Life Cycle Analysis of Mattress Recycling in California

Final Study Report

SCOPE 3 CONSULTING

v0.3

Nov 16, 2022

Table of Contents

Executive Summary

Introduction
The Mattress Recycling Council (MRC), a non-profit organization which administers mattress recycling programs in states with mattress product stewardship laws, sponsored a life cycle analysis (LCA) of its California mattress recycling operations conducted for calendar year 2021. Since 2016, MRC's California program has collected, transported, and recycled over 8.5 million mattresses and box springs (together called mattresses or units). Scope 3 Consulting conducted the LCA to describe and measure the environmental implications of this mandated statewide recycling program.

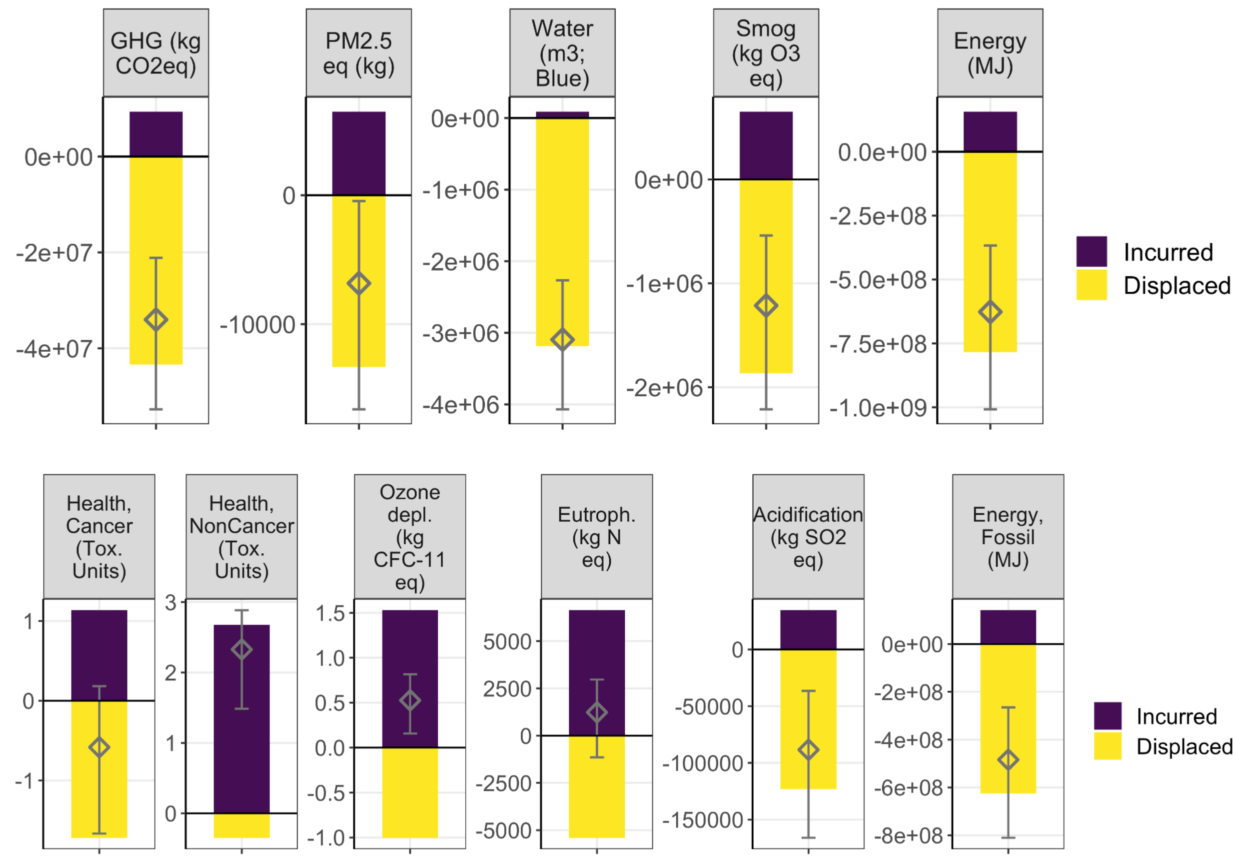
The study establishes baseline environmental performance parameters for the mattress recycling industry. In an effort to improve the mattress industry's environmental performance, members of the mattress supply chain are investing in research and pilot facilities to enhance product and materials designs, develop lower carbon footprint materials and explore alternative recycling technologies. MRC expects to use the results of this study as a benchmark for evaluating future technologies.

