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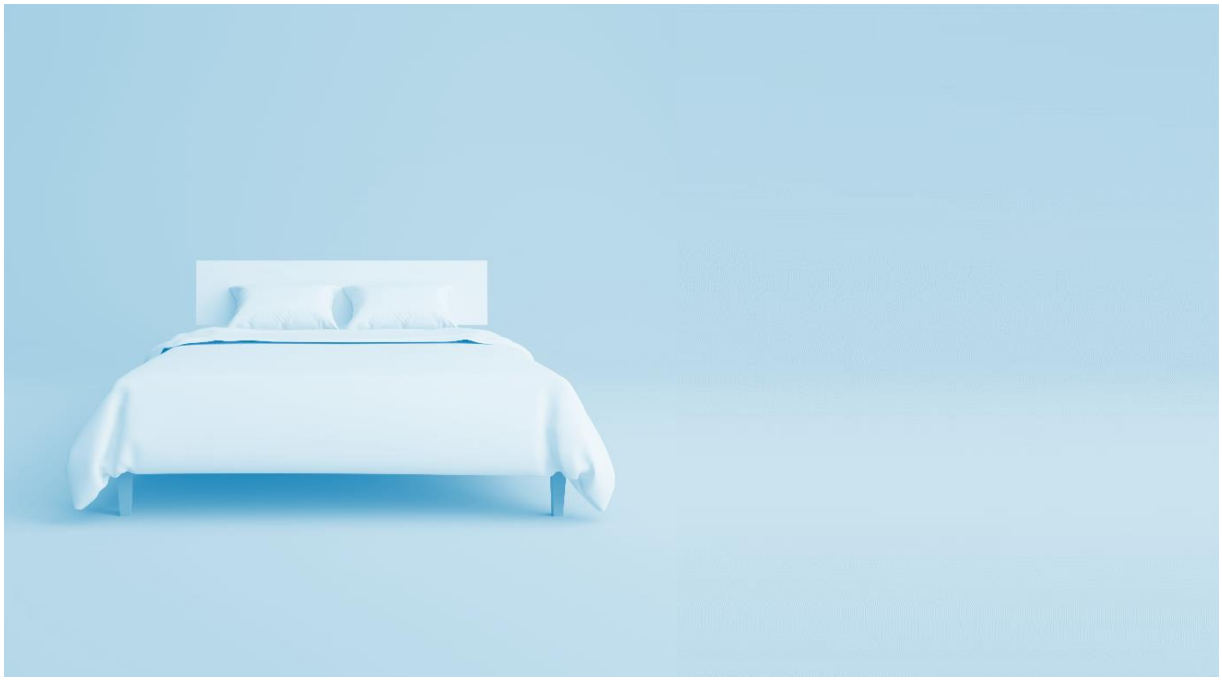

Managing Chemicals of Concern within a Circular Economy: The Impacts and Solutions for Chemical Flame Retardant Use in UK Mattresses

Stakeholder perspectives and economic analysis

July 2023

Prepared for Fidra
(SCIO and Scottish registered charity no.SC043895)

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Contents

Glossary

ADF	Advanced Disposal Fee
BEIS	Department for Business, Energy and Industrial Strategy
BIS	Department for Business, Innovation and Strategy
CFRs	Chemical Flame Retardants
DEFRA	Department for Environment, Food & Rural Affairs, UK
DMR	Dry Mixed Recyclables
EAC	Environmental Audit Committee
EfW	Energy from Waste
EoL	End of Life
EPR	Extended Producer Responsibility
ETS	Emissions Trading Scheme
EU	European Union
FFR	Furniture and Furnishing (Fire) (Safety) Regulations
FRs	Flame retardants
GHG	Greenhouse gas
HWRC	Household Waste Recycling Centre
MS	Member State
NBF	National Bed Federation
POPs	Persistent Organic Pollutants
POM	Placed on Market
RDF	Refuse Derived Fuel
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
SRF	Solid Recovered Fuel
SVHCs	Substances of Very High Concern
WRAP	Waste & Resources Action Programme

Contents amendment record

This report has been amended and issued as follows:

Version	Date	Description	Author	Editor
1	11/05/2023	Draft version 1	PL et al.	PL
2	05/07/2023	Draft version 2	PL et al.	EP
3	31/07/2023	Final version	PL et al.	EP

Executive Summary

Many furniture manufacturers supplying the UK market comply with the Furniture and Furnishings (Fire) (Safety) Regulations (FFRs) 1988 (as amended) by using chemical flame retardants (CFRs). The use of these chemicals, particularly legacy CFRs such as brominated flame retardants (BFRs) and polybrominated diphenyl ethers (PBDE), has been a subject of dispute due to their negative impact on human and environmental health. Emerging evidence suggests that current CFRs in use, including organophosphate esters, may have similar adverse effects.

Previous studies have highlighted the health and environmental risks posed by flame retardants, with some substances being classified as persistent organic pollutants (POPs) and substances of very high concern (SVHCs). Regrettable substitutions have occurred, where banned CFRs were replaced with similar chemicals later subject to the same restrictions. International restrictions on SVHC usage in various products have been increasing, indicating a need for action.

Regrettable substitutions and a lack of chemical transparency and traceability pose significant barriers to achieving a successful circular economy and can undermine public and environmental health. Multiple case studies have demonstrated the detrimental impacts of harmful chemicals used in everyday products.

Regarding CFR use in UK furniture and furnishings, multiple noteworthy reports have recommended measures to restrict regrettable substitutions and introduce a new permanent label for upholstered furniture products containing flame retardants. Studies have also suggested that CFRs limit recycling opportunities and increase end-of-life treatment costs compared to CFR-free waste.

This study focuses on a cost-benefit analysis (CBA) of CFRs in mattresses in the UK, assessing their impact on fire safety, environmental sustainability, human and environmental health, and economics. While fire safety is crucial, the study questions how the UK compares to other jurisdictions in terms of CFR usage, such as continental Europe and North America (who do not require the same stringent flammability tests as the UK). The project took into account the entire mattress life cycle, including manufacturing, use (including online sales), and end-of-life management options like landfill disposal, energy recovery, recycling, remanufacturing, and reuse. It also recognised that not all mattresses contain CFRs since some manufacturers comply with the fire safety regulations by carefully designing and selecting alternative materials and components.

The study is developed around 5 possible scenarios covering different possibilities in the evolution of FFRs and use of CFRs:

- Business as Usual (BAU): Existing Furniture and Furnishings Regulations (FFRs) are retained, with the assumption that there is full compliance with UK and EU REACH where applicable
- Amendments to the existing FFRs that would support a reduction in the use of CFRs during mattress manufacturing
- Introduction of an EPR scheme for mattresses
- Introduction of a landfill and recycling ban due to mattresses containing significant levels of hazardous CFRs (that have been classified as POPs)
- Introduction of chemical traceability measures

These scenarios are analysed, where possible and relevant, through the lens of different types of impacts, namely: fire safety, environmental sustainability, human and environmental health, and economics.

The results are elaborated in each scenario's section, summarised in Table 2, and highlighted in the key findings section. Finally, recommendations are given regarding the future management of the FFRs and use of CFRs.

1 Key Findings

1.1 Stakeholder Feedback

Fundamentally, all participants acknowledged that fire safety was of paramount importance.

Key concerns raised by many of the stakeholders interviewed included the high level of uncertainty in terms of:

- the likelihood that all CFRs will be classified as POPs or SVHCs
- the likelihood that the current FFRs will be revised
- the timing of any revisions to the FFRs and more importantly from their perspective, how long businesses will be given to comply with any revisions
- how the revisions will impact their business,
- regrettable substitutions. The uncertainty of whether a CFR will be restricted under UK and/or EU REACH regulations during the lifetime of the product is a concern from a producer responsibility perspective
- the evidence base. Are CFRs retained throughout the lifetime of the mattress?, Does this depend on the type of CFR used (additive versus reactive)?,
- are they effective in terms of fire safety or do they increase the smoke toxicity of fires, i.e., do we have a problem or not?

This level of uncertainty that many of the stakeholders considered out of their control hinders future proofing their business and hence is considered a significant on-going commercial risk.

1.2 Economic and Cost-Benefit Analyses

Table 1 provides a summary of the five scenarios modelled in this study. These findings should be interpreted as indicative as, prior to the introduction of any policy interventions there will be due diligence in the form of consultations and regulatory impact assessments, where fire safety, environmental sustainability, human and environmental health and economics (implementation and running costs) will be considered.

One of the main conclusions of the research is that in the Business-as-Usual scenario there is evidence of uncertainty, questioning the fitness for purpose of both the current FFRs and REACH in the key impacts studied (fire safety, environmental sustainability, human and environmental health, and economic). As discussed above, the most fundamental question arising from this study is, 'are CFRs fit for purpose?'. Interviews undertaken as part of this study and existing literature highlighted the important question of whether CFRs are retained in mattresses throughout their lifetime. Currently, the tests to determine whether a mattress conforms with the FFRs is a 'point of manufacture' test that does not take into consideration the in-use phase. Additionally, companies reprocessing EoL mattresses reported that the mattresses did not pass the tests. This appears to challenge the Royal Society of Chemistry Toxicology Interest Group's required function of CFRs namely 'Its short-, medium- or long-term stability to ensure the substance will remain 'active' in its ability to prevent fire during its shelf life' (1). CFRs leach out over time entering the human body, environment and wildlife. The extent of this leaching is not yet known and may depend on product, use and other external factors. Additionally, the EAC 2019 report stated that 'evidence has emerged that flame-retardant chemicals increase the toxicity of smoke in domestic fires, which calls into question their overall benefit'.

1.3 Economic Review of Fire Safety

Defra in its 2014 consultation reported that the current FFRs 'save around 54 lives per year and prevent around 800 injuries and 1000 fires. These savings to health and property were valued at around £140m per year'. Since the objective of any amendments to the FFRs is to at least maintain or better still - improve the current level of fire safety, this estimated cost saving is considered the de minimis across any future interventions.

As part of a Parliamentary Review in 2019 (2), the cost of meeting the current FFRs using alternative methods such as the use of natural inherently flame-retardant materials (e.g. wool, excl. polyester) or non-chemical FRs (e.g. graphite) was estimated in two different ways by two different industry stakeholders, and it is concluded that the cost of retaining the current FFRs and meeting the fire safety test using alternative FR methods instead of CFRs (at the manufacturing stage) falls within the range of £129 million to £200 million per year.

1.4 Economic Review of Environmental and Human Health

No literature sources could be identified that specifically quantified the environmental and human health costs associated with the exposure to CFRs from mattresses in the UK or elsewhere. However, to at least quantify the scale of the costs, it is estimated that the health care costs associated with exposure to the polybrominated diphenyl ethers (PBDE) group of flame retardants in Europe is €163 billion, equivalent to £142 billion per year (3). In addition to furniture and furnishings, these flame retardants were commonly used in a wide range of applications including electrical and electronic equipment and construction materials (4).

Table 1 is an estimation of environmental impacts in terms of carbon emissions at different prices per tonne. Greenhouse gas emissions are one of the best described factors of environmental degradation as they are causing global warming, one of the biggest threats to humans and the environment. Additionally, carbon is traded in the form of emission allowances and carbon offsets in different markets, providing price signals for the estimations. However, other environmental impacts are more challenging to quantify, thus there will be no estimation of their cost. The Dasgupta Review, a 2021 report commissioned by the UK chancellor, provides a comprehensive approach to concepts such as Natural Capital, the intrinsic and instrumental value of nature, and the value of biodiversity (5). It is important to bear in mind that any kind of polluting agent has the potential to affect the Natural Capital and carry a cost, even if said cost is unknown.

1.5 Economic Review of Environmental Sustainability

Table 1 provides a more detailed breakdown of the recycling scenarios modelled as part of this study. This shows that the theoretical best-case scenario of 100% recycling of all EoL mattress materials would result in a carbon reduction of 600,000 tonnes and the central series carbon cost saving of £151 million (6). The introduction of an EPR, resulting in a 75% collection for recycling rate, represents the current best practical intervention, resulting in a carbon reduction of 302,000 tonnes and a carbon cost saving of over £76 million in the central series estimate.

Table 1: Estimated carbon impacts and carbon cost savings associated with each policy intervention

Scenario	Carbon reduction (Tonnes CO_2e)	Price of carbon (£ per Tonne CO_2e)*		
		Low series	Central series	High series
		126	252	378
Maximum carbon reduction - 100% recycling of all EoL mattresses (only viable if EoL mattresses do not contain harmful chemicals and there are markets for recycled material)	601,184	75,749,184	151,498,368	227,247,552
Business-as-Usual. Current carbon reduction (24% recycling of mattresses with a yield rate of 58.3%)	137,907	17,376,282	34,752,564	52,128,846
Increased yield rate through **reduction of CFRs** (24% recycling rate of mattresses with a yield rate of 72.9%)	170,581	21,493,206	42,986,412	64,479,618
Introduction of an **EPR** (75% collection for recycling rate with a yield rate of 72.9%)	302,477	38,112,102	76,224,204	114,336,306
Recycling ban due to CFRs being classified as POPs (0% recycling and 100% EfW)**	-35,890	-4,522,140	-9,044,280	-13,566,420

* Low, medium and high series for the price of carbon refers to the uncertainty of prices of carbon as reported by Defra, due to differences in modelling approaches or underlying scenario assumptions (e.g. population forecasts) (7).

**Please note: this is the estimated short term costs. However, it would be anticipated that in light of the recycling ban that the manufacturers would stop using these CFRs, and hence, in the longer term the mattresses free from using these CFRs could be recycled providing there was clear chemical labelling.

