use** Pesticides are a large group of chemicals, used in furniture for the production of organic textiles (such as cotton). Next, biocides are used to prevent spoilage of glue and staining and protection against bacteria. Pesticides are used in upholstery, fabrics and leather. These are bactericidal chemicals. Pesticides are also used in the production of cotton. Pesticides are widely used in agriculture, as it protects crop losses and yield reductions. **Effects on the environment** The main environmental concerns related to pesticides are soil, water or air pollution and damage to organisms including plants, birds, wildlife, fish and crops. These effects are generated in the production phase. Pesticides that are in furniture may impact the environment when being processed as waste or in recycling. Accumulation of pesticides in recycled products may exists, but at this point has not been widely studied.
Formaldehyde	**Description and uses** Formaldehyde (HCHO) is widely used in the production of furniture and other (consumer) products and has different kinds of uses. Mainly, it is used in glue, sealant and lacquer. In furniture that consists of different materials that are glued together, there is a high chance of formaldehyde being used. Next to that, formaldehyde is widely used in so called composite materials (such as plywood, fibreboard or particle board), whereby materials are glued and pressed together. Formaldehyde also keeps cotton bedding wrinkle-free.

[24] Lellis et al. (2019). Effects of textile dyes on health and the environment and bioremediation potential of living organisms. https://www.sciencedirect.com/science/article/pii/S2452072119300413

	Effect on environment In the latest substance evaluation by ECHA[25], effects on the environment have not been included. In general, formaldehyde breaks down relatively fast in the atmosphere in other chemical bonds. Regarding health, there are areas of concern, relating to carcinogenic and mutagenic properties. In (very) high doses, exposure to formaldehyde is life threatening. In medium doses, it can have an irritative effect on skin and eyes. (Long term) effects of exposure to low doses is not fully established, but currently seems relatively harmless. Formaldehyde occurs naturally - humans are exposed to formaldehyde when eating apples or walking through a pine forest.
DMF	**Description and uses** DMF is a chemical that is no longer allowed to be used within the EU, but can still be found in products imported from outside the EU. It is a pesticide against mold. It is widely used when products are stored or transported for long periods of time. It is used in products made from leather. DMF is a white crystalline powder, which is packed in sachets to protect leather goods like recliners, sofas, couches, or armchairs, against mold attack. **Effect on the environment** Acute (short-term) exposure to dimethylformamide has been observed to damage the liver in animals and in humans. Human studies have identified increased rates of testicular cancer in humans exposed to dimethylformamide. Animal studies have documented teratogenic effects, including decreased foetal weight and increased spontaneous abortions. As a result of its complete solubility in water, DMF moves readily through soils and would not be expected to accumulate in the food chain.

This table is based on data provided online by the RIVM (the Dutch National Institute for Public Health and the Environment) and information provided on the website of ECHA, using the 'Substance Information Database' and press releases. The table also describes DMF and formaldehyde as they are a chemicals that were/are widely used in furniture manufacturing.

3.1.3 Quantities of chemicals used in furniture

It is nearly impossible to establish the total volume of potentially hazardous chemicals used in furniture. Firstly, there are many different chemicals used in furniture production. The table in the previous paragraph describes different types of chemicals; these different types consist of different 'subgroups' of chemicals, which in turn are split into the actual different chemical substances. In furniture production, hundreds of different chemicals are used. One furniture item (such as a typical sofa made from a wood-pressed frame, metals, foam and upholstery) can contain dozens of different chemicals.

Secondly, information on the use of potentially hazardous chemicals in furniture is generally lacking. Labels do not inform consumers on potentially hazardous chemicals used in furniture. Several studies suggest not all furniture producers and assemblers exactly know what type of chemicals and concentrations are used in furniture items, because the chemicals were added in a previous stage of production by a different manufacturer. The exact presence and concentration of chemicals can only be established 'a posteriori' – or actual chemical measurements after a furniture item is fully assembled.

Currently, it is safe to assume that many of the chemicals described in the table above are present in furniture items, unless it is explicitly claimed by the manufacturer that there are no chemicals present.

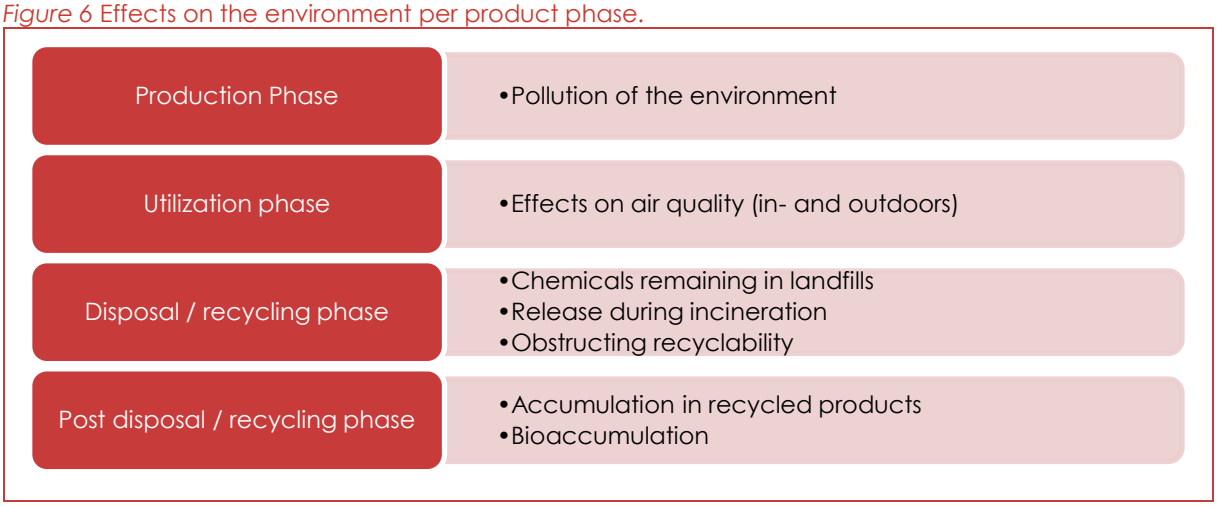
[25] ECHA (2019). Substance Evaluation Conclusion. https://echa.europa.eu/documents/10162/cc0acabf-6e82-f2ed-5dbe-8058f48ce6c4

3.2 Impacts of potentially hazardous chemicals used in furniture

3.2.1 Impacts of potentially hazardous chemicals on the environment

Potentially hazardous chemicals in furniture impact the environment in several ways. Below, we list different effects on the environment, which are categorized in different product phases (from production to post-disposal/recycling).

Figure 6 Effects on the environment per product phase.



Source: Technopolis.

Production phase

- Pollution of environment

Potentially hazardous chemicals have an effect in the production phase. As mentioned above, chemicals used for dying have a large effect on the environment in the production phase, traveling with residual waters used in the dying process into the environment[26]. Chemicals are also released into the atmosphere, via dust, oxides and VOCs in the production phase. While materials that are produced in the EU generally have a smaller environmental impact in the production phase (due to regulation and higher production standards), materials and compounds produced outside the EU generally have a larger impact on the environment. Effects of chemical use on the environment in the production phase is relatively large, and also negatively affects the health of many workers and producers.

Utilization phase

- Effects on air quality (indoors & outdoors)

Different chemicals may enter the environment in the utilization phase, when furniture is being used by the consumers. The exact mechanisms by which chemical substances enter the environment in this phase is topic of current research[27]. Chemical substances may enter the environment via skin-contact, inhalation or directly into the atmosphere, affecting both indoor air quality (in homes and offices) and outdoor air quality.

[27] Halios et. Al. (2022). Chemicals in European residences – Part I: A review of emissions, concentrations and health effects of volatile organic compounds (VOCs). https://www.sciencedirect.com/science/article/pii/S0048969722032983

Disposal / Recycling phase

- Chemicals remaining in landfills

When furniture is disposed in landfills, there is a relatively large risk of several groups of chemicals to accumulate in these landfills. According to the EU's waste hierarchy, landfilling is the least preferable option and should be limited to the necessary minimum. Chemicals related to furniture that are found in landfills are (halogenated) flame retardants[28], PFAS[29], pesticides and solvents. Under normal circumstances, management of landfills (especially in the EU) prevent such chemicals leaking further into the environment. However, such management is necessary on a long term and leaks and contamination into soil and groundwater are common is areas and countries with less regulation.

- Release of substances during incineration

When furniture is incinerated as part of waste disposal, it is possible some chemicals 'survive' this process and re-enter the environment. According to the EU's waste hierarchy, incineration is listed above landfilling but below waste prevention, reuse, and recycling. Chemicals associated with furniture, including (halogenated) flame retardants, PFAS, pesticides, and solvents, may be released during the incineration process. For example, although several studies show a large portion of PFAS are fully degraded in incineration, some PFAS may continue to exist in materials resulting from incineration, such as ash, gypsum, treated process water and flue gas[30].

While modern incineration plants often utilize technology to control emissions, there remains a risk of these chemicals entering the environment. Proper monitoring and advanced filtration systems are crucial in reducing the dispersion of these harmful chemicals during the incineration of waste, driving up costs for incineration.

- Obstructing recyclability

Several chemical substances influence the recyclability of materials. Even in the situation where furniture items are collected separately, can be disassembled in different components and materials can be separated in different homogeneous material streams, the presence of chemicals can still obstruct the possibilities for recycling. As mentioned in 3.2.2, products that use recycled materials need to be compliant to REACH and other regulatory frameworks regarding chemicals. The (suspected) presence of chemicals in collected waste, can therefore obstruct recycling[31]. This applies mostly to the Substances of Very High Concern, which are covered in the REACH framework.

Post-disposal/ recycling phase

- Accumulation in recycled products

Materials that are output of the recycling process, still may contain different sorts of chemicals that were present in the ingoing materials entering the recycling process. Little research is done

[28] Sharkey et al. (2023). Halogenated flame retardants in waste plastics from ireland: concentrations, legislative compliance, and temporal trends. https://www.researchgate.net/publication/371698133_HALOGENATED_FLAME_RETARDANTS_IN_WASTE_PLASTICS_FROM_IRELAND_CONCENTRATIONS_LEGISLATIVE_COMPLIANCE_AND_TEMPORAL_TRENDS

[29] Sharkey et al. (2023). Rapid Determination of Selected PFAS in Textiles Entering the Waste Stream https://www.researchgate.net/publication/366919658_Rapid_Determination_of_Selected_PFAS_in_Textiles_Entering_the_Waste_Stream

[30] Brojklund. (2023). Emission of Per- and Polyfluoroalkyl Substances from a Waste-to-Energy Plant─Occurrence in Ashes, Treated Process Water, and First Observation in Flue Gas. https://pubs.acs.org/doi/10.1021/acs.est.2c08960

[31] Dutch National Institute for Public Health and the Environment (2016). Waste Handling and REACH. https://www.rivm.nl/bibliotheek/rapporten/2016-0159.pdf

in this area. One study[32] from the Dutch National Institute for Public Health and the Environment shows that clothing made from recycled (consumer) textiles usually meet the legal limit value for SVHCs. However, the accumulation in different types of furniture is unknown, and in general, textiles in clothing are held to a higher standard than other types of consumer products. The Dutch National Institute for Public Health recommends creating a standard protocol to measure the presence of these substances.