Key Findings
<u>Baseline Performance</u>
In 2021, the California program recycled 1.6 million mattresses. Of the 40.7 thousand metric tons (90 million lbs.) of materials recovered, 31.4 thousand tons (77%) were recycled, and 9.3 thousand tons (23%) were landfilled. The LCA analysis of the 2021 recycling system found that it provides the following significantly favorable environmental benefits:

Greenhouse gas displacement	34,000 metric tons (75 million lbs.) CO_2 equivalents
Energy demand reduction	627 terajoules (174,000 kWh)
Blue water demand reduction	3.1 million m^3 (818 million gallons)
Particulate matter reduction	6.8 metric tons PM2.5e (15 million lbs.)
Smog reduction	1,220 metric tons O_3 equivalents (2.7 million lbs.)

According to the LCA model, the mattress recycling system provided environmental benefits in all 5 of the main study indicators. For supplemental indicators, the overall impact was mixed. Two of the indicators showed consistently better performance (acidification; fossil energy), two had consistently worse performance (non-cancer health; ozone depletion), and two were marginal (cancer; eutrophication). The body of this report defines these indicators and discusses findings in greater detail. Incurred impacts, avoided impacts (displacement) and net results are illustrated in Figure ES.1

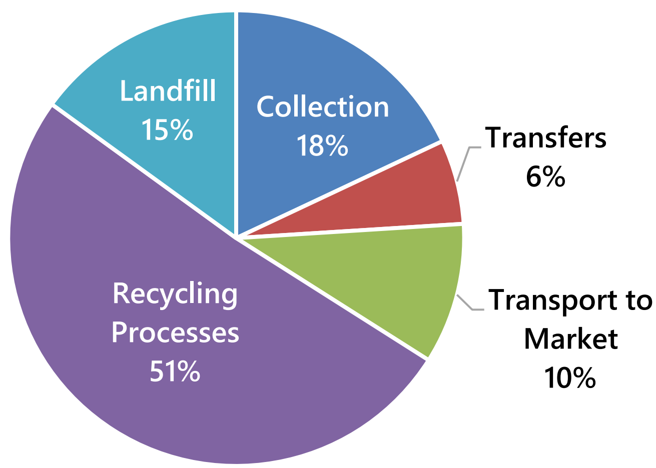
Figure ES.1. Total system impacts for managing 41 thousand tonnes (kt) of used mattresses. Each pane shows the incurred, displaced, and net total impacts of mattress recycling in CA (yr2021). The Diamonds represent the Net total. Top panes show the headline indicators. The Error bars show net total results for a range of assumed displacement rates (see §Displacement rates for explanation, and §Displaced production for ranges). Tabular data in §Appendix.



<u>Incurred Impacts</u>

The environmental impacts incurred includes processes related to used mattress collection, transportation, deconstruction, reclamation, transport of extracted mattress materials to final disposition and re-manufacturing. Figure ES.2 illustrates the major drivers for greenhouse gas emissions resulting from the mattress recycling system. Within the Recycling Processes category, the activity of California recyclers and rebond foam pad production are major drivers. The production of methylene diphenyl diisocyanate (MDI) used in rebond foam pad production is a significant contributor to impacts.

Figure ES2. Incurred Greenhouse Gas Impacts by Process, 7.7 KT/yr.