1.6 Impact Map from Different Scenarios

Evidence points to the need for amending the current FFRs to reduce reliance on CFRs and that an EPR scheme could help improving the EoL management of mattresses from a circular economy perspective. Additionally, three of the four potential scenarios can be considered complimentary, meaning they could be implemented together in some form:

- Amendments to the existing FFRs that would support a reduction in the use of CFRs during mattress manufacturing
- Introduction of an EPR scheme for mattresses
- Introduction of chemical traceability measures

The one scenario that poses a short-term risk to the mattress recycling sector is the hypothetical introduction of a mattress landfill and recycling ban due to them containing significant levels of hazardous CFRs (that have been classified as POPs). This is currently the case for domestic seating furniture through the EA's (Environment Agency's) POPs incineration ruling. If this came to fruition, this would have a significant impact on the EoL mattress recycling and remanufacturing sector. As there is currently no chemical transparency and labelling requirements for mattresses, it is likely EoL mattresses would need to be incinerated until such a time as POPs use had been phased out and/or restricted chemicals use was limited and labelled to enable separation. Introducing testing to assess if POPs or SVHCs (which are likely to be subject to restriction at a later stage) are present in the product prior to recycling or incineration is a possibility, but experience from local authorities in domestic seating furniture indicates this is likely to be too expensive to implement. The impacts on the recycling sector could be mitigated by classifying textiles components as hazardous and in need of incineration, but allowing the steel components to be recovered and recycled, provided sufficient precautions were put in place to protect workers from known hazardous materials.

Table 2: Review of policy impact for each scenario, with boxes denoting a subsequent favourable, unfavourable and uncertain future (shown as ticks, crosses and empty boxes, respectively) in the four impact categories shown.

Policy intervention	**Impact**			
	Fire safety	**Environmental sustainability**	**Human and environmental health**	**Economic**
Business as Usual. Current FFRs are retained, and EU REACH is fully adopted in the UK	☑ The primary objective of the FFR is fire safety. ☐ There is growing evidence questioning the functionality of CFRs in terms of reducing fatality rates from fires.	☑ UK REACH reduces the risk of chemicals undermining EoL mattress recycling, reuse or remanufacturing. ☒ The 'long life' nature of mattresses can result in restrictions on chemicals being enforced during the life of the mattress, restricting the EoL circular economy options available. ☒ The susceptibility to regrettable substitutions.	☑ This is a primary objective of UK REACH. ☒ Increasing evidence of the health and environmental impacts of CFRs. ☒ The 'long life' nature of mattresses can result in restrictions on chemicals being enforced during the life of the mattress, resulting in potential exposure to harmful chemicals during the life of the mattress. ☒ The susceptibility to regrettable substitutions.	☐ From the perspective of REACH compliance, this is dependent on the cost of the substitute materials.
Amendments to the existing FFRs that enable a reduction or elimination in the use of CFRs	☑ The primary objective of the FFR is fire safety.	☐ The environmental impact would be dependent on the type of amendments, e.g. A move to CFR-free products would result in the potential to recycle more material but the amendment would not necessarily result in a direct financial incentive to do so, i.e., would be dependent on market forces. ☒ A major criticism of the existing FFRs is the use of CFRs and their impact on the environment.	☑ A major criticism of the existing FFRs is the use of CFRs and their impact on human health. This scenario would result in reduced chemical exposure.	☐ The economic impact would be dependent on the type of amendments, e.g., a reduction in the use of CFRs would be an economic benefit for the producers.
Introduction of an EPR for mattresses resulting in a recycling rate for EoL mattresses of 75%	☐ EPR is primarily an environmental policy.	☑ A primary objective of the EPR is to increase recycling rates through the funding of recovery infrastructure. ☑ The eco design (eco modulation) could restrict the use of potentially damaging materials/chemicals. Incentives to reduce harmful chemicals could future-proof recycling initiatives against future restrictions.	☑ The eco design (and eco modulation) could restrict the use of potentially damaging materials.	☐ The producer pays nature of the EPR could shift costs from LAs to producers.

Introduction of a mattress landfill and recycling ban due to significant content of CFRs classified as POPs	☐ The primary objective targets environmental and human health.	☐ The ban could have a major detrimental short to medium term impact on recycling while POPs were in use but would prevent potentially contaminated material entering the recycling system. ☑ The ban would be enforced on the basis that evidence shows the CFRs as substances of concern. The ban would intend to prevent environmental contamination.	☑ The ban would be enforced on the basis that evidence shows the CFRs as substances of concern. The ban would therefore prevent human and environmental exposure to these materials.	☒ The pre-treatment and EfW processing costs will likely be higher than the existing EoL management options.
Introduction of chemical traceability measures for mattresses	☐ Current mattress labelling shows that a product meets FFRs.	☑ Traceability future proofs the product in terms of enabling the decision on whether a product is recyclable or not and negates the need for testing every EoL product / or losing materials assumed to be contaminated (waste domestic seating case study). ☑ In long-life products such as mattresses, chemical traceability can enable an assessment of legacy chemicals to be made – taking consideration of new restrictions and protecting the environment from exposure to harmful chemicals.	☑ In long-life products such as mattresses, chemical traceability can enable an assessment of legacy chemicals to be made and protect human and environmental health from exposure to harmful chemicals.	☐ Setting up a system of traceability can be costly, but it can help avoid the even more costly EoL testing and potential unnecessary loss of materials (all domestic seating products assumed to be contaminated if can't be proven otherwise).

2 Scope and Methodology

2.1 Research Aims

The overarching aim of this project is to assess the impacts of CFRs on mattress recycling, reuse or remanufacturability in the UK, both qualitatively and, where possible, quantitatively from a fire safety and sustainability perspective. The data generated from the research provides:

- A cost benefit analysis that allows a better understanding of the economic as well as environmental and human health impacts of CFRs; and
- Options for industry to meet fire safety requirements for mattresses in a more safe and sustainable way.

2.2 Research Scope

All furniture sold in the UK must comply with current fire safety regulations. Mattresses were selected as a case study due to existing industry interest and engagement in improving product circularity and increasing recycling rates.

The scope of the project covers the whole life cycle of the mattress, as shown in Figure 1. Note that the arrow from 'mattress manufacturing' to 'use' refers to mattresses sold direct to consumers, such as, online sales. Additionally, end of life refers to the various management routes such as landfill disposal, Energy from Waste (EfW), recycling, remanufacturing and reuse.

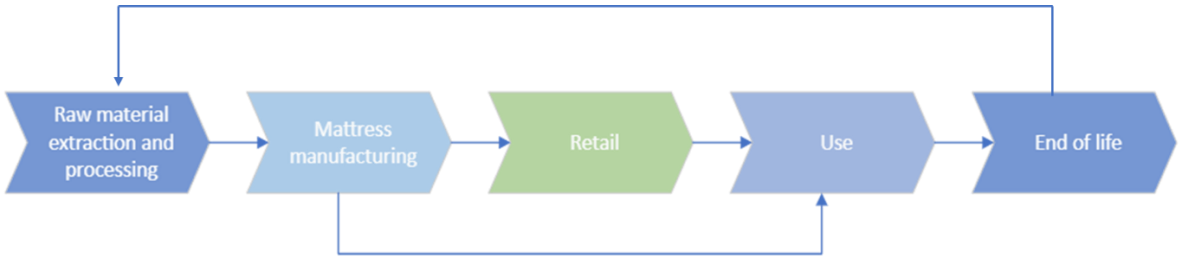

Figure 1: The mattress life cycle considered in this project with arrows showing supply chain and end of life waste management

2.3 Methodology

The study focused on the development of 5 possible scenarios regarding the future of the FFRs and the mattress industry, and evaluating their impacts:

- Business as Usual (BAU): Existing Furniture and Furnishings Regulations (FFRs) are retained and the assumption that there is full compliance with UK and EU REACH where applicable
- Amendments to the existing FFRs that would support a reduction in the use of CFRs during mattress manufacturing
- Introduction of an EPR scheme for mattresses

- Introduction of a landfill and recycling ban due to mattresses containing significant levels of hazardous CFRs (that have been classified as POPs)
- Introduction of chemical traceability measures

The study comprised of a typical three step approach:

- Data gathering
- Data interpretation
- Validation of findings

2.3.1 *Data collection*

This stage comprised of two key elements:

- Comprehensive literature review with a focus on published / citable evidence. Please note: this report builds on the recently published evidence review conducted by the environmental charity Fidra (4) (available at https://www.fidra.org.uk/download/the-impacts-and-solutions-for-chemical-flame-retardant-use-in-uk-mattresses-evidence-review/).
- Semi-structured interviews. 14 interviews were undertaken in January 2023 with industry stakeholders across the UK and EU, including material and mattress manufacturers, retailers, recyclers/reusers/remanufacturers, waste management companies and trade associations. Table 3 shows a summary of interviewees who contributed to this project, with both small scale and large-scale recyclers, as well as manufacturers covering a wide range of mattress types (i.e. low to high level price points) and components (i.e. foam, textiles, natural fibres).

Table 3: Summary of stakeholder interviews

Type of stakeholder	Number of interviews
Trade Association	2
Manufacturer (including both mattress and component manufacturers)	6
Retailer	2
Waste Management	2
Recycler (including reuse/remanufacturing)	2

2.3.2 *Data interpretation*

This comprised of two key elements:

- Economic analysis: this focused on the economic impacts associated with the 5 scenarios across the value chain from mattress manufacturing to end of life.
- Cost Benefit Analysis: this formed the appraisal of the 5 scenarios taking into consideration the four key impacts discussed above, namely, fire safety, environmental sustainability, environmental and human health, and economics.

2.3.3 *Validation of findings*

On 21st June 2023, Fidra and Oakdene Hollins hosted a roundtable of 25 industry experts to gather sentiments regarding the future of the FFRs and use of CFRs within the UK mattress industry, and to share early findings of this study. The roundtable was chaired by Oakdene Hollins and gathered stakeholders from across the mattress and furniture supply chain to ensure a broad range of informative discussion. Attendees included mattress manufacturers, retailers and recyclers, trade associations, government bodies, local authorities, environmental and waste management services, and representatives from the furniture sector.

Some of the questions and issues raised in this session were:

- Are the current FFRs effective and fit for purpose?
- How can the FFRs be amended to retain fire safety and reduce reliance on CFRs?
- How do CFRs affect product circularity?
- What are the impacts of fire retardancy compared to smoke toxicity for different CFRs?
- How can improved chemical transparency and traceability be achieved, and to what degree is it needed (i.e. to inform decision making at each stage of the supply chain)?
- How can chemicals be traced and managed in imported mattresses?
- Where are the current knowledge gaps and how can these be addressed?

The engagement of different stakeholders in discussing these issues was remarkable. All showed interesting identifying solutions that combine effective fire safety with high standards of health and environmental protection and sustainability. A defined solution is not yet clear, but there was consensus on the need for addressing the issue of the amount and nature of CFRs going into mattresses and other products. Fidra will look to liaise with these stakeholders towards pragmatic ways forward.

3 Scenarios

This section will look at the different scenarios to elaborate where possible on the impacts of the four aforementioned key aspects:

- Fire safety
- Human and environmental health
- Environmental sustainability
- Economic impacts

3.1 Scenario 1: Business-as-Usual: The Impact of Using CFRs in Mattresses

3.1.1 *Fire Safety*

Domestic mattresses sold in the UK must adhere to the Furniture and Furnishings (Fire) (Safety) Regulations 1988 (as amended). The Furniture and Furnishings Regulations (FFRs) were introduced in 1988, due to increased use of flammable synthetic foams and materials and following an increasing trend in the number of fire-related deaths in domestic dwellings in the 1960s to 1980s (8). The FFRs were also introduced as a response to the 1979 Woolworth's fire in Manchester, where damaged electrical cable ignited the flammable polyurethane foam contained within furniture (9). Statistics shows that from 1988 to 2011, the number of fire deaths in the UK decreased by over 50% (10). Three cited key contributing factors to the decrease in fire deaths are (11):

- Reduction in people smoking
- Increased installation of smoke alarms
- Introduction of the FFRs

Reduction in people smoking

Figure 2 shows that the percentage of the UK population that smoke has dropped from 31.6% in 1988 to 12.7% in 2021.

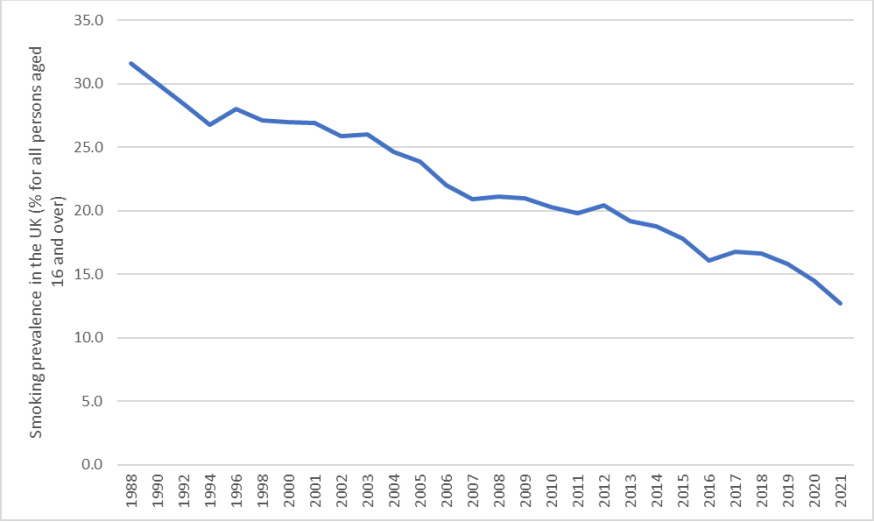

Figure 2: Smoking prevalence in the UK, 1988 to 2021 (12).