- Post recycling - bioaccumulation in organisms

Bioaccumulation is the gradual accumulation of substances, such as pesticides or other chemicals, in an organism. Bioaccumulation occurs when an organism absorbs a substance faster than it can be lost or eliminated. Poisoning of soil, plants and (small) animals can be passed along the food chain to affect the consumers later in the chain. Several groups of chemical substances may bio accumulate. Regarding furniture, several PFAS substances and chemicals belonging to a family of brominated flame retardants are known to bioaccumulate. Next to PFAS, there are chemicals known as POPs – or Persistent organic pollutants. These are different types that chemicals persist in the environment. These chemicals have an adverse effect on environment and health.[33]

3.2.2 REACH and Substances of Very High Concern

In the EU, the use of potentially hazardous chemicals in furniture is primarily regulated through the REACH[34] framework[35]. In addition to various regulations on use of chemicals, the REACH framework includes a list of Substances of Very High Concern (SVHC's).

Substances of Very High Concern are chemicals and other substances that possibly have serious effects on human health and the environment. These are substances which are carcinogenic, mutagenic or toxic to reproduction as well as substances with persistent and bio-accumulative characteristics. For these substances, the actual (long term) effects of exposure to humans and environment are not yet fully evaluated and therefore not fully known.

When a substance has been officially identified in the EU as a SHVC, it will be added to the Candidate List. This list indicates to consumers and industry which chemicals are identified as SVHCs. These substances may still be used in products. Companies manufacturing or importing articles containing these substances in a concentration above 0,1% weight of the article, have legal obligations. They are required to inform recipients of the articles about the presence of the substance and therefore how to use it safely. They also need to inform consumers requesting this information.

Substances placed on the Candidate List can move to the Authorisation List. This means that, after a given date, companies will not be allowed to place the hazardous substance on the market or to use it, unless they have been authorised to do so. If it is found that there are grave effects of a substances on the candidate list to humans and/or environment, they are moved to the 'restricted list'[36] and therefore cannot be used in products). The Candidate,

[32] RIVM (2023). Textile Recycling in the Netherlands. Considerations for ensuring chemical product safety. https://www.rivm.nl/publicaties/textile-recycling-in-netherlands-considerations-for-ensuring-chemical-product-safety

[33] POPs are regulated by several frameworks, primarily through international regulations following the 'Stockholm Convention' in 2001.

[34] REACH is an acronym for Registration, Evaluation, Authorisation and Restriction of Chemicals and can be found here.

[35] Next to the REACH framework, there are other frameworks regarding the regulation of substances, such as the Persistent Organic Pollutant regulations and regulations regarding solvents in paint (2004/42/EG). Additionally, there may be national regulations that designate substances as 'of very high concern' and limit their uses.

[36] ANNEX XVII of the REACH framework. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02006R1907-20221217

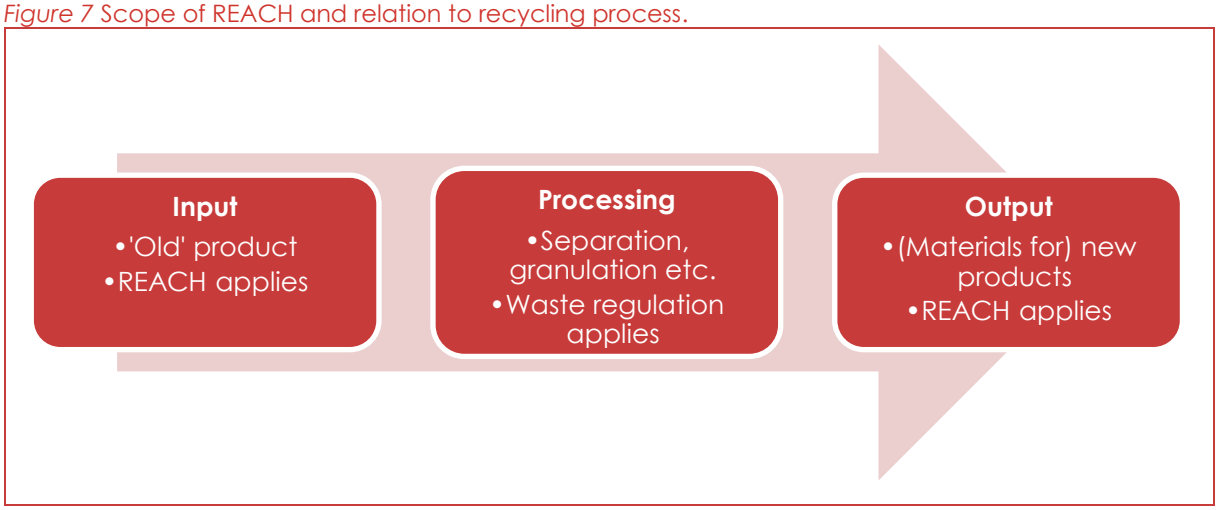
Authorisation and Restricted list are updated on a regular basis (ca. every 6 months). Over time (especially since the EU Green Deal) it has become more of an EU goal to ban all SHVCs.

The scope of REACH and SHVCs related challenges arising for recyclers

The scope of the REACH regulations is limited to 'products', but not to 'waste'. This legal distinction between 'products' and 'waste' causes vagueness and uncertainty for waste recyclers, as is mentioned in a recent Dutch study[37].

Although technically not applicable to 'waste', REACH has influence on the recycling of waste. As an old product is collected for waste processing, and then recycled into a new product, it is subjected to different legal frameworks (see picture below).

Figure 7 Scope of REACH and relation to recycling process.



Source: Technopolis.

In essence, if a recycler processes waste for recycling purposes, the waste in the processes itself is not directly subjected to REACH regulations. However, the output of the recycling process (which consists of materials or recyclate for a new product), is subjected to the REACH regulation.

This means that the recycler has to have some idea of the presence of SHVCs in the input of the recycling process (i.e. the old products it is trying to recycle). As the input for the recycling process often consists of mixed materials, the exact amounts of SHVCs in these materials are hard to establish without actually measuring it and it is hard to separate SHVCs from recyclable materials. The Dutch study recommends[38] more standardized testing in input and output of materials in the waste stream.

[37] Dutch National Institute For Public Health and the Environment (2016). Waste Handling and REACH. https://www.rivm.nl/bibliotheek/rapporten/2016-0159.pdf

[38] Idem.

3.3 Alternatives for potentially hazardous chemicals in furniture

3.3.1 Alternatives for potentially hazardous chemicals

The following table lists alternatives for the previously mentioned potentially hazardous chemicals. Per group, we will list alternatives and substitutes.

Table 3 Alternatives for chemicals used

Substance	Alternatives
Flame retardants	Recently, more and more studies show potentially harmful effects of brominated flame retardants. Currently, these brominated flame retardants are candidate for restriction under REACH[39]. Halogen-free flame-retardants (HFFRs) offer similar fire performance and technical application capabilities as BFRs, while limiting health and environmental concerns[40]. In a 2014 Horizon study, ammonium polyphosphate (APP), aluminium diethyl phosphinate (Alpi), aluminium hydroxide (ATH), magnesium hydroxide (MDH), melamine polyphosphate (MPP), dihydrooxaphosphaphenanthrene (DOPO), zinc stannate (ZS) and zinc hydroxstannate (ZHS) were found to have a good environmental and health profile. These chemical substances were found to have a much lower tendency to bioaccumulate in fatty tissue than the studied brominated flame retardants.
Volatile organic compounds (VOCs)	VOCs can be reduced by reducing the amounts of materials that emit VOCs, such as particleboard and replacing these with other materials. Water-based adhesives are available that may require upfront costs to achieve higher drying temperatures, but use far fewer hazardous chemical ingredients. These are the safest alternatives. Solvent-based adhesives and fabric coating formulations may also be feasible alternatives. Instead of using VOCs as a cleaning agent, water and soap will suffice in many cases. Methylcyclohexane-based adhesives may be used as substitutes for adhesives containing restricted VOCs. N-Heptane can be used as an alternative to benzene in paints, paint thinners, synthetic resins, rubber adhesives and textile finishes[41].
Phtalates	The need for alternatives for phthalates has led manufacturers to create alternatives that share many properties of the phthalate plasticizers without creating endocrine disruption. Di(2-ethylhexyl) terephthalate (DEHT) is considered to be an alternative that has no disruption in sexual development for mice. DINCH is another phthalate alternative that can be used as an alternative to DINP. Thermoplastics, unlike phthalates, can be used in injection moulding for small geometries (less than 2 mm) and complex shapes. This enables manufacturers to design smaller and lighter-weight hardware. For example, polycarbonate/acrylonitrile butadiene styrene (PC/ABS) blends have been used in electronic enclosures due to their high modulus, ductility, heat resistance, and impact strength, and are relatively inexpensive. Also, bio-based plasticizers can be used. However, some of these are made from genetically modified organisms, which effects on the environment are not yet fully clear[42].

[39] EC. (2013). ECHA identifies certain brominated flame retardants as candidates for restriction. https://echa.europa.eu/-/echa-identifies-certain-brominated-flame-retardants-as-candidates-for-restriction

[40] EC. (2014). Next-generation flame retardants to reduce health and environmental risks https://ec.europa.eu/newsroom/horizon2020/items/17054/en

[41] ZDHC. (2023). Guidance Sheet; VOCs – Benzene. https://mrsl-30.roadmaptozero.com/guidancesheet?sheet=18

[42] University of Maryland (2023). Phthalate Risks and Alternatives https://calce.umd.edu/phthalate-risks-and-alternatives

PFAS	Manufacturers of impregnating agents have developed non-fluorinated alternatives (such as paraffin repellents) to PFAS-based finishing agents in recent years in response to a demand for more environmentally-friendly finishing agents[43]. Many different agents providing water repellency are marketed, but none of these agents provides efficient repellency against oil, alcohol and oil-based dirt. The alternatives may be used for textiles and agents appear to be available for all types of fibres and fibre blends.
Dyes	Some dyes and chemicals used in the preparation of colouring can be replaced with other substances. Artificial dyes may be replaced by natural pigments. Instead of using Alkylphenols (APs), calcium/zinc stabilisers can be used. Chromium VI, which is already banned in the EU but can still be found in dyestuffs and leathers in products produced outside of the EU, can be replaced by Chromium VI free tanning agents or changes in production and transportation process. Instead of using chemicals to dye furniture components, digital printing techniques might also be considered.
Pesticides	Several strategies are available to reduce pesticides in the production phase, such as planting diverse species, rotating crops, companion planting and using more sustainable substances[44]. Biocides (substances that prevent effects of bacterial growth on materials in the production/transportation/utilization of furniture) can be replaced with alternatives, such as natural biocides or REACH compliant acrylic and styrene acrylic binders. However, many alternatives to biocides are in an early stage and effects on the environment are not yet fully known[45].

3.3.2 Effects of application of alternatives on the industry

What will happen to the furniture industry if certain potentially hazardous chemicals are restricted and/or reduced? This of course depends on the type of measures taken. Based on interviews and documentation, we expect the following general effects.

- Modifying production methods

Manufacturing and production methods need to change to accommodate for a reduced use of chemicals. Especially production of furniture components and materials that heavily rely on the use of chemicals (such as MDF or other types of particle boards, foams, textiles, plastics et cetera) would need to shift to different methods.

This will be a challenge for larger companies, who have large standardized and international production processes. It is also expected that a reduction in the use of chemicals will increase the intensity of manual labour, as less standardized components can be used.

- Supply chain adjustments and improved needs for transparency

Supply chains need to be adjusted. In general, furniture manufacturers will need to move away from suppliers that cannot provide chemical free materials and components to suppliers that can provide these components and materials. Or, manufacturers can pressure suppliers into providing components and materials without harmful chemicals by setting requirements.