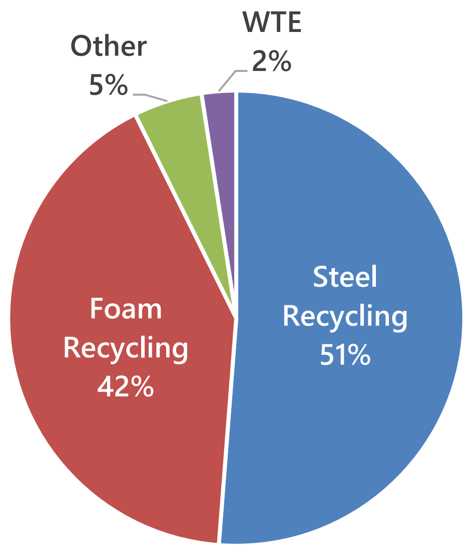


<u>Material, Product and Energy Displacement</u>

In addition, the study reports potentially avoided impacts, which would occur if the supply of recycled materials from mattresses displaces primary (virgin) materials. This relationship between the supply of mattress-derived materials and the displaced production of primary materials is an important uncertainty in this study. For this reason, we model a range of displacement values (depending on the material), and always show incurred impacts (from the mattress recycling system) and potentially avoided impacts (from displaced production), not just a net total.

Figure ES.3 illustrates the major drivers for avoided greenhouse gas impacts were steel recycling and avoided polyurethane foam production.

Figure ES3. Greenhouse Gas Displacement by Material, 34.0 KT/yr.



For climate impact, water use, smog, and energy use, the magnitude of the potentially displaced impacts is consistently larger than the incurred impacts of the recycling system. For the particulate matter indicator, the net benefit is negligible for only the most pessimistic displacement rates.

Alternative Process Assessments

As mentioned previously, global industry research and investments are in progress to develop alternative mattress recycling technologies which aim to create greater circularity and establish new pathways for recycling end-of-life materials. This study made a preliminary assessment of several promising technologies by incorporating published data into the California model.

Initial findings indicate that all established recycling processes, including mechanical recycling, chemical recycling, incineration, and pyrolysis, are more preferable options than landfilling. Chemical recycling may have more favorable environmental impacts particularly with net energy use and water demand than current mechanical recycling processes and market channels. However, it is important to note that an ISO 14040 compliant evaluation of an actual commercial scale facility is necessary to make that firm conclusion.

Improvement Opportunities

The study identified potential short- and long-term opportunities for improving the environmental impacts of mattress recycling.

- **Transportation** of mattresses from collection nodes to recyclers and recovered materials to secondary markets represented approximately 34% of incurred environmental impacts. The number, size and location of collection nodes and primary and secondary recycling facilities is an important consideration as the mattress recycling industry expands.

- **Automation** to improve recyclers' ability to efficiently separate materials has the potential to increase throughput, reduce landfill rates and reduce the environmental burden and cost per ton of recovered materials.
- **Development of new end markets** for recovered materials remains a key driver for growing and diversifying demand. To maintain and improve current baseline performance, recycling rates for all materials recovered should exceed 75% and must be robust through economic cycles.

Conclusion

The LCA found that the current industry led product stewardship program offers significant environmental benefits. Approximately 34,000 metric tons (75 million pounds) of greenhouse gases were avoided when compared with the production of products from virgin raw materials – the same amount as burning 12.6 million gallons of diesel. The program also saved an estimated 818 million gallons of water and mitigated the production of 636.7 terajoules of electricity.

This LCA report follows ISO 14040 guidelines. Following release of this report, a critical review by an independent panel will be completed in Q1 2023.

1 Goal and Scope

Mattresses and box springs (mattresses) are bulky, and thus can be challenging to properly manage at their end-of-life (EOL). At the same time, they contain materials that have value and materials that have a relatively high energy content in energy recovery applications.

As a consequence of these factors, mattresses are increasingly the target of extended producer responsibility (EPR) programs, where mattress manufacturers are responsible for developing EOL management solutions. In 2013, EPR laws in Connecticut, Rhode Island, and California were passed that required the industry to develop statewide recycling programs for discarded mattresses. The Connecticut program launched first in 2015, followed by California and Rhode Island in 2016.