Increased installation of smoke alarms

Figure 3 shows the strong correlation between increased smoke alarm ownership and decreased dwelling fire deaths.

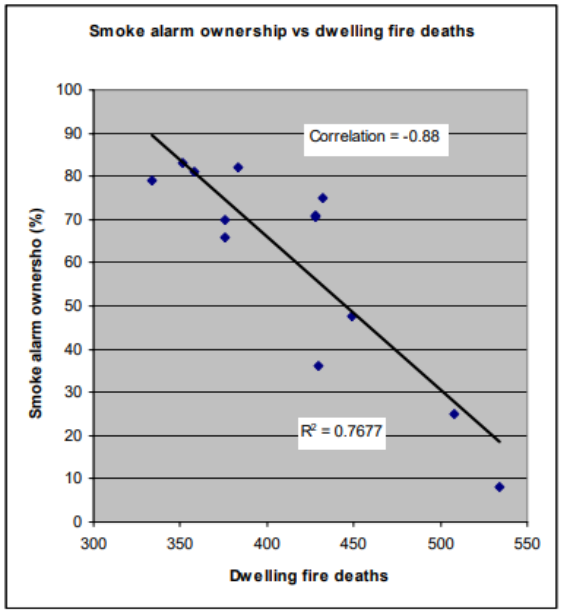

Figure 3: Smoke alarm ownership and dwelling fire deaths (England 1998 to 2001) (13)

Introduction of the FFRs

A study undertaken by the Department for Business, Innovation and Skills (BIS) in 2009 compared the fire statistics pre FFRs (1981-85) with the post introduction of FFRs (2002-07) and to isolate the impact associated with the FFRs, furniture and furnishings fires covered by the FFRs were compared against other fires (non-furniture and furnishings fires). The results can be seen in Table 4, which shows that in all three recorded categories (fires, non-fatal casualties, and deaths) the furniture and furnishings fires show a much greater reduction than other types of fires, which can be considered strong evidence that the FFRs have been impactful (13).

Table 4: Change between 1981-85 and 2002-07 in number of furniture and furnishings fires and other fires.

	Furniture and furnishings fires	Other fires
Fires	-37%	-10%
Non-fatal casualties	-26%	+75%
Deaths	-64%	-44%

A 2017 study by the Federation of European Fire Officers (FEU) reported that:

> *'At the present time about 5,000 people die each year as a result of a house fire in the European Union. Several American and British studies indicate that the number of deaths can be reduced by at least 25 percent by the use of fire safe furniture'* (11).

Conversely, the Fidra 2023 evidence review and a University of Central Lancashire 2017 report compared the UK with other jurisdictions that did not have FFRs, and the most conclusive comparison was against New Zealand. Figure 4 shows the results of the comparison and the report concluded that:

> '*It is evident that despite the greater statistical fluctuations from New Zealand's smaller population, the decrease in fire death rate is comparable to that in the UK*'.

Furthermore, when comparing the UK to other developed nations without FFRs, it is evident that despite the UK having one of the lowest rates of fire related deaths, the reduction of such rates between 1990 and 2019 is in line with the rest. This can be seen in Figure 5.

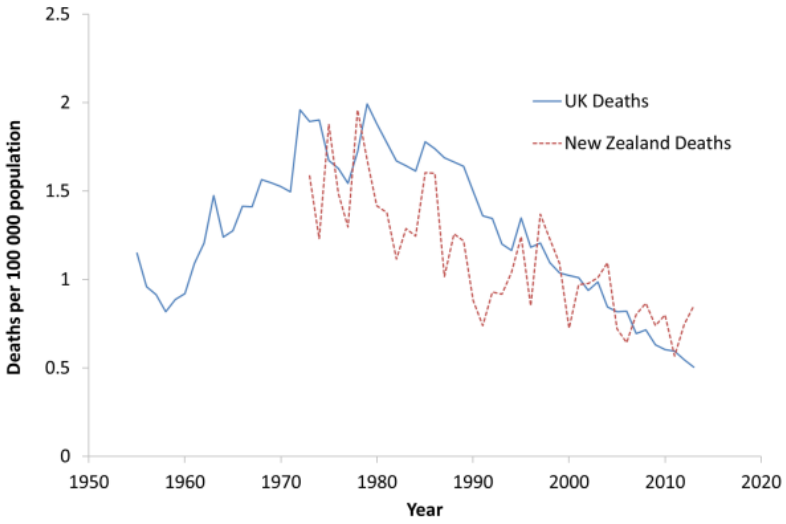

Figure 4: Fire deaths per 100,000 population in UK (with furniture flammability regulations) and in New Zealand (where there are no domestic furniture flammability regulations) (14).

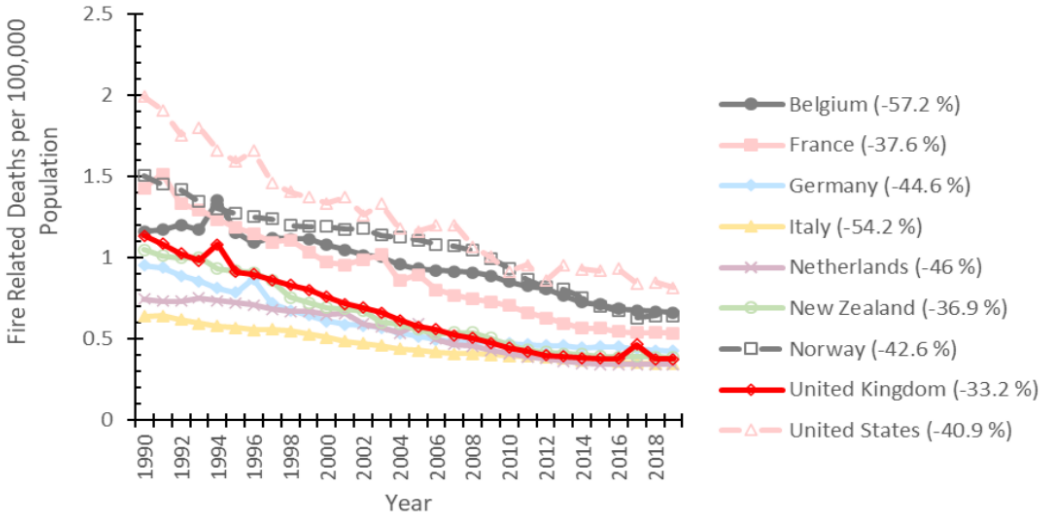

Figure 5: Fire related deaths per 100,000 people in the UK and other developed economies. (4)

Additionally, the FEU 2017 study reported that many European countries do not have any regulations regarding how upholstered furniture should be tested to make them safer from a fire perspective, and hence, a comparison can be made between EU countries without fire safety regulations for mattresses and the UK, with fire safety regulations. The FEU report states that in 2017 (11):

- 6% of all fatal fires in the Netherlands were due to 'combination ignition source' mattresses
- 12% of all fatal fires in Sweden were due to 'combination ignition source' mattresses

The UK government reported that in 2017/18 there were 8 fatalities attributed to bed mattresses in England and there was a total of 263 fatalities due to domestic fires, which equates to 3% (15). Although this is lower than that of the Netherlands and Sweden, Figure 6 shows that the percentage of fatalities due to mattress fires fluctuates dramatically and 2017/18 represented the lowest rate across the 12 years studied and in 5 of the 12 years the number of fatalities due to mattress fires in England exceeding that of the 6% in the Netherlands.

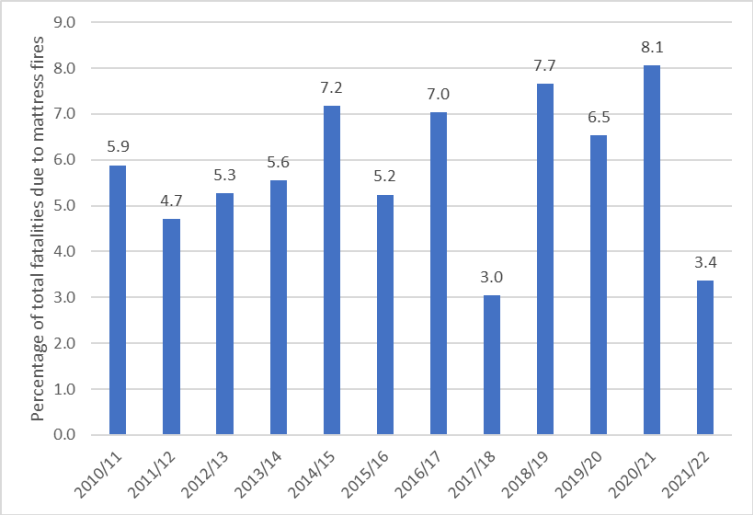

Figure 6: Percentage of total fatalities due to mattress fires in England from 2010 to 2022 (16)

For context and to gain a more holistic perspective, Figure 7 shows the number of fatalities in England from clothing/textiles – bedding fires. This shows that in 11 out of 12 of the years covered there are more fatalities from bedding fires than from mattress fires.

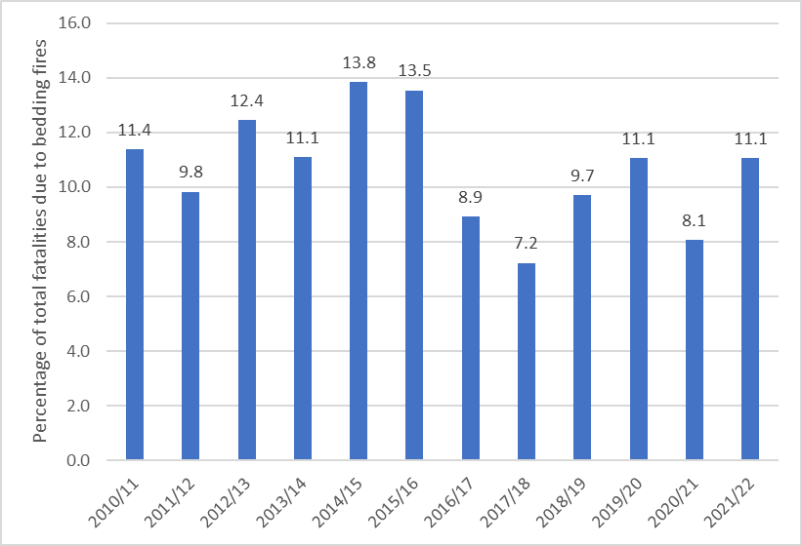

Figure 7: Percentage of total fatalities due to clothing/textiles – bedding fires in England (16)

Table 5 provides a summary of the impacts of CFRs used to meet the FFRs on fire safety from two key literature sources.

Table 5: Summary of conclusions on the impact of CFRs on fire safety

Impact	FEU 2017 (11)	UKRI 2023 (17)
Fire safety	Latest studies declare no clear link between the use of CFRs and fire safety (Study from ARCADIS EBRS in France). The use of CFRs in furniture may even increase the production of soot, smoke, toxic gases, and other harmful combustion products in a fire.	There is significant uncertainty about whether and to what extent CFRs contribute to fire safety. The UK's approach to securing fire safety is narrowly focused on passing ignition tests. This incentivises the addition of large amounts of CFRs to furniture and other items and materials, without a clear net benefit in reduction of harm. There is evidence that CFRs exacerbate fire smoke toxicity. A significant proportion of fire deaths are caused by inhalation of toxic fumes, including hydrogen cyanide gas and carbon monoxide.

Please note on the point of 'impact on fire safety' a number of interviewees for this study questioned whether the CFRs were retained in the mattresses across their whole lifetime. The FFR tests are at the 'point of manufacture' and not 'through life' and recyclers who tested used mattresses (typically ≥ 8 years old) suggested that they were not passing the FFR tests. If this is true, it indicates that CFRs do not stay in the product and are released into the home environment, adding to the concern of their effect on human health. Further research is needed to determine FFR compliance of mattresses in different stages of their lifecycle, and the impact this has on different dimensions.

FFRs test methods

The current FFR flammability tests require furniture and furnishings to pass a 'smouldering cigarette test' and a 'match flame test'. It should be noted that flammability tests for mattresses are not as strict as those for other furniture such as sofas where textiles undergo water soak and cleaning test procedures. In the Environmental Audit Committee's (EAC) 2019 report, Toxic Chemicals in Everyday Life, the match test was criticized for its inaccurate representation of real-world scenarios (2), such as cover fabrics being tested over flammable foam, despite such materials no longer being allowed in furniture construction. Lack of consideration for modern furniture construction, such as 'barrier' materials, was also highlighted.

3.1.2 *Impact of FFRs on environmental and human health*

Many of the mattress manufacturers in the UK meet the requirements of the FFRs by using CFRs and there is an ongoing public debate on the health and environmental risks of CFRs. The 2016 BEIS consultation on FFRs stated that:

> '*Whilst the current FFRs do not stipulate the use of CFRs, their use is widespread as the primary means of meeting the requirements of the Regulations. There are some concerns over the health and environmental impacts of certain CFRs: evidence suggests that flame retardant chemicals, particularly brominated flame retardants, when broken down into individual constituents, can be harmful to human and animal health, and the environment*'. '*For this reason, REACH the EU's chemical legislation, is proposing to restrict the use of decaBDE, a Brominated Flame Retardant (BFR) widely used in furniture production. If adopted the restriction would come into force in*

2018. A substitute has been found for decaBDE but the possibility of it also being restricted at some point in the future cannot be ruled out'.