Generally, larger manufacturers and retailers have a large influence on the supply chain. When large manufacturers and retailers change the requirements of materials needed, the supply

[43] Danish Ministry of the Environment. (2015). Alternatives to perfluoroalkyl and polyfluoroalkyl substances (PFAS) in textiles. https://www2.mst.dk/Udgiv/publications/2015/05/978-87-93352-16-2.pdf

[44] EC. (2022). Sustainable use of pesticides. https://food.ec.europa.eu/plants/pesticides/sustainable-use-pesticides_en

[45] Royal Haskoning DHV. (2021). In can preservatives in paint industry and alternatives to biocides. https://www.government.nl/binaries/government/documenten/reports/2021/11/23/in-can-preservatives-in-the-paint-industry-how-to-stimulate-alternatives-to-biocides/in-can-preservatives-paint-industry-alternatives-biocides.PDF

chain needs to conform to these requirements to keep their market position. Again, a shift in the supply chain will be a major challenge for larger companies with standardized and international production processes.

- Increased demand for alternatives

Switching to materials and components with less or no harmful chemicals will increase the demand for alternatives. A sudden shift in requirements would also put pressure on suppliers that can provide the newly required materials/components, but have to deliver them on a large scale. In other words: there need to be foundations for a market that can provide the required materials and components.

- Increased costs and consumer prices

It is expected that a shift in materials and components (and the changes mentioned in the previous sections) will have an impact on costs of manufacturing and therefore consumer prices. Currently, many companies that manufacture eco-friendly or circular furniture aim at the upper sections of the market, providing 'luxury' products.

Increase in prices will likely stay for an initial period, and can over time decrease as companies, supply chains and markets adjust to a new situation. While initially, it may be possible automated processes need to be manually performed, over time these manufacturing and production processes can change again into automated procedure, reducing costs in the long run.

- Competitive Advantage

Companies that adapt early to changes and offer products with no or fewer chemicals may gain a competitive edge. Early adopters can use their position to enhance their brand reputation and enlarge their market share.

In general, many alternatives to potentially hazardous chemicals are currently already technically available and are being used in the manufacturing of different types of furniture. However, these alternatives are mainly implemented by smaller and specialised furniture producers, whose products aim at a higher segment (thereby covering for the increased production costs). Smaller producers, who build and assemble furniture in house are less dependent on suppliers. They can switch more easily from suppliers if alternatives pop up and (because manufacturing is largely in house and more reliant on manual labour) can switch more easily to alternative manufacturing processes.

For larger retailers and manufacturers, issues arise when switching to alternatives, as they rely more on standardised production methods, operate on a larger and international scale. Their business models are structured around this larger scale, selling mass produced furniture. This makes them more inert to changes.

However, the scale on which large manufacturers operate in turn can also be utilized: large manufacturers have such an influence over the market for materials and suppliers, that when they do switch to alternatives (by regulation or by self-commitment to alternatives), suppliers are forced to provide these alternatives in order to survive in their respective markets.

4 Results - 2 Ferrous and non-ferrous metals in furniture

In this chapter we explain the use of metals in furniture. We start by showing how much and which ferrous and non-ferrous metals are used in furniture. Then we give indications on the use of recycled metals in furniture. Then, we describe the potential of the use of recycled metals in furniture, by looking at the environmental benefits and the feasibility of using more recycled metals. Finally, we discuss how the use of metals in furniture can be improved.

4.1 Use of metals in the furniture industry

4.1.1 Types of metals used in furniture

Both ferrous and non-ferrous metals are used in furniture. Ferrous metals are materials (often alloys) in which iron is the main component. Most of the metal used in the furniture industry is steel. There are over 2.000 different types of steel, of which different types of stainless steel are the most used in the furniture industry.

Examples of non-ferrous metals are aluminium, copper and bronze. Non-ferrous metals are not magnetic and do not rust (although they can corrode). Regarding non-ferrous metals, aluminium and copper are regularly used (but not nearly as much as steel). Other types of (ferrous- and non-ferrous) metals (chrome, nickel, zinc) are barely used for furniture[46].

4.1.2 Value of metals in the furniture industry

Approximately 12% of the value of EU27 furniture production comes from metal furniture. The EU27 total value of furniture production in 2020 was €65.256.714.995, from which €7.602.161.786 was metal furniture production[47].

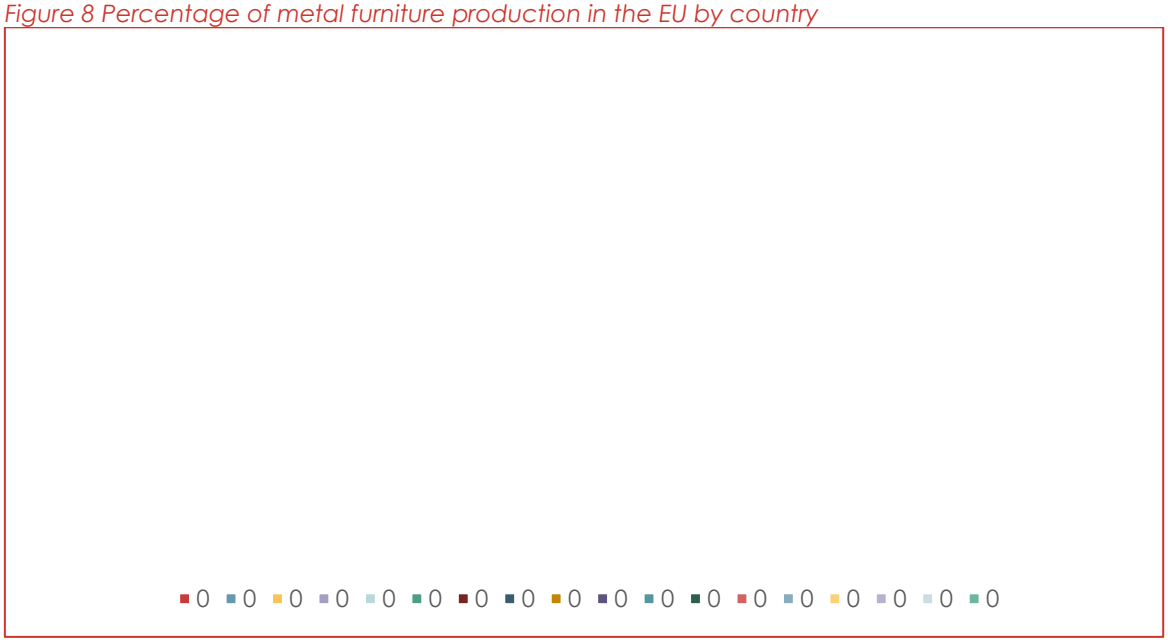
4.1.3 Metal furniture production per country

As can be seen in the figures below, Italy and Germany together produce more than half of the metal furniture in the EU. This is in line with the total furniture production which is also much higher in these countries compared to others (as can be seen in chapter 2.1).

[46] Based on expert interviews

[47] Based on Eurostat data from 2020 (https://ec.europa.eu/eurostat/databrowser/view/DS-056120__custom_7442499/default/table?lang=en). This is in line with a previous study (The Eu Furniture Market Situation And A Possible Furniture Products Initiative 2014 – Centre for European Policy Studies), where Eurostat data was used to come to an estimate of 12% metal furniture.

Figure 8 Percentage of metal furniture production in the EU by country



Technopolis graph based on Eurostat data

4.1.4 Metals used in different types of furniture

Although there's no good data available on the type of furniture that uses metals, a market research organization indicates that globally metals are mostly used for beds and sofas, followed by chairs and tables.[48]

For France, there is more specific data available. French research[49] from 2015 made estimates of the different materials used in different furniture, with input from the French furniture industry. With the data from their report, Technopolis made an overview of the percentage of metals used for different product groups (see below). Although the numbers give a good indication of the percentage of metals used, this could differ over time and per country.

Table 4 Estimated percentage of metals used in different types of furniture (in France, 2015)

Type of furniture	Sub-type	% of metal used	Remarks
Seating		23%	
	Sofas/ padded chairs	16%	Mostly on office chairs, which were composed of 50% metals.
	Non—padded chairs	41%	
Sleeping/ lying	Bed frames	20%	
Storage	Storage	9%	
Tables		10%	

[48] KBV Research (2021), Metal Furniture Market Size https://www.kbvresearch.com/metal-furniture-market/

[49] Éco-mobilier (2015), Innovation & éco-conception en vue du recyclage Le guide de la filière mobilier

	Tables	6%	Including kitchen worktops that only consist of 3% metals
	Outdoor tables	39%	

Source: Technopolis Group 2023, based on data from Éco-mobilier (2015), Innovation & éco-conception en vue du recyclage Le guide de la filière mobilier: https://www.bioenergie-promotion.fr/wp-content/uploads/2016/12/guide_recyclage_291116_web3-bd.pdf

4.2 Use of recycled metals in furniture

The percentage of recycled metals from metal suppliers can differ over time. European metal suppliers often do not have access to large amounts of recycled content and sometimes they do not know the exact amount of recycled content in their materials, as it differs much over time. They blend the recycled metals and virgin materials and often do not offer 100% recycled material. For furniture producers it is therefore difficult to know the exact percentage of recycled metals and it can also be difficult to get metals with a high recycling percentage.

Approximately 20% of today's steel production comes from recycled steel. For aluminium, 32% of the aluminium production comes from recycled products.[50] As recycled steel and aluminium are often blended with virgin materials, it is estimated that this amount is similar for the furniture industry. In the next part, we will provide information regarding the potential of recycled metals for furniture.

4.3 The potential of recycled metals

4.3.1 Environmental benefits of metal recycling in furniture

Recycling of metals can save large amounts of energy: by recycling steel 70% of the energy use in production can be saved and for aluminium this is even 95%.[51] The maximum recycling benefit of metal furniture is 3.20 tonne CO_2 equivalent per tonne of material used. This is very high compared to other furniture items[52]. Therefore, using more recycled metals in furniture can seriously reduce the environmental impact.

As many of the metals used are still made of virgin materials and the environmental benefits of using recycled metals are large, there is still much potential to gain here. In the next part we briefly describe the feasibility of using more recycled metals in furniture and reasons this amount is not higher yet.

4.3.2 Feasibility of using more recycled materials in furniture

It is generally technically feasible to use recycled metals instead of virgin metals. This even works when the recycled metals are of lower quality, as the quality conditions for furniture are not as high as many other sectors (e.g., ships, cars, construction). Furthermore, it is technically feasible to recycle metals into functionally equivalent products, instead of downcycling.

[50] World Aluminium (2020), Aluminium Recycling Factsheet 2020: https://international-aluminium.org/wp-content/uploads/2021/01/wa_factsheet_final.pdf

[51] CIRCO (2020), CIRCO Materialenmodule https://www.circonl.nl/resources/uploads/2020/04/20200414-CIRCO-Materialenmodule-final.pdf

[52] KBV Research (2021), Metal Furniture Market Size https://www.kbvresearch.com/metal-furniture-market/
Assuming all recyclable materials are recycled. The maximum recycling benefit of other furniture items (tonne CO_2 equivalent per ton of material used): non upholstered seats 1.70, upholstered seats 1.42, other furniture 0.59, kitchen furniture 0.07 and wooden furniture 0.01.