The Mattress Recycling Council (MRC) is a non-profit organization that operates mattress recycling programs in states with mattress recycling requirements; it was formed by the mattress industry in 2014. MRC's California subsidiary coordinates the activities of over 200 collection sites and 10 independently operated recyclers to handle the state's flow of EOL mattresses.

In 2020, MRC commissioned a life cycle assessment (LCA) study in order to better understand the environmental footprint of its current recycling practices. The study methodology and reporting follow ISO 14044 guidelines. MRC selected Scope 3 Consulting LLC, a California-based consulting firm, to conduct the study.

1.1 Goal of the Study

Purpose of the Study

The end-of-life (EOL) management of mattresses and box springs (mattresses) is a multi-functional activity that generates recycled materials and products, and that disposes of waste. The primary goals of this life cycle assessment (LCA) study are to understand the major contributors to environmental impacts arising from EOL management of mattresses. The study will evaluate the environmental performance of several proposed or emerging recycling pathways, as well as the current baseline. Another important goal is to develop a modeling framework that could support the development of an assessment tool for stakeholders, and foster international collaboration and knowledge sharing with similar programs abroad.

The results generated during the mattress LCA will be numerical indicators of potential environmental burdens. The work will use primary data, existing inventory databases, as well as published research and documentation to estimate a suite of environmental impacts. Data privacy and anonymity are primary concerns throughout and after the study.

Intended Application

The study will be conducted by first establishing a baseline model that describes the material flow of EOL mattresses generated in California in recent years. The model will then estimate the environmental impacts directly attributed to the actions of individuals and firms within the recycling system. These impacts will be compared to the impacts of new products in the marketplace that compete with mattress-derived products.

Models representing existing and novel treatment routes will be constructed and evaluated under different recycling pathways to understand the advantages and disadvantages of each route. These models will be used to perform consequential analyses and will also serve as the basis for knowledge sharing with outside partners.

Intended Audience
This report is intended primarily for internal use by the Mattress Recycling Council (MRC). The results will be used to direct future efforts, pursue collaborations, and for reporting to regulators. Some of the results presented represent comparative assertions, where the performance of different recycling pathways are compared (e.g. for foam recycling routes; see §Material Disposition Routes). In such cases, critical review is required to satisfy ISO requirements (ISO 14044, 2006). This report has been written to comply with ISO requirements and guidelines, and 3rd party experts will conduct a critical review.

1.2 Scope of the Study

There are several types of sleep products to be recycled (Table 1.1). In this study, the term "mattress" is used generically to denote any sleep product type considered.

1.2.1 Function of the System

There are many functions of End-of-Life (EOL) mattress management. The functions we consider in this study include:

1. Collection of EOL mattresses to satisfy regulatory requirements
2. Production of mattress-derived products (which includes raw materials, finished products, and fuels made from recycled mattress components)
3. Responsible disposal of the mattress-derived materials that do not provide a marketable material or service

The product system under study includes the processes and facilities engaged in EOL management of mattress and box springs (collectively mattresses) in California. These actors work together to pursue the goal of responsible product stewardship established by California's Used Mattress Recovery and Recycling Act, SB 254, as amended. Their collective activities are the subject of the analysis. The specific material being managed are the five types of sleep products shown in Table 1.1.

Table 1.1. The five sleep product types considered in this study.

Mattress (sleep product) type	Examples of Recovered Materials
pocket coil innerspring mattress	steel; polyurethane foam; latex/rubber foam; quilt panels

	& toppers; fabric; felt/shoddy; fibers; plastics
wire-tied innerspring mattress	steel; polyurethane foam; latex/rubber foam; quilt panels & toppers; fabric; felt/shoddy; fibers; plastics
foam mattress	polyurethane foam; latex/rubber foam; quilt panels & toppers; fabric; plastics
box spring support (containing metal and wood support)	wood; steel; polyurethane foam; cardboard; fabric
all-wood box spring support (no metal support)	wood; polyurethane foam; cardboard; fabric

1.2.2 Functional Unit

The functional unit of the study is one tonne of used mattresses recycled. Since mattresses are commonly quantified in terms of number of mattresses, we define a second functional unit: one mattress of a standard size. The standard size could be specified separately for each of the five mattress types. However, for the purpose of scenario building, it is more appropriate to define a standard area for “box-spring type” sleep products, and another standard area for “mattress-type” sleep products. The mass and area of each type and size of mattress was determined from primary data (a project separate from this LCA study), and is described in §Mattress Unit Characterization.