The Fidra Evidence Review reports that CFRs are readily lost to the environment through production, use and disposal of everyday products. They have now been recorded in air, water, and soil, where they are known to persist and bioaccumulate. A study which compared UK and Norwegian dust, found that the levels of CFRs were higher in UK dust, including polybrominated diphenyl ethers (PBDEs) which were 20-30 times higher and several organophosphorus flame retardants which were 11 times higher (18).

Figure 8 shows the relationship between environmental health and human health, i.e. how environmental chemical exposure translates into firstly disease burden (measured in terms of Disability-Adjusted Life Year – DALY) and then monetary burden.

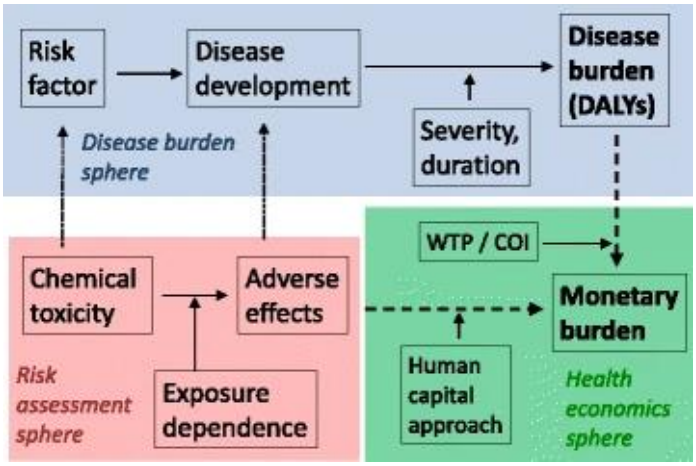

Figure 8: Calculation of the disease burden associated with environmental chemical exposures. Taken from Grandjean and Bellanger (19).

Using this framework, a study reported in the Lancet Diabetes and Endocrinology journal stated that PBDE flame retardants were the "greatest contributor to intellectual disability" in children. There is also the health care costs of such exposure and, in Europe, it was valued at €163 billion (3) (19). Despite the restrictions placed on PBDEs, the health effects likely still remain prevalent due to the presence of these CFRs in old items of furniture. As well as this estimation of the economic impact of health care due to chemical exposure, there is also a monetary burden associated with chemical contamination of the environment. The UK Government spent £14.5 billion in 2018 towards environmental protection, with the majority spent on solid waste management (including waste mattresses etc), as well as elimination/prevention of pollution (20).

This possible risk makes the substitution fall into the category of potential regrettable substitution. The recent UKRI (2023) report states that (17):

'*Scientific evidence of harm typically accumulates only after the introduction of CFRs to market and exposure has already become widespread*'.

2021 research by Blum et al. looks at the decline of PBDEs due to EU restrictions, and replacement of these CFRs with OPFRs. This research compared these two classifications of CFRs, and concluded that, this was an example of a regrettable substitution; given the likelihood of OPFRs being subject to policy restrictions and the similar characteristics between the two CFRs when considering health impacts.

Table 6 summarises the comparison.

Table 6: Comparison of evidence for different categories for both PDBEs and OPFRs. Adapted from Blum et. Al (21)

Evidence of	PBDE – Polybrominated Diphenyl Ethers	OPFR – Organophosphate Esters Flame Retardants
Global transport	☑	☑
High indoor abundance	☑	☑
Human exposure	☑	☑
Toxicity and ecotoxicity	☑	☑
Epidemiological findings	☑	☑
Policy changes	☑	Needed

While it has been argued that CFRs leaked into the environment can affect animal and wider environmental health, it is very challenging to quantify the effects of pollution as there are no common frameworks for assigning monetary values to nature. It is even more challenging to separate the effects of a specific group of chemicals in a complex system such as the environment. The 2021 report by Prof. Dasgupta, commissioned by the UK chancellor, is a detailed attempt to provide such frameworks and the concepts behind them (5). The report, titled 'The Economics of Biodiversity', provides a thorough introduction to concepts such as natural capital and ecosystem services, and frames them in terms which are compatible with financial systems and risk management, bringing these analyses a step closer to the business and government realm. While it is still complex to determine specific causality relationships for specific chemicals in specific geographies, there exists a relationship of pollution leading to the detriment of natural capital and environmental services, and said detriment causing ultimately an economic loss. The impacts summarised in Table 7 are the input of that causal relationship.

Table 7: Summary of conclusions on the impact of CFRs on human and environmental health

Impact	FEU 2017 (11)	UKRI 2023 (17)
Human health	The scientific community has identified many flame-retardant chemicals as substances of concern (SOCs) (22) for several adverse effects such as persistence, bioaccumulation, toxicity, mutagenicity, endocrine disruption and carcinogenicity. In furniture items, CFRs are added to foam and textiles. Firefighters suffer from increased exposure to toxic fumes such as hydrogen cyanide released from the combustion of materials containing CFRs. The exposure leads to adverse impacts on firefighters like multiple myeloma, Non Hodgkin lymphoma, prostate and testicular cancer. These are all associated with dioxin	A large and rapidly-expanding evidence base shows that exposure to CFRs increases risks of deleterious health effects including developmental and behavioural disorders, neurotoxicity, endocrine disruption, metabolic disruption, cancer, and many other effects.

	and furan exposure. Note that release of these compounds occurs during fires but CFR use exacerbates release of halogenated dioxins and furans (23). A 2015 study published in the Journal 'Environment International' showed that the UK had the highest concentration levels of a number of organophosphate flame retardants (PFRs) in household floor dust (24)	
Environmental health	CFRs migrate out of products and accumulate in the environment. Many CFRs are persistent and can undergo long range environmental transport.	CFRs migrate out of the goods to which they are added and are found in homes, classrooms, offices, public buildings, vehicles, and the wider environment. CFRs are ubiquitous environmental chemical pollutants and are present in rivers, lakes, sediments, soil, air, mammals, birds, and fish throughout the world.

Impact of REACH on environmental and human health

UK and EU REACH can be regarded as a legally binding chemical management system. The aims of UK REACH include: providing a high level of protection of human health and the environment from the use of chemicals make the people who place chemicals on the market (manufacturers and importers) responsible for understanding and managing the risks associated with their use (25). The Federation of European fire officers (FEU) considers REACH as the means of policing the chemicals contained within products that are placed on the market (POM). Unfortunately, interviewees suggested that REACH is best applied to products with a short shelf life rather than products such as mattresses since the whole issue of legacy chemicals and regrettable substitutions is raised, i.e. a chemical can be compliant with REACH at the point of manufacture, but during the product's lifetime the chemical can be moved to the prohibited list due to advancement in evidence. This issue was also highlighted in the EAC 2019 Toxic Chemicals in Everyday Life report (2):

> *'…for example soft furnishings that contain chemicals which were legal at time of manufacture, but which have subsequently been banned.'*

Figure 9 provides a summary of the CFRs used within mattresses in the UK and their current REACH classification. 4 of the 6 CFRs that are listed as POPs or restricted are brominated organic chemicals, with the other two being organophosphorus and chlorinated organic chemicals. The 36 different CFRs used within UK mattresses, identified in the Fidra Evidence Review alone, highlights the complexity of the challenge of maintaining a robust evidence based chemical management system.

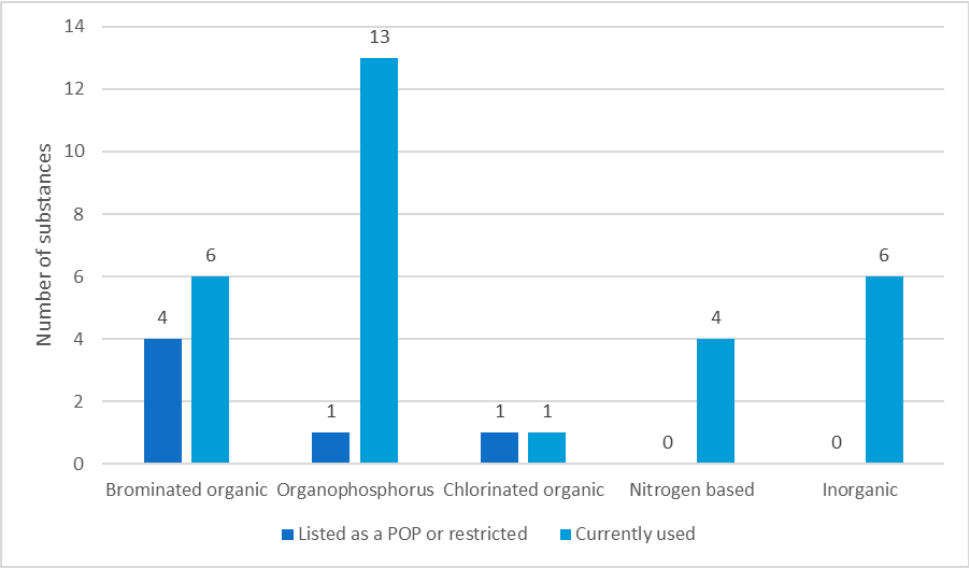

Figure 9: A summary of the CFRs used or that have been used in mattresses and their EU REACH classification (4).

Due to the uncertainty of the effectiveness of REACH in preventing the regrettable substitution of chemicals in long life products, and lack of chemical transparency along supply chains, the environmental impacts are very difficult to quantify. REACH on its own does not appear to be effective at supporting the recycling and remanufacture of mattresses. For REACH to support a circular economy it needs to prevent regrettable substitution. This could be achieved through a grouping approach to chemicals of concern and regulatory requirements for chemical traceability.

Environmental sustainability impacts: End-of-Life mattress recycling

The National Bed Federation (NBF) reports that only 24% of End-of-Life (EoL) mattresses are collected for recycling and further to this, only 14% of mattress materials are destined to be recycled (Figure 10), with landfill disposal and Energy from Waste (EfW) being the two most prominent disposal routes, from both collection losses and reprocessing waste.

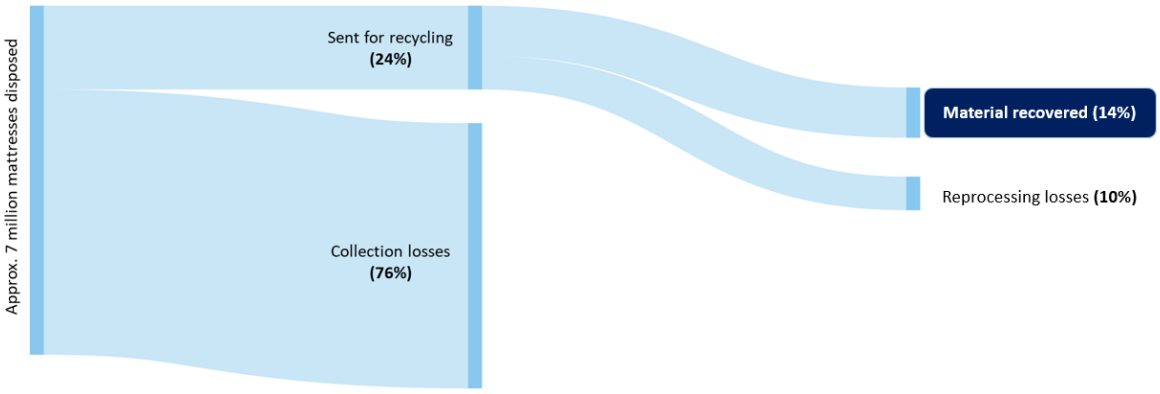

Figure 10: Sankey diagram showing the current recycling rate of mattresses in the UK.

The NBF has set a target of diverting 75% of EoL mattresses from landfill disposal by 2028 with EPR being considered a primary option to meeting this target. In addition, the NBF's 'Pledge for Our Planet' also

highlights a core requirement for signees to improve the transparency of SVHCs, with the intention of reducing or limiting their use (27).

Conversely, the recent Environment Agency (EA) regulations surrounding POPs in soft furnishings have resulted in EoL waste upholstered domestic seating being forbidden from being landfilled or recycled, and instead must be (high temperature) incinerated, unless they can be proven not to be contaminated, which, without transparency, is very difficult and expensive. Whilst mattresses are not currently categorized under this same regulation, due to containing lower levels of CFRs in comparison to soft furnishings, more robust evidence is needed to solidify this decision. If this regulation was applied to mattresses, due to the presence of CFRs, it would result in the NBF target being met by an unfortunate default scenario of incineration. However, this would clearly impact the mattress recycling industry, as well as placing immense strain on incineration processes and local authorities. Therefore, mitigation strategies to ensure that recycling of EoL mattresses remains viable and is future proofed against evolving chemicals regulations must be considered.

"[If mattresses were banned from recycling / landfill due to POPs] it would result in the NBF target being met by an unfortunate default scenario of incineration."

3.1.3 *Economic impact*

The general consensus among participants in the earlier BIS consultations was that a high level of fire safety should be maintained and that any changes to FFRs should maintain or advance this. As noted before, in 2014 the government provided an estimate of the impact the FFRs were having, stating that (28):

> '*The FFRs provide the highest levels of fire safety for domestic upholstered furniture in the world (only the Republic of Ireland has similar requirements). They save around 54 lives per year and prevent around 800 injuries and 1000 fires. These savings to health and property were valued at around £140m per year.*'

Conversely, we can see in Section 1.3 that this £140m per year benefit could potentially be eclipsed by the health care costs of exposure to CFRs, such as PBDE flame retardants valued at €163 billion per year across Europe, as well as the cost of environmental pollution abatements.