However, while metal with low rates of recycled materials is easily available, metal with high or even 100% recycled material use is difficult to obtain. One reason is that it can be difficult and expensive to recycle metals. There are many different alloys, e.g., there are over 2.000 different types of steel, that need to be separated for recycling. As detailed product information is often not available, metals need to be tested to see the composition of the alloy. Ferrous metals (like steel) are easier to recycle than non-ferrous metals, like aluminium, copper and bronze. Ferrous metals are magnetic, making it easier to separate them from other waste flows. Non-ferrous materials can be separated as well, with an eddy current separator. However, smaller non-ferrous particles are more difficult (not worthwhile) to detect. For both ferrous- and non-ferrous materials we do not know how much is not recycled (or downcycled) because of difficult disassembly: this has to be further investigated. However, it is plausible, that easy disassembly will improve the recycling rate and/ or the quality of the scraps.

Furthermore, despite the high percentage of metals that are being recycled (see part 4.2), not all of this is used in Europe. Export rates of steel scraps in the EU are much higher than the import rates (19 million metric tonnes exported versus 5 million metric tonnes imported)[53]. Metal scraps are exported to China and the USA. Perhaps a reason for this is that Electric Arc Furnaces, that are better fit for metal scraps compared to blast furnaces, are more common there.

4.4 Improving the use of metals in furniture

The carbon footprint of metals is very high compared to other materials[54]. But as metals have a long lifespan and can be recycled into functionally equivalent products, it can still be interesting to use metals from an environmental perspective. As seen in the paragraph above, there is still much potential to gain, as much of the metals used still come from virgin materials and the environmental benefits of using recycled metals are large.

Furthermore, only a small part of metal furniture is currently recycled. According to rough estimates from a European study in 2017[55], 8% of metal furniture was reused and 8% recycled. Experts we interviewed had similar estimates, between 5 and 10%. The rest of the discarded furniture ends up in landfill or incineration[56]. These rates are very low compared to other sectors: in general, 85-95% of end-of life steel is recycled back into new steel products, and approximately 76% of end-of life aluminium is recycled.[57] We did not find a study explaining this large difference, but it is known that the recycling rate in the automotive and building sectors are over 90%[58]. Also, in general, furniture recycling is challenging because of the composition of multiple different materials[59]. Therefore, we assume that this is also one of the main reasons for the low recycling rate of metals from furniture.

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[53] Eurofer (2022), European Steel in Figures: https://www.eurofer.eu/assets/publications/brochures-booklets-and-factsheets/european-steel-in-figures-2022/European-Steel-in-Figures-2022-v2.pdf

[54] 8billiontrees.com, 2023, Carbon footprint of steel per kg & lb. https://8billiontrees.com/carbon-offsets-credits/carbon-footprint-of-steel/

[55] European Environmental Bureau, 2017. Circular Economy opportunities in the furniture sector. https://eeb.org/library/circular-economy-opportunities-in-the-furniture-sector/.. Based on available literature and expert views.

[56] European Environmental Bureau, 2017. Circular Economy opportunities in the furniture sector. https://eeb.org/library/circular-economy-opportunities-in-the-furniture-sector/.

[57] World Aluminium (2020), Aluminium Recycling Factsheet 2020: https://international-aluminium.org/resource/aluminium-recycling-fact-sheet/

[58] European Aluminium (2022), Enabling the circular economy with aluminium. https://european-aluminium.eu/blog/enabling-the-circular-economy-with-aluminium/

[59] RTS (2020), Furniture waste – The forgotten waste stream: https://www.rts.com/blog/furniture-waste-a-growing-issue/

Using different scenarios, with different policy options, the study estimates that the percentage of metal furniture reused can increase up to 40% (compared to 8% in the baseline) and the percentage of recycled metals furniture can also increase up to 40% (compared to 8% in the baseline)[60]. It did not became clear in the report why these estimates were not higher. Mandatory EPR (Extended Producer Responsibility) has a large expected impact on the reuse and recycle rate, and can be complemented with mandatory eco-design measures on durability, repair and recyclability for a larger effect. The study does not elaborate on what the eco-design measures must exactly look like.

Finally, some preliminary suggestions for improving recycling of metal furniture (as well as other metal products) are using common alloys, making the furniture easy to disassemble and keeping transport distances short.[61]

[60] European Environmental Bureau (2017). Circular Economy opportunities in the furniture sector. https://eeb.org/library/circular-economy-opportunities-in-the-furniture-sector/ Based on available literature and expert views.

[61] CIRCO (2020). Materialen module. https://www.circonl.nl/resources/uploads/2020/04/20200414-CIRCO-Materialenmodule-final.pdf

5 Results - 3 The lifespan of furniture

In 2019, a quarter of the globally produced furniture was consumed in Europe[62]. Furniture is a durable good and is characterized by a relatively long lifespan[63,64]. It is purchased infrequently, and consumers spend more time on the buying process than they do with frequently purchased goods.

In this chapter, we discuss the lifespan across product groups, trends, and the most important factors in lifespan.

There are no universally agreed upon product groups, so we base them on Smardzewski (2015)[65] and on the definition as given in the tender. There are four product groups:

1. Seating
   i) For single and multiple people available, so this includes both seats and couches.
2. Sleeping or lying
   i) Such as bed frames, headboards, and loungers. Mattresses are not included.
3. Tables
   i) Such as kitchen tables and nightstands.
4. Storage
   i) Such as cupboards, wardrobes, and closets.

These products can all be used indoors and outdoors.

5.1 Lifespan of the different product groups within furniture

5.1.1 What is the lifespan of furniture across product groups?

In general, estimates on the lifespan of furniture are far apart. Almost **all estimates vary between 5 and 20 years**. This broad range is partly due to the lack of research into the lifespan of furniture, but mostly because of the big differences in lifespan (see section 5.1.2).

In the table below, the estimated lifespan for the different product groups is discussed. The sources for this are mostly blogs on when furniture *should* be replaced. The research into lifespan that is available is based on surveys and expert estimates.

[62] European Furniture Industries Confederation (2020). The FURNITURE SECTOR and CIRCULAR ECONOMY 2.0.

[63] Zwierzyński, P. (2017). The determinants of consumer behaviours in the furniture market. Annals of Marketing Management & Economics, 3(1), 131-143.

[64] Centre for European Policy Studies, commission by the European Commission (2014). The EU Furniture Market Situation and a Possible Furniture Products Initiative.

[65] Smardzewski, J. (2015). Classification and characteristics of furniture. Furniture Design, 47-95.

Table 5 Estimated lifespan per product group of furniture.

	Details	Product details	Estimated Lifespan	Source
Seating	For individuals and multiple people, so chairs and couches.	Seating	7 to 15 years	TAUW (2022)[66], Leverette (2019)[67] Mallon (2018)[68]
		Seating	11.7 years	Economic lifespan as maintained by insurance services, according to TAUW (2022)[66]
		Upholstered chair	7 to 10 years	Leverette (2019)[67]
		Leather couches	> 20 years	CE Delft (2019)[69]
		Wooden chair	10 to 15 years	Leverette (2019)[67]
		Couches in the middle segment (between 1000 and 2000 Euros)	15 years	According to experts in TAUW (2022)[66]
		Couches in the high segment (over 2000 Euros)	20 years	According to experts in TAUW (2022)[66]
		Sofa	8.8 years	Wieser et al. (2015)[70]
Sleeping/lying	Such as bed frames, headboards, and loungers. Mattresses are not included[71]	Beds in general	5 to 20 years	Hom Furniture (2020)[72] and Haren de Krant (2020)[73]
		Beds in general	15 to 20 years	Leverette (2019)[67]
Tables	Such as kitchen tables and nightstands	Tables in general	5 to 20 years	Hom Furniture (2020)[72]
		Dining room table	15 to 20 years	Leverette (2019)[67]
		Solid wood tables	15 to 20 years	Hom Furniture (2020)[72]
		Desk	15 years	Leverette (2019)[67]
		Desk	8.8 years	Wieser et al. (2015)[70]
Storage	Such as cupboards, wardrobes, and closets.	Dresser or chest	5 to 20 years	Hom Furniture (2020)[72]
		Dresser or chest	10 to 20 years	Leverette (2019)[67]

[66] Tauw (2022). Grootzitmeubilair: Productstromen en materialen in kaart gebracht. https://www.afvalcirculair.nl/nieuws/afvalnieuws/2022/inzicht-circulariteit-groot-zitmeubilair/

[67] Leverette (2019). When Should You Replace Your Furniture? Source: When Should You Replace Your Furniture? (thespruce.com)

[68] Mallon, B. (2018). 10 HOUSEHOLD ITEMS WITH ACTUAL EXPIRATION DATES. Source: How Often to Replace Furniture — When to Buy New Furniture (elledecor.com)

[69] CE Delft (2019). The environmental benefit of Marktplaats trading. In opdracht van: Marktplaats.

[70] Based on a survey where Austrian consumers were asked how long they use their furniture. Wieser, H., Tröger, N., & Hübner, R. (2015). The consumers' desired and expected product lifetimes. Product Lifetimes And The Environment.

[71] Mattresses are not in the scope of this research.

[72] HOM Furniture (2020). FURNITURE LIFESPANS: How long should your furniture last? Source: Furniture Lifespans - design blog by HOM Furniture

[73] It is, however, unsure what this data is based on. Source: Haren de Krant (2020). Algemeen informatief: Hoe lang zouden uw meubels mee moeten gaan. Source: https://www.harendekrant.nl/nieuws/algemeen-informatief-hoe-lang-zouden-uw-meubels-mee-moeten-gaan/

	Details	Product details	Estimated Lifespan	Source
		Bookcases	15 to 20 years	Hom Furniture (2020)[72]
		Wardrobe	10.5 years	Wieser et al. (2015)[70]

Technopolis B.V., 2023

Based on these sources, beds and tables are likely to last longest, followed by storage and lastly seating. The replacement cycle of outdoor furniture in Europe is between three and four years, up to six years[74]. Indoor furniture generally lasts slightly longer than outdoor furniture. On average, Europeans acquire new kitchen furniture every 15 years[74]. This is usually done when they move to or renovate a new house or flat.

5.1.2 What factors are most important in determining the lifespan of furniture?

The estimates on the lifespan are very broad, which is mostly because there are crucial factors, apart from product type, that influence the lifespan[75]:

- Quality of the materials and construction
  - This is the most important factor for lifespan. The better the quality of construction and of the materials, the longer the lifespan. Wooden and metal furniture generally last long, as well as well-maintained leather. Furthermore, Mid to high segment furniture is generally agreed upon to last a lot longer, although it is difficult to quantify how much (TAUW, 2022).
- Cleaning, maintenance, and reparations by the consumer
  - Consumers are rarely given guidance on how to maintain and repair furniture, in order to prolong and extend the product lifespan[76]. If it is regularly cleaned and waxed, and it not put under too much of a strain, it can make a very big difference in lifespan and quality. Furthermore, damage to upholstery is highly visible and may (correctly) lead to consumer association with low quality products and perhaps result in premature end-of-life of the entire product[77].
- 'Timelessness' of the furniture
  - Is the product sensitive to trends or is there an important connection to the piece. Heirloom furniture emotionally connects with consumers and thus realizes longer lifespans[78].

By reusing, repairing, and maintaining the furniture, the lifespan can be elongated. However, reparations are often expensive. Reapplying the upholstery of a couch is often equally expensive as buying a new one from the lower segment.

[74] Centre for European Policy Studies, commission by the European Commission (2014). The EU Furniture Market Situation and a Possible Furniture Products Initiative.

[75] TAUW (2022), Grootzitmeubilair: Productstromen en materialen in kaart gebracht. In opdracht van de Rijkswaterstaat.

[76] Furn360. Circular Economy in the Furniture Industry: Overview of Current Challenges and Competences Needs. Co-funded by the Erasmus+ Programme of the European Union.