1.2.3 System Boundary

Used mattresses enter the Recycling system when they are received by a registered used mattress collector. The system boundary is illustrated in Figure 1.1. The study includes activities relating to collecting scrap mattresses and transporting them to recyclers, processing the mattresses to recover materials, and disposal of wastes. Post-deconstruction manufacturing processes that convert mattress-derived materials into products are also included. In addition, the potentially displaced products are included within the system boundary as well (see §Products). Thus, the study boundary includes two distinct systems, the Recycling system (logistics, deconstruction, disposal, and manufacturing of mattress-derived products), and the Displacement (Expanded) system.

An EOL mattress enters the product system boundary when it is transferred into the physical possession of a network participant. We assume that mattresses arrive at takeback/collection points with zero environmental burdens. This means that none of the impacts of mattress manufacturing, mattress use or interim transportation activities (including the consumer’s transport to a drop-off location) are “carried over” to the recycling system.

The transport of mattresses from collection sites to deconstruction facilities is included, along with transfers between facilities. In addition, transport from recycling facilities to disposition locations is included. Transportation of mattresses by consumers (whether to collections sites or recyclers) and informal haulers (to recyclers) is not included, but sensitivity cases are presented.

All upstream inputs to mattress recycling (trucks, road infrastructure, recycling equipment, electricity, etc.) are modeled “cradle to grave”, meaning from the raw material acquisition through to the delivery of the product or service for its use in mattress recycling. This is true for mattress recycling, manufacturing processes, and potentially displaced products.

In general, the recycling system boundary ends when the mattress-derived material becomes a substitute for another product/material. For some recovered materials, like steel, the material will leave the recycling system boundary when it leaves the recycling facility. For other materials, the LCA system boundary will include the post-deconstruction manufacturing processes required to produce a mattress-derived product. An example is recovered foam being used in the manufacture of rebond foam padding (a process which includes electricity use, heat, binder, and equipment).

For energy uses, the energy itself will be the co-product, and thus the combustion or other means of heat extraction will be included in the system boundary.

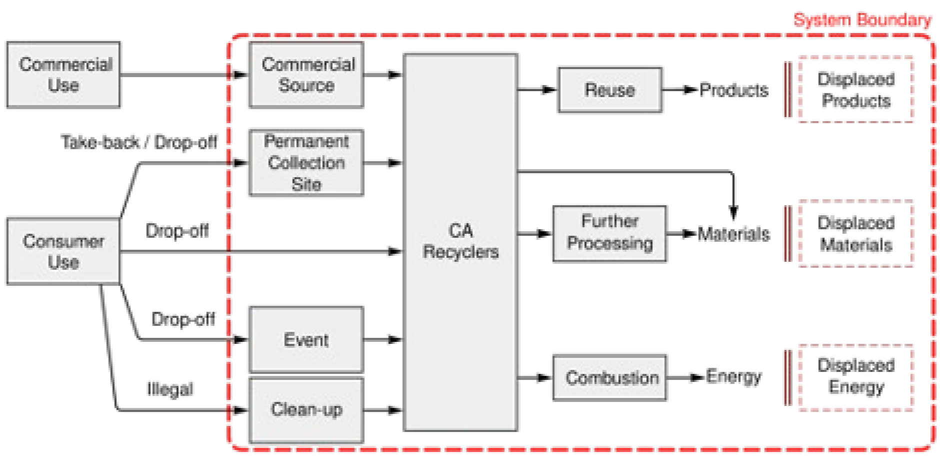


Figure 1.1. Basic system boundary diagram. The LCA system boundary includes activities related to scrap mattress management, in addition to activities displaced by the products of scrap mattress management. (The “Further Processing” box to the right of “CA Processors” represents additional processing (downstream of the recyclers) required to produce some of the mattress-derived products. Mattress-derived products are described in §Mattress-derived products; the processing steps are described in §Other processing and manufacturing activities.)