3.1.4 *Section conclusions*

Table 9 provides a summary of the section conclusions. For all four key impacts there are questions over the fitness for purpose of the current BAU activities. This coincides with the findings from a European Commission report, that stated (29):

> *'in some instances, drops in the number of fire deaths coincide with the introduction of non-flammability requirements for domestic consumer products. In other instances, however, there is no change in the ongoing trend of fire deaths. This suggests that these numbers do not reflect the stringency of non-flammability requirements, respectively that non-flammability requirements do not visibly decrease the number of fire deaths'.*

Additionally, from a circular economy perspective the EAC report states 'It will not be possible to implement the ambitions of the Government's 25 Year Environment Plan and the Resources and Waste Strategy without a rapid transition to a more circular economy for chemicals'.

Table 8: A summary of the section findings, with boxes denoting a subsequent favourable, unfavourable and uncertain future (shown as ticks, crosses and empty boxes, respectively) in the four impact categories shown.

Key Impact	Assessments
Fire safety	☑ The primary objective of the FFRs is fire safety

	☐ There is growing evidence questioning the functionality of CFRs in terms of reducing fatality rates from fires
Human and environmental health	☒ REACH aims to reduce the risk of chemicals, however, it has failed to prevent regrettable substitutions therefore undermining EoL mattress recycling, reuse or remanufacturing ☒ Vast and ever-increasing evidence of the health and environmental impacts of CFRs ☒ The 'long life' nature of mattresses can result in restrictions on chemicals being enforced during the life of the mattress, restricting the EoL circular economy options available ☒ The susceptibility to regrettable substitutions
Environmental sustainability	☑ This is a primary objective of UK REACH ☒ The 'long life' nature of mattresses can result in restrictions on chemicals being enforced during the life and at the end of life of the mattress, resulting in potential exposure to harmful chemicals during the life of the mattress ☒ The susceptibility to regrettable substitutions
Economics	☐ From the perspective of REACH compliance, this is dependent on the cost of the substitute materials ☐ The potential costs of CFR exposure could far outweigh the estimated cost savings from fire risks. However, there is currently a high level of uncertainty and this would need to be quantified to draw more robust conclusions

3.2 Scenario 2: Amendments to the Existing FFRs

In 2014, the BIS consultation on amendments to the Furniture and Furnishings (Fire) (Safety) Regulations proposed changes to the FFRs that would reduce the level of CFRs used whilst retaining the current levels of fire safety. The consultation stated that '*It is agreed that in around 98 – 99% of fabrics, a cover fabric that satisfies the match test of the FFR (Schedule 5) will satisfy that the cigarette test (Schedule 4)*'. The consultation concluded that: '*the proposed changes would reduce flame retardant use by up to 50%, saving the industry up to £50m per year, citing growing evidence that CFRs are harmful to health and the environment*' but would also '*meet the policy objective of maintaining, or improving, current levels of fire safety*'. At the time of writing, the FFRs are being reviewed and revised by the UK Government with a consultation expected in 2023.

3.2.1 *Policy review*

Section 3.1.1 demonstrates there is uncertainty on whether the current FFRs provide a high level of fire safety when compared with the fire statistics from other jurisdictions. However, rather than challenging this, at this stage it is considered more appropriate to take a bottom-up approach, namely, do the CFRs often used to meet the FFRs serve their required primary function? As discussed, current literature and interviews undertaken within this study questions whether CFRs are retained in mattresses and other soft furnishings, and hence, do they serve their primary function of providing high levels of fire safety throughout the lifetime of the product? This brings with it a multitude of questions:

- If the CFRs do not remain in the product, where do they go?
- Is the current 'point of manufacture' nature of the FFR testing 'fit for purpose'?
- How long do the CFRs remain in products and what are the determining factors?
- Ultimately, is the use of CFRs 'fit for purpose' from a fire safety perspective, throughout the lifetime of the product?

The determining factors will include the type of CFR used. For example, reactive CFRs that are chemically bound will not migrate as easily as the additive CFRs that are not chemically bound (30). The Environment Agency reports that '*The timescale of release of either type of flame retardant is likely to be long-term*' but does not quantify what 'long-term' refers to in terms of number of years (31).

Additionally, the University of Central Lancashire 2017 report highlighted the significance of fire toxicity and how its inclusion in the FFRs would reduce the use of CFRs and improve fire safety (14). Fire toxicity is dependent on the mode of action of the CFR and the Environment Agency suggests that there are five different modes (31):

- Gas dilution – use of additives which decompose into non-flammable gases. This reduces both fuel and oxygen levels in the vicinity of the flame (metal hydroxides, metal salts, and some nitrogen compounds).
- Thermal quenching – flame retardants which undergo endothermic decomposition, reducing the rate of burning (metal hydroxides, metal salts, and some nitrogen compounds).
- Protective coating – additives which promote charring or the formation of a liquid barrier, thus shielding the flammable material from the flame (phosphorus compounds, intumescent systems based on nitrogen or phosphorus compounds).
- Physical dilution of the flammable material – introduction of an inert non-flammable component (e.g. glass or minerals such as graphite).
- Chemical interaction – a flame retardant that decomposes into radical species, which compete effectively with the burning process (halogenated compounds).

Changes to the FFRs can lead to innovation. For example, a change in the furniture flammability standard in California (32) included the exclusion of the flaming ignition test and reduced the use of CFRs. Fibre fire barrier layers were one approach to meeting these new standards and companies, such as, IKEA developed new innovative products. IKEA reports that in the US, mattresses and mattress sets have a fibre fire barrier made of rayon/polyester batting that has an inherently fire-resistant property (33).

3.2.2 *Assessment of economic and environmental impact*

Economic impact to mattress manufacturers

The current FFRs result in both components and the composition of the whole mattress requiring flame retardants. This can be achieved through natural FRs, such as wool, or CFRs, such as TCPP. The level of CFRs required is dependent on the support system used, with spring-based mattresses only requiring FRs (natural or chemical) in the comfort layer, due to the natural flame retardancy of steel, but mattresses with a foam-based support system require CFRs in the support system and either natural or CFRs in the comfort layer. As part of a Parliamentary Review in 2019 (2), the cost of meeting the current FFRs using alternatives to CFRs was estimated in two different ways:

- Estimated at £19 per mattress. With 6.8 million mattresses Placed on Market (POM) in 2022, the cost of the whole mattress industry moving to alternatives to CFRs would be £129 million.
- At 25% of the retail price of the mattress. Statista reports that the UK mattress industry was worth $1 billion or £800 million in 2022, and hence, the switch to alternatives to CFRs is valued at £200 million.

Therefore, it is concluded that the estimate falls within the range of £129 million to £200 million.

Alternatively, what if the FFRs were revised to reduce the reliance on CFRs? Based on the feedback from stakeholder interviews, the cost of CFRs in foam-based mattresses is estimated to be in the range of £5.77 to £13.52 per mattress. The NBF 2022 annual report stated that foam mattresses accounted for 26% of the 6.8 million mattresses POM in 2020, with the remaining 74% being either coil spring or pocket spring mattresses. Therefore, with an estimated 1.77 million foam mattresses POM in 2020 the cost saving of moving to CFRs free support systems is estimated at £10.2 million to £23.9 million per year.

Economic impact to local authorities

Table 9 shows that currently landfill is the cheapest form of management of EoL mattresses for Local Authorities, at a cost including bulking up at the transfer station, transport to the landfill, gate fees and landfill tax of £4.49 per mattress. The cost of recycling and Energy from Waste (EfW) is very similar at £7.33 and £7.50 respectively. To put this into perspective, Figure 11 shows the total costs if all 6.4 million EoL mattresses went down each of these routes. This shows that recycling instead of landfill would cost Local Authorities over £18 million per annum. This is a reminder of why the recycling rate for mattresses sits at just 24%.

Table 9: Current cost in gate fees and taxes of EoL mattress waste management to local authorities

	Mean cost per tonne	Range of cost per tonne	Mean cost per mattress @ 25kg per unit
Non-Hazardous Landfill	Gate fee of £83 (median) + Tax of £96.70 = £179.70 (34)	£111.7 to £246.7	£4.49

Non-Hazardous EfW	£300[1]	£180 to £420	£7.50
Recycling	£293[2]	£180 to £480	£7.33

Any cost savings to the local authorities for moving to CFR free mattresses is heavily dependent on the mattress recyclers and whether they have any increase in revenue from the sale of recovered material that could be passed on to the local authorities in the form of lower gate fees.

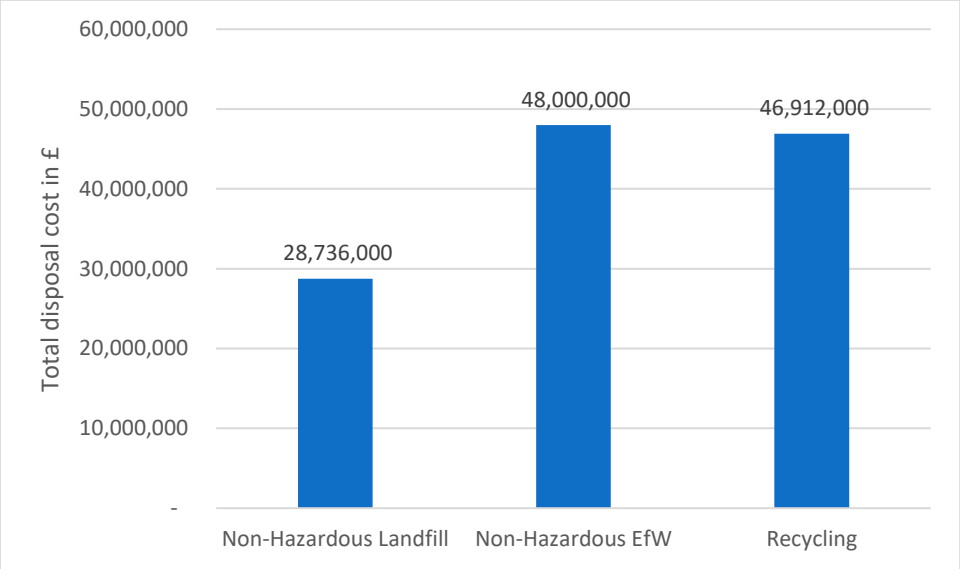

Figure 11: Comparison of the cost associated with the three EoL options for disposal of the 6.4 million EOL mattresses in the UK

Economic impact on mattress recyclers

Figure 12 shows that currently the gate fees of £7.33 per mattress accounts for over two-thirds of the mattress recyclers revenue, with the remainder split between the sale of recovered steel and the sale of recovered textiles.

[1] Waste management company estimate which includes shredding / pre-treatment of mattresses prior to incineration.
[2] Derived from interviews with 5 mattress recycling companies.

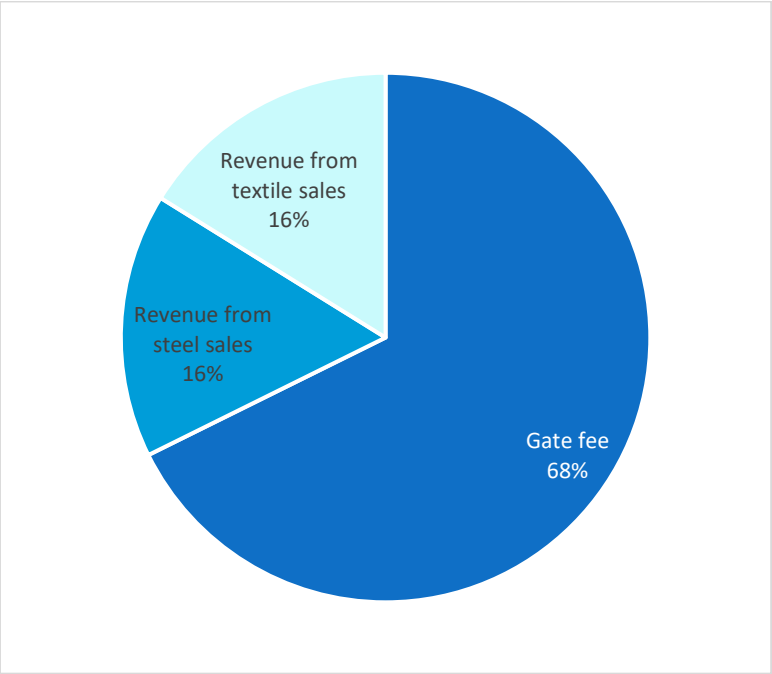

Figure 12: Estimated revenue from the recycling of mattresses

Figure 10 showed that 24% of EoL mattresses in the UK are collected for recycling but only 14% of material is actually recovered, i.e., an average yield rate of 58.3%. Contributing factors to this relatively low yield rate include:

- The small scale / volume of certain textile materials that do not command any economic value.
- The textile materials that are considered contaminated by CFRs which are either not recycled or have limited market demand / value[3].

Based on feedback from stakeholder interviews it is estimated that the removal of the CFRs would result in a 25% increase in the average yield rate, i.e. increasing the yield rate from 58.3% to 72.9% and that the non-contaminated materials would command a higher price of 10%, due to the opening up of such markets as the closed loop recycling of foam back into the mattress market, then the potential revenue from the sale of textiles would increase from £1.75 per mattress to £2.41. Based on the current recycling rate of 24% and 6.4 million EoL mattresses being generated, this increase would represent just over one million pounds (£1.014m).