[77] Joint Research Centre (2017), the European Commission's science and knowledge service. Revision of EU Ecolabel criteria for furniture products

[78] Bumgardner, M. S., & Nicholls, D. L. (2020). Sustainable practices in furniture design: A literature study on customization, biomimicry, competitiveness, and product communication. Forests, 11(12), 1277.

5.2 Trends in lifespan of furniture

Decreasing lifespan of furniture

The consumption of a piece of furniture was once a lifetime purchase. Since around two decades, however, furniture is bought a lot more frequently. In a report by the Centre for European Policy Studies in 2014[79], they noted that the lifespan of furniture was longer in the past than it is today. This is partly explained by a decrease in quality, at least in the lower price segments[74]. The consumers also respond to other needs than durability, such as functionality, adaptability to small spaces (as in tiny houses) and to the ageing population, and costs. This might be at the expense of durability. According to experts interviewed by TAUW (2022), interior design and thus furniture are also increasingly subject to trends. About 12% of designs registered in the European Union Intellectual Property Office relate to furniture[79].

The lifespan of this trendy furniture is generally lower than 'classic' furniture. This urges consumers to buy furniture more often. Furniture from the mid to high segment is less sensitive to trends.

Second-hand furniture

Although trading in second-hand furniture has taken place for a long time between acquaintances, the launching of online trading places like Facebook, Marketplace and Marktplaats in the Netherlands has allowed for it to rapidly expand. CE Delft (2019) conducted a study into the sustainable benefits of such second-hand trading, where furniture was one of the analysed categories. This research was in commission of Marktplaats itself. A survey was conducted among people selling their furniture on this website. They found that by trading there, the lifespan of furniture became about 1.4 to 1.6 times longer than the standard lifespan. Although reselling the furniture expands the lifespan, the second-hand market for furniture has not been very successful in large quantities. This is because the price differential between new furniture against the cost of second-hand furniture is not significant enough to drive more sustainable purchasing behaviour[80]. This point is confirmed by the European Furniture Industries Confederation[81].

This price differential is caused by the low prices for furniture. The increasing competition in large-scale distribution channels[82] reinforces a trend of weaker design and **cheaper materials that are of lesser quality**. This restricts the potential for a successful second life. A report[82] on the furniture sector in the European Union (EU) shows that we are moving from solid wood and metal furniture to cheaper materials, such as plywood or rubber wood[83]. According to the aforementioned European Furniture Industries Confederation, new innovations and thus investments are necessary to expand the lifespan of furniture in a cost-effective way. Producers thus need (financial or regulatory) incentives to consider environmental considerations along the lifespan of products.

Importance of sustainability for purchasing behaviour

[79] European Commission (n.d., 2014 at the earliest). Furniture Industry. Source: https://single-market-economy.ec.europa.eu/sectors/raw-materials/related-industries/forest-based-industries/furniture-industry_en

[80] Furn360. Circular Economy in the Furniture Industry: Overview of Current Challenges and Competences Needs. Co-funded by the Erasmus+ Programme of the European Union.

[81] European Furniture Industries Confederation (2020). The FURNITURE SECTOR and CIRCULAR ECONOMY 2.0.

[82] Centre for European Policy Studies, commission by the European Commission (2014). The EU Furniture Market Situation and a Possible Furniture Products Initiative.

[83] Kurzius, R. (2023). Why furniture got so bad. The Washington Post. Source: Why new furniture doesn't last long - The Washington Post

Sustainability becomes a bigger factor for some in purchasing behaviour. Some consumers are willing to pay more when a product is (or is believed to be) more sustainable[84]. In a survey in England from 2020[85], most of the respondents claim to consider which raw materials are used when they choose new furniture. They also say they consider the raw materials when they decide either to sell or donate their old furniture or send it to a landfill. This consideration of sustainability seems to mostly occur during the purchasing behaviour, since the majority of respondents do replace their wooden furniture long before it has reached the end of its useful lifespan.

Indeed, only 39% of the consumers deem disposal and recycling important for purchasing decisions[82]. An important driver of innovation mentioned in the 2014 report by the Centre for European Policy Studies, is the need to meet new consumer' values, such as sustainable production. With the EU Ecolabel, it is attempted to fulfil those needs. This is the official European environmental label for non-food products and services. It makes it easier for consumers to make sustainable choices. The criteria for the EU Ecolabel on furniture are also related to the lifespan. The aim is to encourage the production of durable products that are easy to repair to maximise their useful lifetime[86]. Criterion 9.2 for example, obliges manufactures to provide a five-year guarantee for their products at no additional costs to the consumer[87]. Another criterion is the provision of spare parts by the producer for a period of five years. This to incentivize producers to produce higher quality, and consumers to not throw away the product when it is less useful.

In general, furniture is made from cheaper materials and is replaced more often, although there are consumers that explicitly seek more sustainable furniture.

Electronics in furniture and 'smart furniture'

Lastly, one emerging trend at the moment consists of electronics in furniture and so-called smart furniture. More and more furniture items are equipped with electronic parts and 'smart' applications.

This means that more and more electronic parts are embedded in furniture. Examples include electric motors (in reclining sofas, beds and desks), heating and cooling elements, screens, 'smart' systems and applications (which need screens and communication devices and sometimes have touch sensitive controls), lighting, (Bluetooth) speakers, USB ports, power outlets and wireless charging pads.

Market studies suggest a rise in smart furniture[88], not only for the consumer market but also for the business market (the latter already having a larger market share). Estimates on the impact of embedded electronics on the lifespan of furniture have not been found.

The embedding of electronics in furniture would in theory cause more issues in the recycling phase. As with chemical and other non recyclable components, requirements around disassembly and removability of these parts should enable repairers and recyclers to repair and separate these components, making recycling easier and less costly.

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[84] Joshi, Y., & Rahman, Z. (2017). Investigating the determinants of consumers' sustainable purchase behaviour. Sustainable Production and consumption, 10, 110-120.

[85] Joshi, Y., & Rahman, Z. (2017). Investigating the determinants of consumers' sustainable purchase behaviour. Sustainable Production and consumption, 10, 110-120.

[86] Joint Research Centre (2017), the European Commission's science and knowledge service. Revision of EU Ecolabel criteria for furniture products

[87] European Commission (n.d., latest amendment was in 2022). EU Ecolabel – Furniture and mattresses.

[88] Mordor Intelligence (2023). Smart furniture market size & share analysis – growth trends & forecasts 2024-2029. https://www.mordorintelligence.com/industry-reports/global-smart-furniture-market

6 Case study

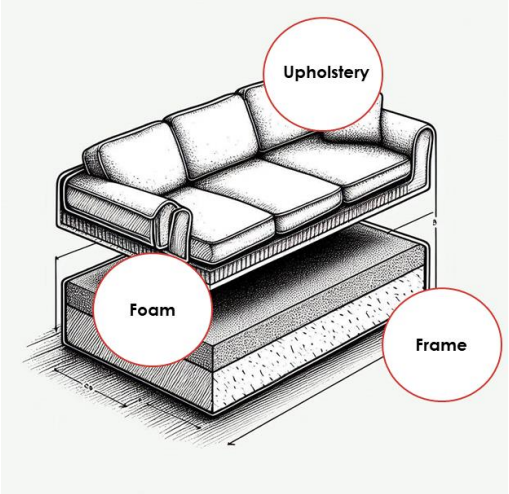
6.1 Introduction

Two sofas will be compared with each other to highlight the differences between the current common practice in the furniture industry and the possibilities for best practices. The alternatives are compared to the current practices based on environmental impact (including recycling options[89]) and economics (especially with regards to costs, scalability, and changes in the production process).

A fabric sofa was chosen as the object of study since, according to interviews, these are the most complex products. They comprise many different materials which are often connected or glued together. Sofas are therefore currently difficult to recycle and are often burned once they have reached the end of their lives. Three parts of the sofa will be further examined: the upholstery, foam, and frame (see Figure 9).

The purpose of this case study is to display the alternatives that are currently available and their benefits, but also to show the dilemmas and consequences that arise from implementing these alternatives on a large scale.

Figure 9 Examined layers of the sofa



Technopolis B.V., 2023

6.2 Comparison between the current common and best practices

In Table 6, the costs and benefits of two sofas are compared:

Sofa A: Sofa with current common practices.

Sofa B: Sofa with possible best practices, the alternative.

[89] Exact quantitave effects of the application of alternatives (such as reduction in CO2 or reduction of applied chemicals) are currently hard to provide, since the environmental impact of a single sofa are hard to quantify to begin with.

Table 6 Overview of the upholstery, foam and frame of sofa A and B, and the costs and benefits of the alternative

	Sofa A: Current common practice	Sofa B: Alternative with possible best practices	Costs & benefits of the alternative	
			Environment	Economics
Upholstery				
Materials	Polyester, often mixed with organic textiles such as cotton. Currently it is more common to recycle PET into the polyester[90]	Recycled textile from old clothes and other textile products[91] Upholstery solely made from natural fibres, such as cotton or linen[92] Upholstery rental services[93]	• Cotton production requires large amounts of water[94]. The process of manufacturing polyester from petroleum relies on higher amounts of energy[95] than the alternatives. As a solution, recycled PET is used. • However, demand for that might currently be bigger than the supply.[96] It can also not be recycled after usage and does not biodegrade. Therefore, the current practice is to burn it instead of reusing it. Using natural fibres or upholstery from old textile might allow for biodegrading and extends the pool of raw materials.	• Petroleum and cotton are readily available in the current system, whereas old clothes need to be collected, which requires extra steps in the supply chain. • Upholstery rental services would require uniformity in couches to switch. It would also require changes in consumer behaviour, • Cotton and linen are more expensive than polyester. Polyester is also more resistant to wear and tear than natural fabrics.

[90] According to the interviews common practices also for bigger producers, for example at IKEA: https://www.ikea.com/nl/en/this-is-ikea/sustainable-everyday/recycled-plastic-pub8903811a

[91] For examples, see the Upcyclist (2017): https://www.upcyclist.co.uk/2017/11/furniture-decor-recycled-textiles/ or the Reborn project (2022): https://designwanted.com/reborn-furniture-old-clothes/ or the Reborn project (2022): https://designwanted.com/reborn-furniture-old-clothes/

[92] As mentioned in interviews.

[93] This is not a common practice, but the idea has been suggested in one of the interviews in response to the alternating trends in furniture.

[94] Chapagain, A. K., Hoekstra, A. Y., Savenije, H. H., & Gautam, R. (2006). The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries. Ecological economics, 60(1), 186-203.

[95] Kilgore (2023). Carbon Footprint of Polyester vs Cotton vs Wool vs Leather vs Nylon (Calculator). See link: https://8billiontrees.com/carbon-offsets-credits/carbon-footprint-of-polyester/#:~:text=Negative%20Impacts%20of%20Polyester&text=The%20creation%20of%20polyester%20requires%2070%20million%20barrels%20of%20oil%20every%20year.&text=Polyester%20sheds%20microfibers%20that%20build,pollution%20found%20in%20the%20ocean.&text=One%20wash%20can%20release%20up,per%20gram%20of%20polyester%20fabric)

[96] Based on interviews.