1.2.4 Allocation Procedures and System Expansion

We apply the “cut-off” system modeling methodology throughout our inventory model. With the cut-off approach, a mattress is “reborn” when it goes from being an “in-use” mattress to a “used, to be recycled” mattress. When the used mattress enters our system (e.g. when it arrives at a collection site, or is delivered by an independent collector to a recycler), it has zero burdens - the products' prior life cycles are "cut off" when the product is made available for recycling.

Mattress recycling generates environmental impacts, just as any other industrial activity. In an LCA of a recycling system, the impacts of recycling are weighed against the potential benefits of the recycled material. Thus, the activity of mattress recycling has two functions: management of the end of life mattress, and production of secondary materials for later use. In order to avoid allocating the burdens of mattress recycling between these two functions, we accounted for the effects of supplying mattress-derived products using *consequential system expansion*. This means that we expand the scope of the study to include the production of products judged to compete with mattress-derived products in the marketplace. We distinguish between the recycling system (collection, deconstruction, and manufacturing mattress-derived products) and the displacement systems that produce similar products as the recycling system, but with non-mattress-derived (usually virgin) materials. These displaced products are shown in small, dashed boxes on the right side of Figure 1.1.

When recycled materials are made available for use, these products may or may not reduce the production of virgin material – the effect on the market is often unknown. However, it is conventional to consider that the use of recycled products can offset demand for similar products from other sources. We calculate "avoided burdens" that result from the displacement of those competing production activities. Avoided burdens (or credits) usually have negative impact scores and are always reported separately from incurred burdens.

By modeling the activities that give rise to displaced products, we can perform a direct comparison of the impacts of the competing routes. This allows us to build "what if" scenarios to describe the possible effects of changes in the supply of mattress-derived recycled products. These scenarios could be further validated by an economic analysis of the markets where mattress-derived materials are sold, but that is beyond the scope of this study.

1.2.5 Mattress-derived products and Potentially displaced products

For each mattress-derived product or service, a Displaced Product is defined (Table 1.2). We assume that for each recycling route shown in Table 1.2, the mattress-derived product and the displaced product provide the same function, and therefore compete with each other in the marketplace. To account for the effects of supplying mattress-derived products, we use a *consequential system expansion* framework (Earles & Halog, 2011; Ekvall & Weidema, 2004; Guinee, 2002). The scope of the study includes not just the recycling system, but it also includes the products judged to compete (in the marketplace) with mattress-derived products. We calculate the potentially avoided burdens that result from the displacement of those competing production activities. Avoided burdens (or credits) have negative impact scores and are always reported separately from incurred burdens of the recycling system.

Table 1.2. The recycling routes considered in the study. Left column shows mattress-derived materials, as they exit the primary recycling chain (collection, handling, and deconstruction). The columns “Mattress-derived products” and “Displaced products” represent products that perform the same functions. The column “Post-processing required?” indicates whether the mattress-derived material must undergo further processing and/or manufacturing to produce the mattress-derived products.