Environmental analysis

The environmental analysis sections throughout this report use the following assumptions:

- Number of EoL mattresses generated per year = 6.4 million
- Average weight of an EoL mattress = 25kg
- Average composition of an EoL mattress = 51% steel and 49% textiles (including foam)
- Carbon impact ($kgCO_2e$/tonne), Table 10. Please note: the Defra statistics on carbon emissions reported a closed loop recycling value for textiles of -14,315 $kgCO_2e$ / tonne, however, this figure comprises of a mix of reuse and recycling. Defra states that '*the factor is very low because the*

[3] Feedback from stakeholder interviews

bulk of textile recycling is the reuse of clothing. The factor is weighted to around 70% reuse and 30% recycling'. Therefore, the ZWS figure is considered more representative of EoL recycling of mattresses.

Table 10: Carbon impact ($kgCO_2e$/tonne) by material and end fate (i.e. negative numbers represent carbon reduction)

Material	Closed loop recycling (35)	EfW (36)	Landfill (36)
Steel	-1,768	19	9
Textiles	-5,828	438	445

Figure 13 shows the total carbon impacts if all 6.4 million EoL mattresses went down each of the three routes. This show that recycling all mattresses with a yield rate of 100% would result in a carbon reduction of 600,000 tonnes, whereas both EfW and landfill would result in over 35,000 tonnes of carbon being generated.

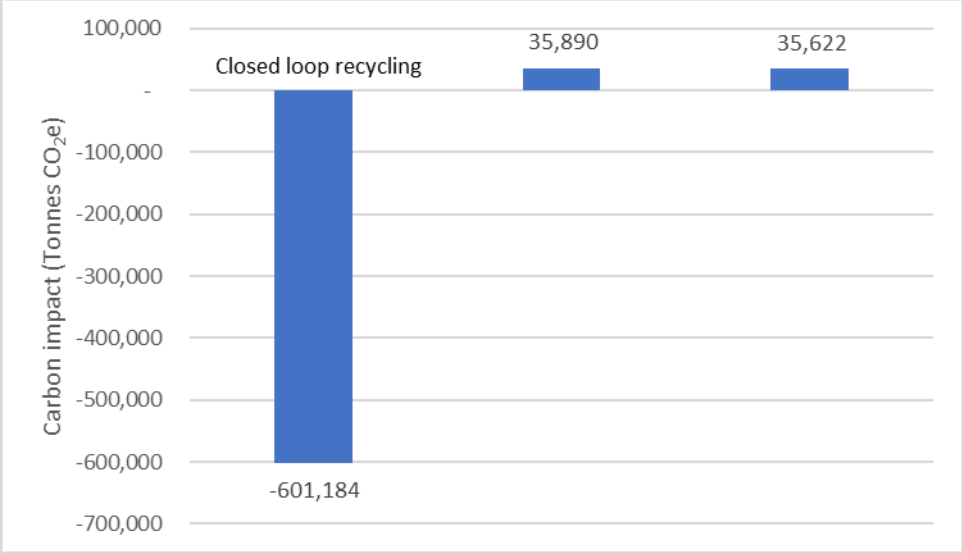

Figure 13: Comparison of the carbon impacts with the three EoL options for disposal of the 6.4 million EoL mattresses in the UK

Figure 14 shows the current situation with a 24% recycling rate and a 58.3% yield rate. It is assumed that the remaining 76% of mattresses is split evenly between EfW and Landfill at 38% each. This shows that only circa 27.5% of the potential benefits of recycling, shown in Figure 13 is currently being realised and this drops to 22.9% when the carbon impacts associated with EfW and landfill are taken into consideration. Please note: it is assumed that steel is recovered first and then the textiles, and hence, a 58.3% yield rate was taken as 51% steel and 7.3% textiles.

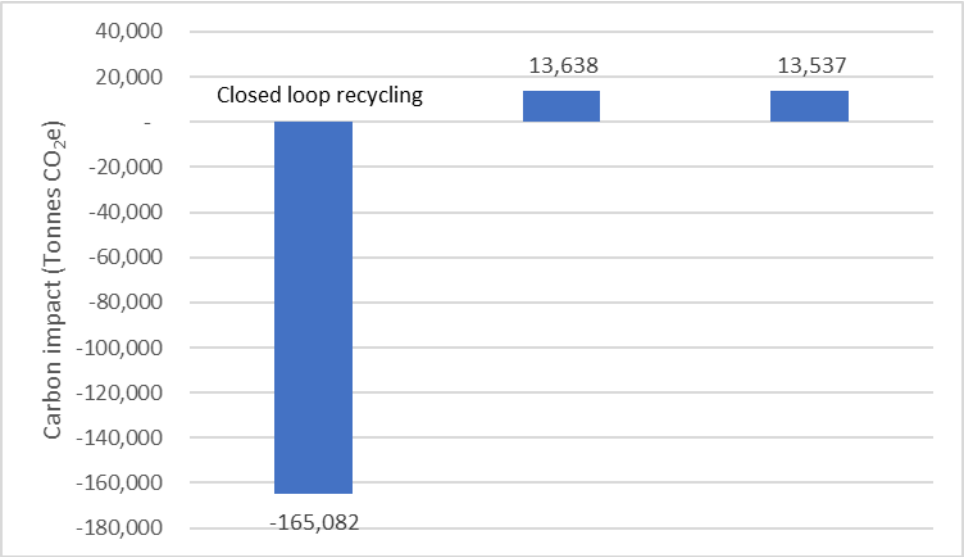

Figure 14: Current situation with a 24% recycling rate for mattresses and 58.3% yield rate

Referring back to the impact on mattress recyclers, if the amendment to the FFRs resulted in an increased yield rate to 72.9%, then the carbon reduction due to recycling would increase from circa 165,000 tonnes to 197,000 tonnes (an increase of 32,000 tonnes), shown in Figure 15. This would result in 33% of the potential carbon reduction through recycling being realised.

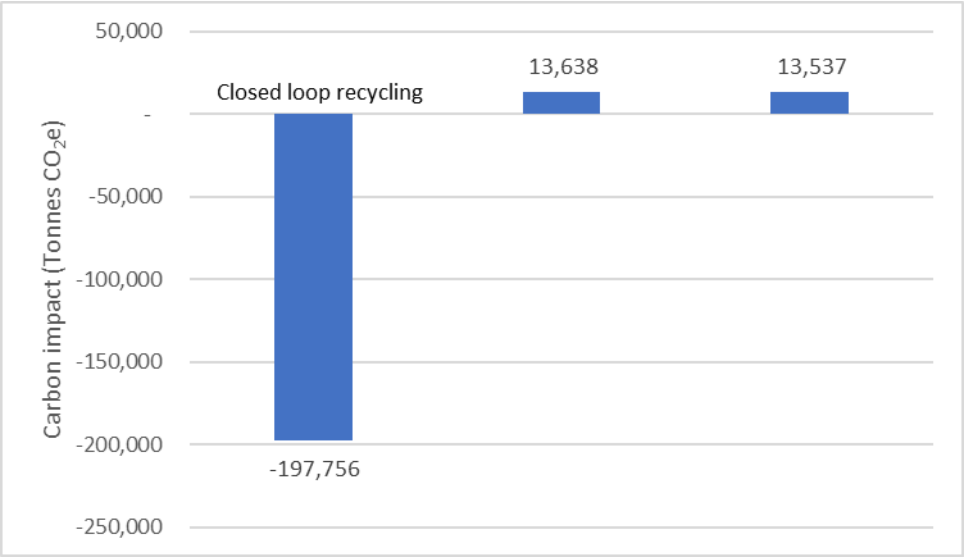

Figure 15: Revised scenario with a 24% recycling rate for mattresses and 72.9% yield rate

3.2.3 *Section conclusions*

This scenario allows for a reduction or elimination of CFRs used in mattresses, whilst also maintaining the primary objective of the FFRs – fire safety. This scenario would therefore result in reduced chemical exposure. However, this may not directly result in increases to the mattress material recycling rate, as this will depend on economic factors and market forces – dependent on the type of amendments.

3.3 Scenario 3: Introduction of an EPR for Mattresses

EPR comprises of two main goals at either end of the value chain, as can be seen in Figure 16:

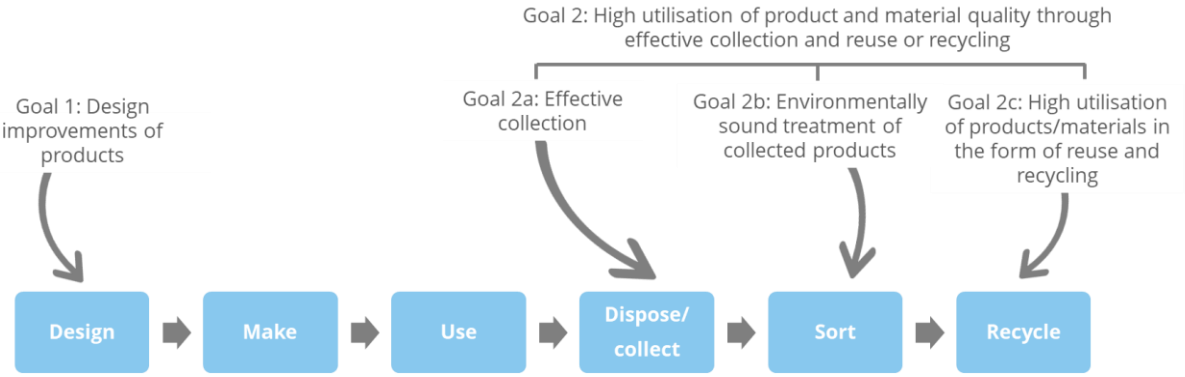

Figure 16: The original aims of an EPR

From an EoL mattress perspective, Goal 1 is focussed on increasing the recycling and, where possible, the reuse rate of EoL mattresses through effective collection (Goal 1a) and recycling / reuse treatment (Goal 1b) and finally, to close the loop by making the recovered products and materials available at the expected quality to the market (Goal 1c). Within the EPR, the development of the infrastructure to achieve this is funded through a producer fee, i.e., producers placing mattresses on the market must pay a fee into the EPR according to how many mattresses they place on market (POM).

This is aligned to the recommendations of the EAC 2019 report which stated that (2):

> *'We recommend that the Government works with the EU environment plan and REACH to mandate the phase out of chemicals harmful to the environment. This should include a ban on the use of substances of very high concern, including those under the threshold level, 'regrettable substitutes' and groups of chemicals whose properties mean they do not easily breakdown in the environment. The Government should introduce an EPR to enable the furniture industry to invest in technology to ensure the safe disposal of hazardous wastes containing harmful chemicals such as brominated flame retardants*'.

Goal 2 (design improvements) is aimed at providing a financial disincentive to placing poor environmentally performing products on the market through an additional 'penalty' fee, called an eco-modulator. In the current EPR consultation on packaging, the focus of the eco-modulation is on recyclability, i.e., those organisations placing packaging on the market that isn't recyclable must pay this 'penalty' fee. In France the EPR for mattresses includes an eco-modulator that refers to the size of the mattress since the larger 'bulky waste' mattresses are much harder to collect. EPR schemes also have the potential to encourage eco-design that includes reduced CFR use/CFR-free alternatives, and so help improve recycling yields. This is aligned with the Danish surcharge or 'circular fee' for beverage containers, i.e., there are circular economy surcharges on bottles and cans in the following cases (37):

- Coloured plastic
- Composite for plastic bottles and cans
- Composite for aluminium or steel bottles and cans
- Sleeves (labels that cover all or most of a bottle or can)
- PVC
- Patent stoppers (differentiated between porcelain and plastic patent plugs)

Additionally, the 2019 EAC Toxic Chemicals in Everyday Life report recommended that (2):

'the Government should use the introduction of an EPR scheme for plastic packaging to phase out the use of chemicals in plastics which have been found to be toxic to human and environmental health'.

This could be extended to the proposed EPR scheme for mattresses with the same focus on chemical safety.

3.3.1 *Policy review*

An EPR scheme is considered the best option for the NBF to meet their diversion from landfill target. However, although fire safety and human health are not the direct focus of this type of policy, due diligence on those effects is clearly of paramount importance for any company (30).

3.3.2 *Assessment of environmental impact*

Economic analysis

The assessment assumes that an EPR is put in place and that the UK meets the NBF target of a 75% diversion from landfill in 2028. Assuming this means a 75% recycling rate, then there would be economies of scale associated with the trebling of recycling from a current rate of 24% to 75%. Interviews with mattress recyclers suggest that the value of the textile fraction could double or treble from the current £1.75 per mattress. Figure 17 shows that if the recyclers profit margins were maintained and the additional revenue was used to reduce gate fees, then a doubling of the revenue from textiles would reduce the margin between recycling and landfill to within £7 million. Figure 18 shows that the trebling of the revenue from textiles would make recycling the lowest cost option.