	Sofa A: Current common practice	Sofa B: Alternative with possible best practices	Costs & benefits of the alternative	
			Environment	**Economics**
			• A large portion of clothes (textiles) are currently not recycled and incinerated. These can be given new life in sofas[97].	
Chemicals	Flame retardants. An example is Hepta BDE, although normally various chemicals are combined[99]. Brominated flame retardants are still used on a large scale (even though more and more subjected to regulation) Stain-guard fabric coatings (PFCs)[98]	Aluminium or magnesium hydroxide used for carpets, automotive seatings[99] Use lower concentrations of flame retardants Change fibre choice or construction to meet flammability requirements	• The current practice of combining different potentially hazardous chemicals to form flame retardants makes it difficult to estimate environmental impact, although brominated flame retardants have been assessed as providing a risk to health and the environment[99]. • However, there is also limited environmental, health and safety data for the chemicals that the alternatives are replacing.	• Needs case by case assessment to see which alternatives are best in which case – expensive and difficult[99] • Changing the fibre choice or the construction requires fundamental changes in the process, which is costly to execute.
Design	Flame retardants are often (but not always) sprayed on the fabric[99]	Add reactive flame-retardant chemicals during the polymerization process to become an integral part of the polymer through co-polymerisation[99]	• By making the flame-retardants chemicals an integral part of the polymer, the harmful impact is minimized and less if needed of it	• Less flame retardants are needed, which might save product costs.

[97] CALPIRG (2021). The Fashion Industry Waste Is Drastically Contributing To Climate Change. See link: https://pirg.org/california/articles/the-fashion-industry-waste-is-drastically-contributing-to-climate-change/

[98] Environmental Working Group (n.d.). Upholstered Furniture. Source: https://www.ewg.org/healthyhomeguide/upholstered-furniture/

[99] Zero Discharge of Hazardous Chemicals (n.d.). Chapter 1: ZDHC MRSL. Source: mrsl-30.roadmaptozero.com/?sword=flame+retardants#chapter_1

	Sofa A: Current common practice	Sofa B: Alternative with possible best practices	Costs & benefits of the alternative	
			Environment	Economics
Foam				
Materials	Polyurethane foam CMHR cold foam	Natural latex foam Soybean foam	• The process of manufacturing polyester from petroleum relies on high amounts of energy[100], which is not necessary for the natural latex and soybean foam[101] • Alternatives are easier to recycle because of the absence of plastic	• Alternatives are more expensive[102]. • Mechanical properties of the alternatives are very distant from the properties of polyurethane foam. The industry currently uses a lot of cold moulds which allows for scalability. That is not possible with the alternatives, which means less foam can be processed at the same time[102]
Chemicals	Smoulder resistant lining from polyester wadding Mixture of flame-retardant chemicals, most of them contain bromine[103] Might emit VOCs[104]	Alternative to benzene (VOC)[105]: water-based adhesives	• Water-based adhesives use fewer hazardous chemical ingredients[105] • Common practice makes it difficult to recycle and to research the effect on environment and health when there is a cocktail of different chemicals	• Requires higher upfront costs because of higher drying temperatures[105]

[100] Kilgore (2023). See link: https://8billiontrees.com/carbon-offsets-credits/carbon-footprint-of-polyester/#:~:text=Negative%20Impacts%20of%20Polyester&text=The%20creation%20of%20polyester%20requires%2070%20million%20barrels%20of%20oil%20every%20year.&text=Polyester%20sheds%20microfibers%20that%20build,pollution%20found%20in%20the%20ocean.&text=One%20wash%20can%20release%20up,per%20gram%20of%20polyester%20fabric)

[101] Aremu, M. O., Ojetade, J. O., & Olaluwoye, O. S. (2015). Production of flexible polyurethane foam using soya bean oil and palm kernel oil as surfactant and polyol respectively. Chemical and Process Engineering Research, 35, 24-31.

[102] Based on interviews

[103] For example, Hepta BDE. Zero Discharge of Hazardous Chemicals (n.d.). Chapter 1: ZDHC MRSL. Source: mrsl-30.roadmaptozero.com/?sword=#chapter_1

[104] Beckett, E. M., Miller, E., Unice, K., Russman, E., & Pierce, J. S. (2022). Evaluation of volatile organic compound (VOC) emissions from memory foam mattresses and potential implications for consumer health risk. Chemosphere, 303, 134945. Research was based on mattresses however, and not foam in sofas.

[105] Zero Discharge of Hazardous Chemicals (n.d.). Chapter 1: ZDHC MRSL. Source: mrsl-30.roadmaptozero.com/?sword=#chapter_1

	Sofa A: Current common practice	Sofa B: Alternative with possible best practices	Costs & benefits of the alternative	
			Environment	**Economics**
Design	Polyurethane foam is made from large moulds with many different possibilities for shaping.	Sofa with straight lines. Natural latex is a softer material. It is delivered in large blocks and needs to be cut to the right dimensions. Constructing a sofa with rounded or soft lines is more difficult.	• By creating sofas with straight lines, more sofas fit in the same transportation device[106]. This way, there might be less emissions from transportation, although that is a small part of the total furniture emissions.	• Scale benefits for the polyurethane foam • Current trend is the 'curved sofa' with rounded edges[106]. This demand is more difficult to meet with the alternative
Frame				
Materials	Plywood[107] and particle board[108] Solid wood (often FSC-certified) Steel	Recycled steel Wood with a clear traceability Biobased materials (particle board from roses/wood fibres) Bamboo[109]	• Steel requires substantial amounts of energy during mining and manufacturing. By recycling the steel frames, this can be minimized[110] • By being able to trace the wood, sustainability can be guaranteed. Currently, the selling company might be FSC certified but that does not mean that their suppliers are as well • Bamboo is a type of grass that grows very fast, has a strength similar to wood, requires very little water and does not need to be sprayed with pesticides or fertilisers[111]. However, it is currently mainly produced in	• The particle board is made from a by-product from the wood industry, namely compressed wood chips and resin. It is a very cheap material compared to the alternatives. • Using recycled steel requires new steps and actors in the value chain to collect, recycle, reshape, and resell it

[106] According to interviews

[107] Is made from thin layers of wood veneer glued together.

[108] Is made from compressed wood chips and resin. Most common particle board is Medium Density Fibreboard (MDF).

[109] For example, by crushing bamboo chips to produce particleboards, see Bazzetto, J. T. D. L., Bortoletto, G., & Brito, F. M. S. (2019). Effect of particle size on bamboo particle board properties. Floresta e ambiente, 26.

[110] Aydin, E. G. (2018). Designing for sustainability: A comparative analysis of steel and wood based furniture.

[111] NL Agency and Wageningen University & Research (2013). Bamboo. Analysing the potential of bamboo feedstock for the biobased economy. Source: https://edepot.wur.nl/381054

	Sofa A: Current common practice	Sofa B: Alternative with possible best practices	Costs & benefits of the alternative	
			Environment	**Economics**
			China which means it needs to be imported and thus transported to the EU	
Chemicals	Formaldehyde (used as glue, sealant, and lacquer) Adhesives, paints, varnishes, and finishes that can contain VOCs	Vinylic glue Water-based varnishes (containing for example linseed and walnut oil or beeswax).	• Formaldehyde might have carcinogenic and mutagenic properties in high doses[112] • VOCs are toxic and carcinogenic in high amounts[113]. The alternatives are not.	• Vinylic glue is not as strong as formaldehyde, so producers might need more of it. • Use of formaldehyde is increasingly restricted by legislation, so some companies try to look for alternatives to be ahead of legislation.
Design	When the frame is broken, it is difficult to repair (for example with particle board, this is glued together so once it is broken it cannot be fixed	Modular design[114] Choose a material which can be repaired (such as bamboo)	• By reusing existing materials there are no additional raw materials needed. There is also less waste going to the landfill and being incinerated	• Requires a change in infrastructure to repair sofas • Is currently often cheaper to replace the whole sofa than individual components

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[112] Zero Discharge of Hazardous Chemicals (n.d.). Chapter 2: ZDHC MRSL Candidate List. Source: mrsl-30.roadmaptozero.com/?sword=formaldehyde

[113] David, E., & Niculescu, V. C. (2021). Volatile organic compounds (VOCs) as environmental pollutants: Occurrence and mitigation using nanomaterials. International Journal of Environmental Research and Public Health, 18(24), 13147.

[114] This means that the different components of the sofa are loosely coupled and that they can be mixed and matched thanks to standardized interfaces among them. This makes it easier to replace broken or worn components, and to keep up with new trends in furniture. Source: Caridi, M., Pero, M., & Sianesi, A. (2012). Linking product modularity and innovativeness to supply chain management in the Italian furniture industry. International journal of production economics, 136(1), 207-217.

6.3 Conclusion

Overall, for most of the aspects covered in the case above, there are technical solutions that are readily available. They can be implemented to reduce the environmental impact of potentially hazardous chemicals and materials used in furniture. This can also be commercially viable, as proven by several companies that currently already produce sofas in a more sustainable way in the EU and abroad.[115] However, these are almost exclusively sofas in the mid- to high-end segment because switching to alternative best practices is costly. For example, scaling up is more difficult because the standard production and manufacturing processes in the industry are not suited for the new materials or design styles. The materials themselves (such as bamboo or natural fibres) are also more expensive to produce than polyester. This leads to higher costs for the consumers, which makes it less suitable for low-end consumers. Apart from the costs, there is also not an infrastructure in place for sofas after the purchase. Since the current common practice is to incinerate sofas once they are broken or worn-out, there is no structure in place for collecting, repairing, and recycling sofas. Here, policy might provide an incentive for change created by the whole value chain, instead of by individual frontrunner actors.

[115] Such as Biosofa (Italy), Sabai Design (USA), A Lott Of Space (Netherlands) and PLANQ (Netherlands).

7 Ecodesign recommendations and conclusions

During this research, we've found several recommendations by scientists, governments and government organizations to (further) reduce potentially hazardous chemicals in furniture. Some of these policies can be implemented through ecodesign requirements, others can or need be implemented through other means[116].

Therefore, we start this chapter by outlining several general policies, that will be further specified to ecodesign requirements and the three topics of this study: potentially hazardous chemicals used in furniture, metals used in furniture and the lifespan of furniture.

7.1 Policy options for reducing negative impacts

Several policy instruments can be implemented to (further) reduce the environmental impact of furniture. Below, several policy directions and strategies are outlined. These are categorized into four groups: "Promotion and encouragement", "Limitation and restriction" "Standardized testing" and "design and transparency".

Table 7 Policy options to consider

Policy	Remarks
Promotion and encouragement	
Informing producers	There are opportunities in informing producers about the use and impact of potentially hazardous chemicals, as well as the existence of alternatives. Many furniture producers (still) lack knowledge of negative health and environmental effects of potentially hazardous chemicals. This can be done via several routes: informing industry representatives, communicating scientific research (into alternatives of hazardous chemicals), informing producers of the negative effects experienced by recyclers, communicating best practices et cetera.
Fostering knowledge and innovation	Lastly, governments can foster knowledge and innovation in the sector by pushing research and innovation into alternatives to potentially hazardous chemicals. In general, research into the use of chemicals in furniture production and effects on the environment can be improved, gaining more insight and providing more knowledge and tools for policy makers. Encouraging innovation of alternatives to chemicals and production methods would lower the threshold for manufacturers to switch to these alternatives.
Limiting and restricting substances	
Full restriction	Governments can further restrict the use of chemicals, thereby fully forbidding the use of harmful chemicals. Although there are several legislative frameworks under which production, use and entering of chemicals into consumer products are regulated, there are no frameworks aimed at furniture as a product group. It can be investigated in more detail what the opportunities are: in which groups of chemicals the environmental impact is large and alternatives exist. Historically, the full restriction of certain flame retardants and the ban of several POPs after the Stockholm Convention in 2001shows that this is an effective instrument.
Limiting concentrations and number of chemicals used	Besides fully restricting chemicals, governments can limit concentrations of chemicals. Many chemicals are already subject to these types of limitations, where they may be present in certain concentrations but not above a certain threshold.
Standardized testing	
Implementing standardized tests	The lack of knowledge regarding the use and amount of chemicals could be further stimulated by implementing standardized tests. For example, retailers could be required to test samples of furniture items that are being brought to the market. At the same time, such tests need to be implemented in the waste collection and recycling phase, where this would provide information for recyclers and parties that collect and resell recyclable separated materials for the production of circular items on the presence of chemicals.
Design and transparency	
Set design requirements	Setting design requirements could greatly improve the possibilities for recycling and reduction of chemicals. Setting requirements that enables users and repairers to maintain and repair (parts of) furniture items will increase lifespan. Requirements regarding disassembly will enable recyclers to

[116] It should be noted that REACH and other (national) frameworks are the primary instrument to negate adverse health effects of potentially hazardous chemicals. Ecodesign requirements are aimed at reducing negative effects on the environment such as obstructing or hampering of furniture recycling.

	more cost effectively separate recyclable and non recyclable parts and increase recycle rate. This also applies to chemicals in furniture - processed parts should be separable from unprocessed parts through design requirements. "Design for disassembly" is one of the leading principles in this area.
Increase possibilities for maintenance & reparability (non design)	There also are ways to increase the possibilities for maintenance and repair that are outside of the scope the actual product design. Users and repairers can be encouraged to maintain and repair furniture, by providing repair scores, information on maintenance and common repairs and providing spare parts. Producers can also be required to provide access to professional third party professional repairers.
Increase transparency and traceability	Increasing transparency and traceability of chemicals would greatly improve the insight in chemicals being used for suppliers, manufacturers, retailers and consumers. Efforts are currently made to improve transparency: the Ecodesign Regulation will require products which are regulated under the Ecodesign framework to be accompanied by a digital product passport. This would mean that the material flow in the production chain would be supplemented with an information flow, providing details on the (amounts of) chemicals used in different production steps. This gives insight in the product aspects, such as presence of substances, which allow for more circular handling of the product during the use phase and in the waste phase.

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The policies regarding "promotion and encouragement" and "limiting and restricting" can be addressed with policies outside of ecodesign requirements. While being outside of the scope of ecodesign, these policies can have a strong positive effect on the reduction of potentially hazardous chemicals.

Policies regarding "Design and transparency" need to be covered within ecodesign requirements while standardized tests need to be built in place to check compliance with these ecodesign requirements. These will be further elaborated upon in the paragraph below.

7.2 Types of ecodesign requirements applicable to furniture items

Furniture and potentially hazardous chemicals in furniture have a large environmental impact, especially in the production and end of life phase. Furniture consumption has greatly increased in the last decades, thereby increasing the environmental impact ever more over time. The quality of many materials used furniture has declined and – as a result – the lifespan of furniture as well. Ecodesign requirements can greatly reduce the environmental impact of (chemicals in) furniture.

Ecodesign aims

In general, the aims of ecodesign requirements are:

- Increase lifespan
- Increase recyclability
- Decrease negative environmental effects in the production phase
- Level the playing field for domestic and international producers / suppliers.

Ecodesign requirements

While it currently is hard to say which exact components, materials and chemicals need to be addressed in these ecodesign requirements - because there are many different types of furniture and a plethora of materials and chemicals used - there are some general aims, goals and principals for ecodesign requirements that can be applied. These are listed below.

- Require producers to design furniture items that are fully capable of disassembly by waste collectors and recyclers

Currently, not being able to dismantle furniture is the main reason that furniture is not collected separately and recycled by recyclers. A general 'design for dissasembly' would greatly improve the recycle rate of furniture and reduce the environmental impact.

- Require a digital passport

Within the Ecodesign Directive, producers will be required to provide information on materials in products that are sold on the EU market. Regarding furniture and chemicals in furniture, we recommend that all potentially hazardous chemicals that are present in the sold furniture item are labelled (including the quantity), so that consumers are informed and traceability is made possible[117].

- Require producers to use materials that have a low(er) environmental impact in the production phase

As described in chapter 3, many different chemicals have a large environmental impact in the production phase. Requiring producers to use alternatives, will lower this environmental impact. More generally, such requirements will level the playing field between domestic producers and suppliers and those outside of the EU.

- Require producers to use high(er) quality materials

Just as there are components that wear fast or break, certain low material components reduce the lifespan of furniture. Requiring high quality alternatives (see chapter 6 for examples) or setting quality requirements (i.e. materials need to be able to withstand a certain amount of use or certain amount of cycles an item is assembled/disassembled) will increase the lifespan.

- Require producers to design components that can be replaced by users and repairers

This will have a major impact on the lifespan of furniture. Currently, furniture is often discarded when only one or a few parts are worn or broken. These parts can often not be repaired, because they are not removable from the rest of the furniture. Identifying per product group which components wear or break the most and implementing requirements for these components will improve the lifespan.

- Obligate producers to provide guidelines on user maintenance and repair

This will improve knowledge on maintenance and repair for users, making it possible for users to cheaply increase life span.

- Require non-discriminatory access to repairers

Repairers should be given full opportunity to make repairs. Designing products (or use of parts) in such a way that prohibits repairs to make repairs should be limited, increasing life span.

- Obligate producers to make critical spare parts available

Increasing availability of spare parts will enable repairers to more easily obtain these and provide swift repair action in case of worn or broken components. These requirements should include a timeframe in which these parts should be available – increasing the lifespan of furniture.

- Require reparability score

A reparability score informs consumers of the possibilities regarding reparability. When taking the reparability score into account, consumers are made aware of possible future costs (relating to replacement and/or repair) when purchasing furniture items.

There is no one-size-fits all solution for all different furniture products. For some furniture items and some chemicals in furniture, more specific requirements may be needed to reduce the negative environmental effects. For others, more general requirements are applicable. We

[117] This would mean that producers need to have an overview of all chemicals being used by suppliers as well. Alternatively, traceability requirements could be made to chemicals that (potentially) have a large hazardous effect on the environment, such as chemicals that persists and do not degrade. This has downsides however - when future research detects negative effects of chemicals or chemical groups that previously were unknown, the passport may not include this chemical or chemical group and therefore would be untraceable.

recommend further investigation into different product groups, components, materials and chemicals to establish effective requirements per furniture item.

Type of items

In general, low-quality furniture with a short lifespan and a large market share are interesting to start with. Furniture with low quality materials present in fundamental parts of their structure (especially items that consist of combinations of wood processed materials such as MDF and polyurethane foam), such as sofas and couches and 'MDF or plywood' type closets and cupboards could be a good start. Furthermore, composite wood items that are heavily processed with chemical substances could be interesting to look at as well. Finally, furniture with electronics embedded and 'smart furniture' could be an interesting category to start, as replacement of parts and disassembly of the item are expected to be more important in this (growing) category.

7.3 Conclusions and recommendations on potentially hazardous chemicals used in furniture

Conclusions on chemicals used in furniture

Potentially hazardous chemicals are still widely used in the manufacturing of furniture. They provide protection against fire, rot, mould, discoloration abrasion, stains, allergies, bacteria et cetera. Flame retardants, VOCs, Phtalates, PFAS, Dyes and Pesticides are the main categories of chemical substances that are used in production and manufacturing. Each of these groups have shown improvement over the last decades in reduction of environmental impact (mostly due to regulation) and small furniture companies show it is possible to produce high quality furniture without extensive use of harmful chemicals.

These chemical substances have impact on the environment; mainly in the production stage (where they directly impact the environment) and in the recycling and post-recycling phase, where they can obstruct the recyclability of furniture (as recycled products need to comply with REACH regulation, so the suspected presence of chemicals in end-of-life furniture can obstruct the recycling possibilities) and may accumulate in recycled products and in the environment. These chemicals also have an effect in the use phase, where users are exposed to these substances.

One of the main findings of this research is how little still is known about the quantities of chemical substances that are used in the production of furniture. On a macro economic level, it is currently unknown how many chemical substances are used in production and enter the furniture market. On a micro level, there are many unknowns as well – there is a lack of transparency in the production chain that could provide insight in the amount of chemicals in individual furniture items.

Recommendations regarding ecodesign measures and potentially hazardous chemicals

Several of the above listed requirements can be specified for the reduction of chemicals used in furniture. Most potentially effective requirements are:

- Design requirements – separating components treated with potentially hazardous chemicals from non-treated components:
  - requiring manufacturers to produce furniture items that consist of separate components which are treated with potentially hazardous chemicals (which are deemed necessary) from components that are non-treated, thereby increasing recyclability and separating chemicals from homogenous and recyclable material streams and preventing them re-entering the production stage and entering the environment.
- Increasing the transparency and traceability of potentially hazardous chemicals used,

- whereby retailers and manufacturers are required to control and disclose information on the use of potentially hazardous chemicals in furniture items brought to the market, and requiring suppliers to provide this information in an "information flow" parallel to the material flow. Ideally, producers should be required to list all applied chemicals (comparable to ingredient listings used in food safety) per component in a furniture item.

- Require producers to use chemicals that have a low(er) environmental impact in the production of furniture items
  - by further building upon existing legislative frameworks such as REACH, POP and waste directives and national legislation, extending the scope of chemicals which will be (further) limited. Basis of this further limitation is the environmental impact of used chemicals.

7.4 Conclusions and recommendations on metals used in furniture

The amount of energy needed for metal production is high compared to other materials, but much energy can be saved by using recycled metals. Currently, only a small part of metals used in Europe come from recycled materials (20% for steel, 32% for aluminium). Therefore, there is still much potential to gain here.

We recommend further investigating ecodesign requirements:

- Metal recycling rates used (in furniture/ in general)
  - It needs to be further investigated whether it is feasible and relevant to try to improve the metal recycling rate for furniture specifically. On the one hand, there could be opportunities here, as the quality standards for furniture are lower compared to other sectors, making it technically more feasible to use recycled materials. On the other hand, the amount of metals used in furniture is small compared to other sectors and therefore rules regarding recycling rates may not lead to changes on the metal supplier side. This means that furniture producers have to import metal with higher recycling rates from outside the EU. Therefore, increasing the recycling rate of metals in the EU in general may be better.
- Increase information provided on recycling rates
  - As metal suppliers often cannot provide furniture producers with recycling rates and do not offer 100% recycled materials, this hinders ambitious producers with increasing recycling rates. There is much to gain here, with current recycling rates used around 20% for steel and 32% for aluminium. However, this problem seems to be more on the supply-side of the materials instead of the production of furniture.
- Require easy disassembly
  - There is still much potential in increasing reuse and recycling rates for furniture. It is estimated that only 8% of the metal furniture in Europe is currently reused and 8% recycled. This is probably mainly due to the composition of furniture, made from different materials that are difficult and costly to disassembly. Easy disassembly will therefore likely help in higher recycling rates.
- Using common alloys and providing information on alloys(/materials) used
  - For ferrous-metals (of which steel is by far the most used one in the furniture sector), there are many different alloys that can be used. The different alloys need to be separated for recycling and as detailed product information is often not available, metals need to be tested to see the composition of the alloy. Using common alloys and providing information on the alloy used could therefore increase recycling rates.

Interesting product groups to start could be outdoor tables, bed frames and non-padded chairs, as relatively high percentages of metals are used for these product groups.