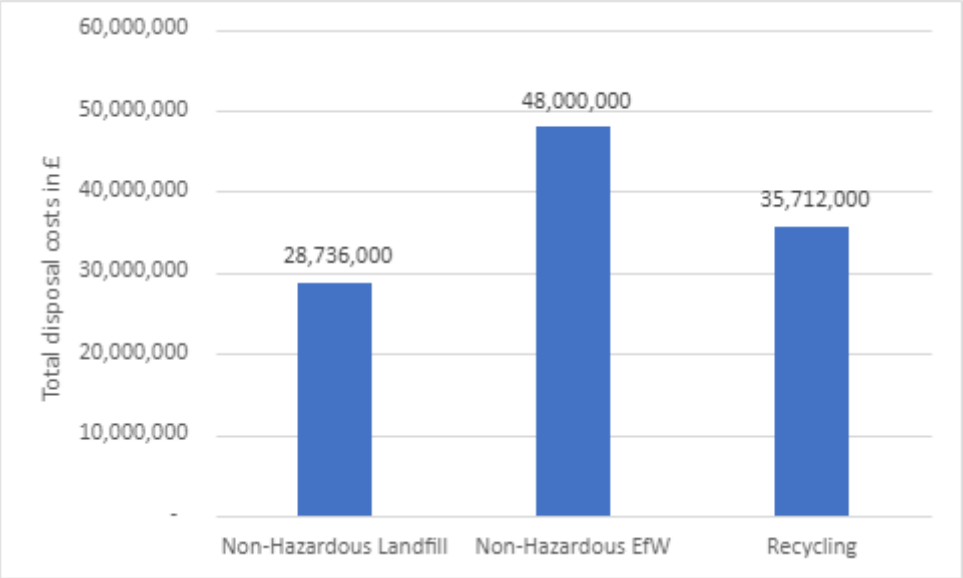

Figure 17: A doubling of the revenue from textiles due to the economies of scale benefit from an increased recycling rate.

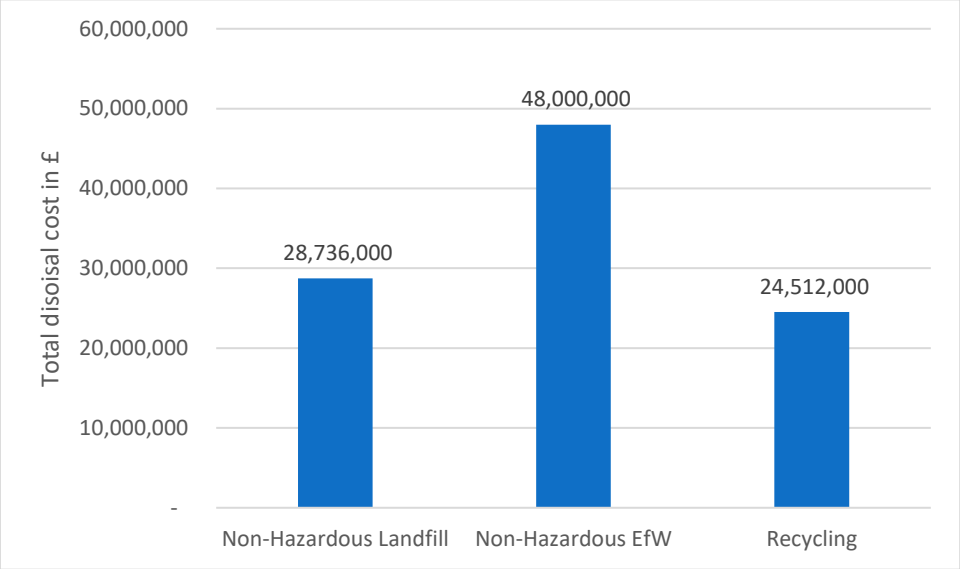

Figure 18: A trebling of the revenue from textiles due to the economies of scale benefit from an increased recycling rate.

Environmental analysis

Figure 19 shows the impact on carbon if the recycling rate increased to 75% (51% steel and 24% textiles). The estimated carbon reduction of 311,416 tonnes is almost 150,000 tonnes (146,334 tonnes) better than the current situation.

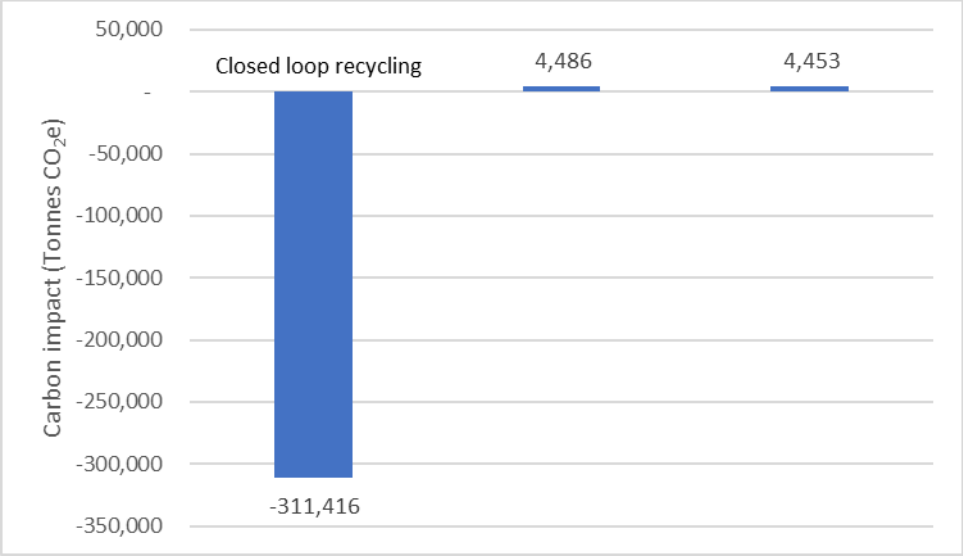

Figure 19: Revised scenario with a 75% recycling rate for mattresses and 72.9% yield rate

3.3.3 *Section conclusions*

Whilst the primary objective of an EPR scheme is not fire safety, included initiatives such as ecodesign and eco-modulation for mattresses will likely restrict the use of potentially damaging chemicals, so reducing the use of CFRs and encouraging an increase in mattress material recycling rates.

3.4 Scenario 4: Introduction of a Landfill and Recycling Ban due to CFRs being Classified as POPs

From an EoL perspective, the presence of CFRs can either be considered an intentional functionality or a contaminant. For organisations remanufacturing or reusing EoL mattresses in the UK it is an intentional functionality, i.e., they are positively hoping that they are present so that they do not have to add them to pass the FFRs themselves. However, for similar operators on continental Europe or for organisations looking to recycle the material into other products that do not contain CFRs, this would be seen as a contaminant. For example, the growing relevance of e-waste recycling has led to a wealth of papers examining waste expected to be recycled, suggesting that they could be the possible source of contamination: restricted POP-BFRs were found in high enough concentrations to classify most Waste Electrical and Electronic Equipment Recycling (WEEE) as POPs waste in England and Wales (30). Additionally, the Environment Agency has placed a ban on the landfilling or recycling of soft furnishings, such as sofas, due to the presence of POPs; this ban however, does not include mattresses. Known use of CFRs in mattresses and evidenced cases of regrettable substitution raises similar uncertainty for the future management of EoL mattresses.

3.4.1 *Assessment of environmental impacts*

This assessment is split into two possible cases:

- Case 1: Restrictions on EoL routes for mattresses containing CFRs.
- Case 2: Restrictions on EoL routes for mattress components containing CFRs.

Case 1: Restrictions on EoL routes for mattresses containing CFRs that are currently in circulation

In the case where the presence of CFRs resulted in the whole mattress being considered non-recyclable, then the whole mattress recycling industry would be lost until such a time as CFRs were banned and phased out of use. The cost to Local Authorities would be dependent on their current means of managing EoL mattresses, but Figure 21 shows that the lowest cost option, namely landfill, will be lost; potentially costing local authorities nearly £20 million per annum, i.e., moving from landfill to EfW[4]. This is likely to be an underestimate, due to the lack of EfW capacity (pre-treatment and processing) for mattresses, and the increased demand would most probably result in increased gate fees to fund the infrastructure required to process this additional material as well as increased fly tipping. There is also likely to be regional disparity in the impact of the ban, due to some jurisdictions having local access to EfW plants whereas others would be subject to large transport costs, as well as cost burdens towards PPE and ensuring separation of the 'hazardous' mattresses during this transit.

Case 2: Restrictions on EoL routes for mattress components containing CFRs

Cost to recyclers:

If the steel could be recycled but the textiles would need to be incinerated, then the revenue generated per mattress would drop by £1.75 and the additional cost of incinerating the textile fraction would be £5.64 per mattress, i.e., a loss of revenue per mattress equivalent to £7.39 per mattress (see Figure 20). Please note: this calculation does not take into consideration the additional abatement costs that would be in place to reduce the human exposure to airborne particles during the disassembly of the mattress.

[4] It should be noted that the calculations shown use the commercial gate fees associated with the alternative waste management methods which may not include the externality costs, e.g. the additional costs to environmental and human health.

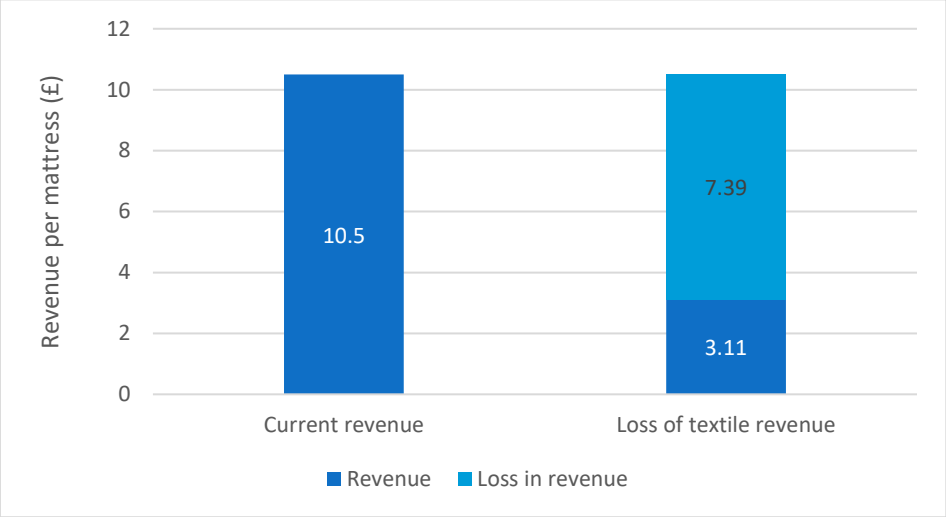

Figure 20: The estimated loss of revenue for recyclers if textiles could no longer be recycled.

Cost to local authorities

Assuming that the recyclers would need to maintain the current revenue levels then they would need to pass the costs onto the Local Authorities in the form of higher gate fees or receive subsidies from government until such a time as waste was no longer hazardous, i.e., gate fees increasing from £7.33 to £14.72 per mattress. Figure 21 shows the impact this would have on the cost of recycling versus current incineration or landfill costs, with the cost of recycling more than doubling to £46 million higher than the next most costly option of EfW. It could also be argued that since it is only the steel that is being recovered and in modern EfW plants the steel is recovered from the bottom ash, then why not simply use EfW?

It is relevant to note that upholstered domestic seating (seating furniture) containing POPs have been defined as not suitable for landfills or EfW in England, and they are required to be incinerated in facilities that are authorised to accept POPs waste (high temperature incineration - HTI) (38). If a similar directive was to be defined for mattresses containing CFRs, the cost of HTI would need to be considered. However, there's no evidence so far for a move towards declaring mattresses as hazardous waste.

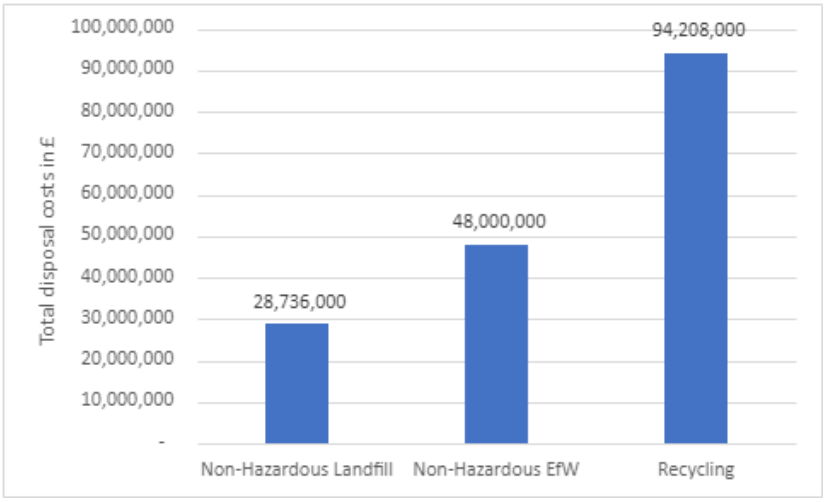

Figure 21: Additional cost of recycling if textiles were deemed non-recyclable

3.4.2 *Section conclusions*

A mattress landfill and recycling ban due to POPs would result in reduced environmental and human exposure to harmful chemicals, due to these contaminated materials being sent for incineration. Whilst there is a clear benefit to reducing pollution, this scenario will result in a major detrimental short to medium term impact on recycling while POPs were in use but would prevent potentially contaminated material entering the recycling system. From an economic perspective, the pre-treatment and EfW processing costs will likely be higher than the existing EoL management options.

3.5 Scenario 5: Introduction of Traceability Measures

The EAC 2019 report 'Toxic chemicals in everyday life' concluded that (2):

> '*We recognise the challenge of communicating complex chemical information to the public. Our desire is not to cause consumers concern about the chemicals used in products but to raise their awareness and to assist them make more informed purchasing decisions. Our survey of attitudes to chemicals indicated that consumers want this knowledge. We recommend reform of the labelling system for chemicals in consumer products'.*

The Fidra Evidence Review determined that the lack of full chemical traceability and effective product recall in current chemical management practices means harmful chemicals may remain in use for the lifespan of a product and continue to resurface through recycled and reused materials. This was highlighted in findings from a recent study for the Office for Product Safety and Standards (OPSS) on chemical safety concerns in recycled materials, which determined chemical safety risks to be driven "by the purposeful addition of functional additives to products", quoting examples such as heavy metals, phthalates and flame retardants (30).