7.5 Conclusions and recommendations on the lifespan of furniture

In general, estimates on the lifespan of furniture are far apart. Most estimates vary between 5 and 20 years. This broad range is partly due to the lack of research into the lifespan of furniture, but mostly because of the big differences in lifespan between products. The quality of materials and construction is the most important factor for the lifespan. Another factor is the maintenance by the consumer. Finally, the ' timelessness' of the furniture is an important factor. Heirloom furniture emotionally connects with consumers and thus realizes longer lifespans.

We recommend further investigating ecodesign requirements:

- Increasing durability
  - There is a trend of weaker design and cheaper materials that are of lesser quality. For example, we see a shift from solid wood and metal (durable, high quality materials) to cheaper materials such as plywood or rubber wood. We therefore recommend investigating possibilities of increasing the durability, to increase the lifespan of furniture.
- Increasing repairability (and disassembly)
  - The lifespan can also increase by increasing repairability. Repairing furniture is currently often difficult, as furniture is difficult to disassemble, and spare parts are not easily available. Ecodesign measures could help improving the repairability.
- Information provided on product care
  - Consumers are rarely given guidance on how to maintain and repair furniture, in order to prolong and extend the product lifespan. If furniture is regularly cleaned and waxed, it can make a large difference in lifespan and quality. Measures on information for product care could therefore possibly increase the lifespan of products.

We should keep in mind that the measures above are aimed at increasing the technical lifespan of products. However, fast furniture trends can still lead to furniture being discarded early. Hence, to further improve the lifespan of furniture, the fast furniture trend needs to be reversed. Ecodesign requirements - that encourage repair & recycling and therefore upgrade aesthetics while reusing fundamental components such as frames - could help curb this trend.

Appendix A Overview of sources

Documentation consulted

The documents consulted for this research, in alphabetical order, are:

- 8billiontrees.com, 2023, Carbon footprint of steel per kg & lb. https://8billiontrees.com/carbon-offsets-credits/carbon-footprint-of-steel/
- ArcelorMittal (2021), Climate Action Report 2: https://corporate-media.arcelormittal.com/media/ob3lpdom/car_2.pdf
- Aremu, M. O., Ojetade, J. O., & Olaluwoye, O. S. (2015). Production of flexible polyurethane foam using soya bean oil and palm kernel oil as surfactant and polyol respectively. Chemical and Process Engineering Research, 35, 24-31.
- Aydin, E. G. (2018). Designing for sustainability: A comparative analysis of steel and wood-based furniture.
- Bazzetto, J. T. D. L., Bortoletto, G., & Brito, F. M. S. (2019). Effect of particle size on bamboo particle board properties. Floresta e ambiente, 26.
- Beckett, E. M., Miller, E., Unice, K., Russman, E., & Pierce, J. S. (2022). Evaluation of volatile organic compound (VOC) emissions from memory foam mattresses and potential implications for consumer health risk. Chemosphere, 303, 134945. Research was based on mattresses however, and not foam in sofas.
- Bumgardner, M. S., & Nicholls, D. L. (2020). Sustainable practices in furniture design: A literature study on customization, biomimicry, competitiveness, and product communication. Forests, 11(12), 1277.
- CALPIRG (2021). The Fashion Industry Waste Is Drastically Contributing To Climate Change. See link: https://pirg.org/california/articles/the-fashion-industry-waste-is-drastically-contributing-to-climate-change/
- Caridi, M., Pero, M., & Sianesi, A. (2012). Linking product modularity and innovativeness to supply chain management in the Italian furniture industry. International journal of production economics, 136(1), 207-217.
- CE Delft (2019). The environmental benefit of Marktplaats trading. In opdracht van: Marktplaats.
- Center for European Policy Studies (CEPS) (2014). EU Furniture Market Situation Report. https://www.ceps.eu/ceps-publications/eu-furniture-market-situation-and-possible-furniture-products-initiative/
- Chapagain, A. K., Hoekstra, A. Y., Savenije, H. H., & Gautam, R. (2006). The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries. Ecological economics, 60(1), 186-203.
- CIRCO (2020), Materialen module https://www.circonl.nl/resources/uploads/2020/04/20200414-CIRCO-Materialenmodule-final.pdf
- David, E., & Niculescu, V. C. (2021). Volatile organic compounds (VOCs) as environmental pollutants: Occurrence and mitigation using nanomaterials. International Journal of Environmental Research and Public Health, 18(24), 13147.
- Éco-mobilier (2015), Innovation & éco-conception en vue du recyclage Le guide de la filière mobilier

- Eurofer (2022), European Steal in Figures: https://www.eurofer.eu/assets/publications/brochures-booklets-and-factsheets/european-steel-in-figures-2022/European-Steel-in-Figures-2022-v2.pdf
- European Aluminium (2022), Enabling the circular economy with aluminium. https://european-aluminium.eu/blog/enabling-the-circular-economy-with-aluminium/
- European Commission (n.d., latest amendment was in 2022). EU Ecolabel – Furniture and mattresses.
- European Commission (n.d., 2014 at the earliest). Furniture Industry. https://single-market-economy.ec.europa.eu/sectors/raw-materials/related-industries/forest-based-industries/furniture-industry_en
- European Environment Bureau (2017). Circular economy opportunities in the furniture sector. https://eeb.org/wp-content/uploads/2019/05/Report-on-the-Circular-Economy-in-the-Furniture-Sector.pdf
- European Furniture Industries Confederation (2020). The FURNITURE SECTOR and CIRCULAR ECONOMY 2.0.
- Eurostat (2020). Guidance for the compilation and reporting of data on municipal waste according to Commission Implementing Decisions 2019/1004/EC and 2019/1885/EC, and the Joint Questionnaire of Eurostat and OECD. https://ec.europa.eu/eurostat/documents/342366/351811/Guidance+on+municipal+waste+data+collection/
- Eurostat (2020). Sold production, exports and imports. https://ec.europa.eu/eurostat/databrowser/view/DS-056120__custom_7442499/default/table?lang=en
- Environmental Working Group (n.d.). Upholstered Furniture. Source: https://www.ewg.org/healthyhomeguide/upholstered-furniture/
- Furn360. Circular Economy in the Furniture Industry: Overview of Current Challenges and Competences Needs. Co-funded by the Erasmus+ Programme of the European Union.
- Haren de Krant (2020). Algemeen informatief: Hoe lang zouden uw meubels mee moeten gaan. https://www.harendekrant.nl/nieuws/algemeen-informatief-hoe-lang-zouden-uw-meubels-mee-moeten-gaan/
- HOM Furniture (2020). FURNITURE LIFESPANS: How long should your furniture last? Source: Furniture Lifespans - design blog by HOM Furniture
- Joint Research Centre (2017), the European Commission's science and knowledge service. Revision of EU Ecolabel criteria for furniture products
- Joshi, Y., & Rahman, Z. (2017). Investigating the determinants of consumers' sustainable purchase behaviour. Sustainable Production and consumption, 10, 110-120.
- KBV Research (2021), Metal Furniture Market Size https://www.kbvresearch.com/metal-furniture-market/
- Kilgore (2023). Carbon Footprint of Polyester vs Cotton vs Wool vs Leather vs Nylon (Calculator). See link: https://8billiontrees.com/carbon-offsets-credits/carbon-footprint-of-polyester/#:~:text=Negative%20Impacts%20of%20Polyester&text=The%20creation%20of%20polyester%20requires%2070%20million%20barrels%20of%20oil%20every%20year.&text=Polyester%20sheds%20microfibers%20that%20build,pollution%20found%20in%20the%20ocean.&text=One%20wash%20can%20release%20up,per%20gram%20of%20polyester%20fabric)
- Kurzius, R. (2023). Why furniture got so bad. The Washington Post. Source: Why new furniture doesn't last long - The Washington Post

- Leverette (2019). When Should You Replace Your Furniture? Source: When Should You Replace Your Furniture? (thespruce.com)
- Mallon, B. (2018). 10 HOUSEHOLD ITEMS WITH ACTUAL EXPIRATION DATES. Source: How Often to Replace Furniture — When to Buy New Furniture (elledecor.com)
- NL Agency and Wageningen University & Research (2013). Bamboo. Analysing the potential of bamboo feedstock for the biobased economy. Source: https://edepot.wur.nl/381054
- Smardzewski, J. (2015). Classification and characteristics of furniture. Furniture Design, 47-95.
- TAUW (2022). Grootzitmeubilair: Productstromen en materialen in kaart gebracht. In opdracht van de Rijkswaterstaat.
- Wieser, H., Tröger, N., & Hübner, R. (2015). The consumers' desired and expected product lifetimes. Product Lifetimes And The Environment.
- World Aluminium (2020), Aluminium Recycling Factsheet 2020: https://international-aluminium.org/wp-content/uploads/2021/01/wa_factsheet_final.pdf
- Zero Discharge of Hazardous Chemicals (n.d.). Chapter 1: ZDHC MRSL (Source: mrsl-30.roadmaptozero.com/?sword=flame+retardants#chapter_1) and Chapter 2: ZDHC MRSL Candidate List (Source: mrsl-30.roadmaptozero.com/?sword=formaldehyde)
- Zwierzyński, P. (2017). The determinants of consumer behaviours in the furniture market. Annals of Marketing Management & Economics, 3(1), 131-143.

Expert interviews:

The experts interviewed for this research, in alphabetical order, are:

- Biosofa (producer of plastic free sofa's)
- Brabantia (producer)
- Dutch Ministry of Infrastructure and Water Management (policy maker with expertise in SVHCs)
- Dutch Ministry of Infrastructure and Water Management (policy maker with expertise in waste processing)
- Dutch National Institute for Public Health and the Environment
- EFIC (European Furniture Industries Confederation)
- La Poubelle (thrift store)
- Saxion (higher education institute)/ Saxcell (chemical recycling initiative)
- The Substitute (community of sustainable brand and professionals in the furniture industry)
- TNO (research organization)
- ZDHC (network organisation in the field of chemical free textiles and apparel)

Appendix B Policy options for increased recycle rates

A European study from 2017 estimates the increase of reuse and recycle rates of metal furniture under different scenarios, where each scenario implies different policy options. Their estimates are shown in the table below.

Table 8 Opportunities for increasing reuse and recycle rates of metal furniture under different scenarios

Scenario	Information	Reuse	Recycle	EfW	Landfill
Baseline		8%	8%	42%	42%
Fully mandatory	Mandatory EPR for take back, with preparing for reuse and recycling targets, or individual producer responsibility (IPR). Mandatory eco-design measures on durability, repair and recyclability. Or mandatory warranty period of five years.	40%	40%	10%	10%
Part mandatory	Mandatory EPR. + Green Furniture Mark (GFM) approach, with A to G rating for furniture with mandatory labelling.	35%	35%	15%	15%
Full voluntary	Voluntary agreements (Self-Regulatory Initiative) to take back, preparing for reuse and recycling. Voluntary use of GFM.	27%	30%	22%	22%
Incentives only	EU-wide SME support for CE innovation + tax incentives, grants, etc. Deposit-refund incentive for consumers to return furniture for reuse and recycling	15%	18%	34%	34%
Information only	Mandatory Product Information Systems. Voluntary use of GFM	12%	15%	37%	37%
Waste management only	EU wide landfill ban on furniture disposal. Clearer regulation/ guidance around end of waste and recycling materials.	12%	38%	41%	9%

Source: Circular Economy opportunities in the furniture sector, European Environmental Bureau, 2017.
EfW = Energy from Waste.
Note from the report: "*A lack of available and robust data has meant that we have needed to make conservative estimates, based on the literature review and assumptions linked to available reference points. The quantitative analysis therefore needs to be treated with caution as it is only intended to indicate the broad potential scale of opportunity, rather than precise forecasts.*"