Research conducted through Fidra's Evidence Review found that UK retailers also consistently highlighted greater transparency of chemical content as an important factor in simplifying their own chemical management; in a 2023 academic consensus paper, developing a "labelling system for tracking the use of chemicals in products, including flame retardants" was one of the key recommendations for the UK government to protect the circular economy from "undesirable substances" (17).

Numerous case studies have demonstrated how lack of chemical transparency, coupled with cases of regrettable substitution, can leave recycling efforts vulnerable to contamination with newly restricted or otherwise harmful chemicals:

- Bisphenol-A (BPA) found in recycled napkins and toilet paper
- Per- or poly-Fluorinated Alkyl Substances (PFAS) found in paper and cardboard food packaging labelled suitable for recycling or composting
- Chemical Flame Retardants (CFRs) found in recycled plastic products such as kitchen utensils and toys

One of the future risks highlighted by the recyclers interviewed for this study, was that there will become a need to test mattresses to establish their chemical composition. The concern being that the testing could be both costly and time consuming. An alternative approach is for producers to provide this information and a number of different options are being considered. For example, California law requires a label indicating whether there are CFRs or not in the furniture. These laws took effect in January 2015 (39).

An alternative approach is the use of smart labelling or 'product passports' to provide a more comprehensive breakdown of relevant chemical content data along supply chains, whilst still ensuring protection of potentially commercially sensitive information. This would also allow information to be dynamic and remain up to date with latest guidelines and restrictions.

These traceability measures would not only benefit the EoL mattress recyclers but also the mattress manufacturers, retailers and consumers wishing to take greater control over the chemicals used in the products they make, sell and purchase.

3.5.1 *Assessment of environmental and health impacts*

The Fidra Evidence Review (4) states that the lack of chemical transparency and traceability allows chemicals to be recycled into products unintended for their use, without means of identification or extraction. This can result in the unintended 'contamination' of recycled material and potential impacts on health and the wider environment.

There is much uncertainty over the impact this scenario will have since it is dependent on the level of 'substances of concern' that are contained in UK EoL mattresses. The introduction of chemical traceability measures will introduce a level of de-risking to the EoL mattress recyclers, in that, they would prevent the need for all mattresses to be classified as hazardous waste (similar to the EA domestic seating POPs ruling), should levels of CFRs classified as POPs be deemed to be significant in mattresses. This would also be the case if other CFRs currently used in UK mattresses were classified as POPs or otherwise restricted in the future.

It is not possible to quantify the benefits of consumers choosing to switch products at the point of purchase or indeed the overall impact this would have on the market, but this can be considered a means of future proofing.

3.5.2 *Section conclusions*

Traceability of mattress materials future proofs the product in terms of enabling the decision on whether a product is recyclable or not and negates the need for testing every EoL product / or losing materials assumed to be contaminated. This traceability aspect becomes more relevant for longer life products, such as mattresses, which may contain legacy chemicals – thereby taking into account new legislation and restrictions, and so limiting human and environmental exposure to harmful chemicals. Whilst the benefits are clear, setting up a system of traceability can be costly. However, this must be balanced by the potential for reduced unnecessary losses of recyclable mattress materials which may have otherwise been classed as 'contaminated'.

4 Recommendations

Throughout this report, scientific and other noteworthy studies have been cited that provide recommendations on how to tackle the issue of CFRs. For example, the 2014 BIS consultation (28), the 2019 EAC report Toxic Chemicals in Everyday Life (2) and the Fidra 2023 Evidence Review (4). For this study we have consolidated the recommendations into four focus points:

- Consensus building through the development of science-based evidence to address the need for a systemic approach to fire safety standards, with consideration and certainty of their effects on human and environmental health. This is in line with calls b and e from Page et. al (17).
- UK Government to produce and adhere to a timeline for the revision of the FFRs. As well as encouraging a reduction in the use of CFRs in UK furniture and furnishings, the revision should have a stronger focus on fire safety in relation to fire smoke toxicity, environmental sustainability, environmental and human health, and economic viability taking all costs into account including externalities (17).
- CFRs in mattresses to be considered in the wider context of improving chemical management systems in other products, such as toys and plastics. This would include improved transparency and traceability measures.
- Current discussions on the implementation of an EPR scheme for mattresses should evaluate different eco-modulation mechanisms that go beyond recyclability with the incorporation of chemical sustainability.

5 References

1. RSC Interest Group Toxicology. *Toxicology Topics in Brief Brominated Flame Retardants (BFRs).* s.l. : Royal Society of Chemistry Toxicology Interest Group, 2022.

2. House of Commons, Environmental Audit Committee. Toxic Chemicals en Everyday Life. *www.parliament.uk.* [Online] https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/1805/180502.htm.

3. LaMotte, S. Plastics and pesticides: Health impacts of synthetic chemicals in US products doubled in last 5 years, study finds. *CNN Health.* [Online] 22 July 2020. https://edition.cnn.com/2020/07/21/health/chemical-endocrine-disruptor-doubled-wellness/index.html.

4. Fidra. *Managing Chemicals of Concern Within a Circular Economy: The Impacts and Solutions for Chemical Flame Retardant Use in UK Mattresses.* s.l. : Fidra, 2023.

5. Dasgupta, P. *The Economics of Biodiversity, The Dasgupta Review.* London : HM Treasury, 2021. ISBN 978-1-911680-29-1.

6. Department for Buisness, Energy & Industrial Strategy. Valuation of greenhouse gas emissions: for policy appraisal and evaluation. *gov.uk.* [Online] 2 September 2021. https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal/valuation-of-greenhouse-gas-emissions-for-policy-appraisal-and-evaluation.

7. Valuation of greenhouse gas emissions: for policy appraisal and evaluation. *Gov.uk.* [Online] [Cited: 25 July 2023.] https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal/valuation-of-greenhouse-gas-emissions-for-policy-appraisal-and-evaluation#annex-1-carbon-values-in-2020-prices-per-tonne-of-co2.

8. Department for Business, Energy & Industrial Strategy. *Consultation on Updating the Furniture and Furnishings (Fire) (Safety) Regulations.* 2016.

9. What happened in the 1979 Manchester Woolworth fire? *BBC News.* [Online] [Cited: 25 July 2023.] https://www.bbc.co.uk/news/uk-england-manchester-20598600.

10. Office for Product Safety & Standards. *Characteristics of Modern Domestic Fires and the Implications for Product Performance Testing.* Birmingham : Department for Business, Energy and Industrial Strategy, 2021.

11. Hagen, R. et al. *Fire Safety of Upholstered Furniture and Matresses in the Domestic Area: European Fire Services Recommendations on Test Methods.* s.l. : FEU, 2017.

12. Office for National Statistics. Smoking prevalence in the UK and the impact of data collection changes: 2020. *Office for National Statistics.* [Online] 7 December 2021. https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/drugusealcoholandsmoking/bulletins/smokingprevalenceintheukandtheimpactofdatacollectionchanges/2020.

13. Consumer and Competition Policy Directorate, BIS. *A Statistical Report to Investigate the Effectiveness of the Furniture and Furnishings (Fire) (Safety) Regulations 1988.* London : Department for Business, Innovation and Skills, 2009.

14. *Flame retardants in UK furniture increase smoke toxicity more than they reduce fire growth rate.* McKenna, S. et al. s.l. : Elsevier Ltd, 2018, Chemosphere, Vol. 196, pp. 429–439.

15. Home Office. Statistical Data Set - FIRE0603: previous data tables. *gov.uk.* [Online] 2018. https://www.gov.uk/government/statistical-data-sets/fire0603-previous-data-tables.

16. —. Collection: Fire Statistics. *gov.uk.* [Online] https://www.gov.uk/government/collections/fire-statistics.

17. *A new consensus on reconciling fire safety with environmental & health impacts of chemical flame retardants.* Page, J. et al. 2023, Environment international, Vol. 173.

18. *Legacy and alternative flame retardants in Norwegian and UK indoor environment: Implications of human exposure via dust ingestion.* Kademoglou, K. et al. Environment International , Vol. 102, pp. 48-56.

19. *Calculation of the disease burden associated with environmental chemical exposures: application of toxicological information in health economic estimation.* Grandjean, P., Bellanger, M. s.l. : Environmental Health, 2017, Vol. 16.

20. Statistics, Office for National. Environmental protection expenditure, UK: 2018. [Online] [Cited: 27 June 2023.] https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/environmentalprotectionexpenditureuk/2018#main-points.

21. *Organophosphate Ester Flame Retardants: Are They a Regrettable Substitution for Polybrominated Diphenyl Ethers?* Blum, A. et al. 11, Environmental science & technology letters, Vol. 6, pp. 638-649.

22. Anthesis UK. *Understanding the Product Data Needs of Waste Operators in the UK.* 2022.

23. *Flame Retardants - Do they save lives or cause harm?* [Online] Green Science Policy Institute. [Cited: 27 June 2023.] https://greensciencepolicy.org/harmful-chemicals/flame-retardants/.

24. *Sources and human exposure implications of concentrations of organophosphate flame retardants in dust from UK cars, classrooms, living rooms, and offices.* Brommer, S., Harrad, S. 83, 2015, Environment international, pp. 202–207.

25. UK registration, evaluation, authorisation and restriction of chemicals (REACH). *Health and Safety Executive.* [Online] [Cited: 26 July 2023.] https://www.hse.gov.uk/reach/.

26. HM Government. *Our Waste, Our Resources, A Strategy for England.* 2018.

27. National Bed Federation. *Pledge for our Planet.* [Online] [Cited: 27 July 2023.] https://www.bedfed.org.uk/nbf-green/pledge-for-our-planet/

28. Department for Business, Innovation & Skills. *Consultation on amendments to the Furniture and Furnishings (Fire) (Safety) Regulations: summary of responses Schedule 5 - The Match Test - Part 1 and Schedule 4 - The Cigarette Test.* 2015.

29. ARCADIS. *Evaluation of data on flame retardants in consumer products.* Brussels : European Commission Health & Consumers DG, 2011.

30. WRAP. *The use of recycled materials in consumer products and potential chemical safety concerns.* s.l. : Office for Product Safety & Standards, 2023.

31. Fisk, P. R.,. *Prioritisation of Flame Retardants for Environmental Risk Assessment.* Wallingford : Environment Agency, 2003. ISBN: 978-1-84432-956-4.

32. State of California - Department of Consumer Affairs. *Requirements, Test Procedure and Apparatus for Testing the Smolder Resistance of Materials Used in Upholstered Furniture.* Sacramento : s.n., 2013.

33. IKEA. Are flame retardants used in IKEA products? *Ikea US.* [Online] [Cited: 8 June 2023.] https://www.ikea.com/us/en/customer-service/knowledge/articles/9e7e4gb6-e11e-4d93-808g-2400b5405g71.html.

34. WRAP. *Comparing the costs of alternative waste treatment options.* 2022. [Online] [Cited 27 July 2023] https://wrap.org.uk/resources/webinar/gate-fees-202122-report-comparing-costs-alternative-waste-treatment-options

35. Zero Waste Scotland. Carbon Metric Factors. *ZWS.* [Online] 15 December 2021. https://cdn.zerowastescotland.org.uk/managed-downloads/mf-xt1k3gt7-1678114685d.

36. Department for Environment Food & Rural Affairs. *Experimental Statistics on the carbon impact of waste from households managed by local authorities in England.* 2022.

37. Dansk Retur System. Cost of having drinks in the deposit system. *danskretursystem.dk.* [Online] [Cited: 13 June 2023.] https://danskretursystem.dk/for-virksomhed/udgifter/.

38. Environment Agency. Manage waste upholstered domestic seating containing POPs. *Gov.uk.* [Online] 2022 December 20. https://www.gov.uk/guidance/manage-waste-upholstered-domestic-seating-containing-pops.

39. My Chemical Free House. How to Reduce Exposure to Flame Retardants in the Home. *My Chemical Free House.* [Online] 22 June 2019. https://www.mychemicalfreehouse.net/2019/06/avoiding-flame-retardants-in-home.html.

40. Office for Product Safety & Standards. *Updating the Furniture and Furnishings (Fire) (Safety) Regulations 1988.* s.l. : Department for Business, Energy & Industrial Strategy, 2019.

41. Home Office. *Detailed Analysis of Fires Attended by FRSs England, April 2021 to March 2022: data tables.* 2022.

42. Breast Cancer UK. *BCUK Background Briefing - Flame Retardants.* London : s.n., 2017.

43. IKEA. *Are flame retardants used in IKEA products?* [Online] [Cited: 27 July 2023] https://www.ikea.com/gb/en/customer-service/knowledge/articles/g8ce95ge-ddc2-44c4-gc05-4d950d652163.html#:~:text=We%20use%20flame%20retardants%20in,only%20add%20them%20if%20necessary.&text=All%20IKEA%20products%20are%20tested,to%20current%20regulations%20and%20standards.

44. Statista. Mattresses - United Kingdom. *Statista.* [Online] 2023. https://www.statista.com/outlook/cmo/furniture/bedroom-furniture/mattresses/united-kingdom.

45. Stewart, J. Experts Highlight Environmental and Health Risks of Current UK Fire Regulations. *Imperial College London.* [Online] 28 February 2023. https://www.imperial.ac.uk/news/243413/experts-highlight-environmental-health-risks-current/.

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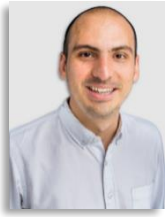

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From its offices in Aylesbury and Brussels, Oakdene Hollins provides research and consulting services to clients under three main themes:

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