Mattress-derived material	Mattress-derived product	Post-processing required?	Displaced product
Steel	Steel, recycled content	no	Steel, displaced
Steel (reused)	Steel spring (reused)	no	Steel spring, displaced
Foam	Rebond Foam Pad	yes	Virgin Polyurethane Foam Pad, displaced
	Scrap foam	no	Post industrial scrap foam, displaced
	Polyol (via acidolysis)	yes	Polyol, displaced
	Polyol (via glycolysis)	yes	Polyol, displaced
	Pyrolysis oil & Char	yes	Crude oil & Black carbon, displaced
Foam (reused)	Foam (reused)	no	Virgin Polyurethane Foam Pad, displaced
Quilt	Rebond Foam Pad	yes	Virgin Polyurethane Foam Pad, displaced
	Scrap quilt	no	Post industrial scrap foam, displaced
Quilt (reused)	Quilt	no	Quilt, displaced
Wood	Mulch	yes	Wood chips, displaced
	Bioenergy (heat from wood fuel)	yes	Heat, natural gas, displaced
Wood (reused)	Wood boards	no	Wood boards, displaced
Whole unit (reused)	Whole mattress	no	New whole unit, displaced
Cotton	Cotton fiber	no	Cotton thread, displaced
Cotton (reused)	Cotton fabric	no	Cotton fabric, displaced
Shoddy	Mixed fibers	no	Polypropylene granulate, displaced
Shoddy (reused)	Shoddy	no	Shoddy pad, displaced
Other fiber	Mixed fibers	no	Fibers (mix), displaced

Other fiber (reused)	Polyester fabric	no	Polyester fabric, displaced
Cardboard	Cardboard, recovered	no	Wood pulp, displaced
Plastic	Plastic, recovered	no	Polypropylene granulate, displaced
Waste-to-Energy	Heat from incineration	yes	Heat, natural gas, displaced
Waste to Landfill	NA	yes	NA

1.2.6 Displacement rates

Although mattress-derived materials are considered to provide the same function as displaced products, it is not necessarily true that the production of secondary materials from mattress recycling leads to the *avoidance* of primary production. In other words, producing one tonne of mattress-derived product does not necessarily displace an equivalent amount of the competing product. The *displacement rate* is the amount of primary product that is expected to be displaced through the generation of secondary material. A rate of 100% indicates that recycled products displace primary products on a one-to-one basis. In reality, the actual displacement rate is likely less than 100%, meaning that some recycled materials will be used to create products that would not otherwise have been created, if the recycling had not occurred. In conducting an LCA of a recycling system, the best practice is to evaluate the sensitivity of the results to the displacement rate (Zink et al., 2018).

Displacement of primary production is more likely when demand for a particular product is inelastic, meaning that the increased supply of a commodity will not necessarily lead to increased consumption. In these cases, a consumer who purchases a product made from recycled mattresses is likely to do so *instead* of purchasing a non-mattress-derived product, thus leading to displacement of primary production. On the other hand, displacement is less likely if the competing product is much more expensive than the recycled product.

For each displacement relationship, the overall displacement rate is calculated as the product of a technical equivalency value, known as **τ**, and an economic displacement factor, known as ε (Figure 1.2). The technical value represents the functional equivalency of the two products, and is determined from physical properties. The economic factor represents the likelihood that the competing product will be avoided because of the production of the mattress-derived product.

For most of the mattress-derived materials, the technical equivalency (**τ**) value is one. The exception is the combustion of waste for energy recovery. The technical displacement is assumed to be 75% because the efficiency of wood and waste combustion is less efficient than the competing option.

Because of fundamental uncertainty in the displacement relationship, we apply sensitivity cases to the economic displacement (ε) rate according to the type of product being displaced (Figure 1.2). For fuels and commodities, we assume there is a high likelihood of displacement, so we consider the range of 80-100% economic displacement, with 90% as the median (reported) case. On the other hand, rebond carpet is a “market leader” - it is the default choice in the market. This type of product is less likely to cause displacement of alternative products, so we assign an economic displacement rate of 20-80%, with 50% as the median.

Figure 1.2. Framework for modeling displacement relationships between mattress-derived products and the competing products in the marketplace.

1.2.7 Scenarios and Scales

Several recycling scenarios are modeled. Scenarios may be distinguished by the system being modeled (e.g. alternative collection methods, different processing routes, and/or different mattress types) and by the scale (whether results are presented per tonne of mattress or recovered material, or at the statewide-scale).

The Baseline system is representative of the management of used mattresses collected in California during the year 2021. The collection statistics and material outputs generated are based on ReTRAC data provided by MRC. In addition to the Baseline system, three other recycling systems are modeled. The four pathways are described in Table 1.3, and a product system diagram for each pathway is illustrated in Figure 1.3.

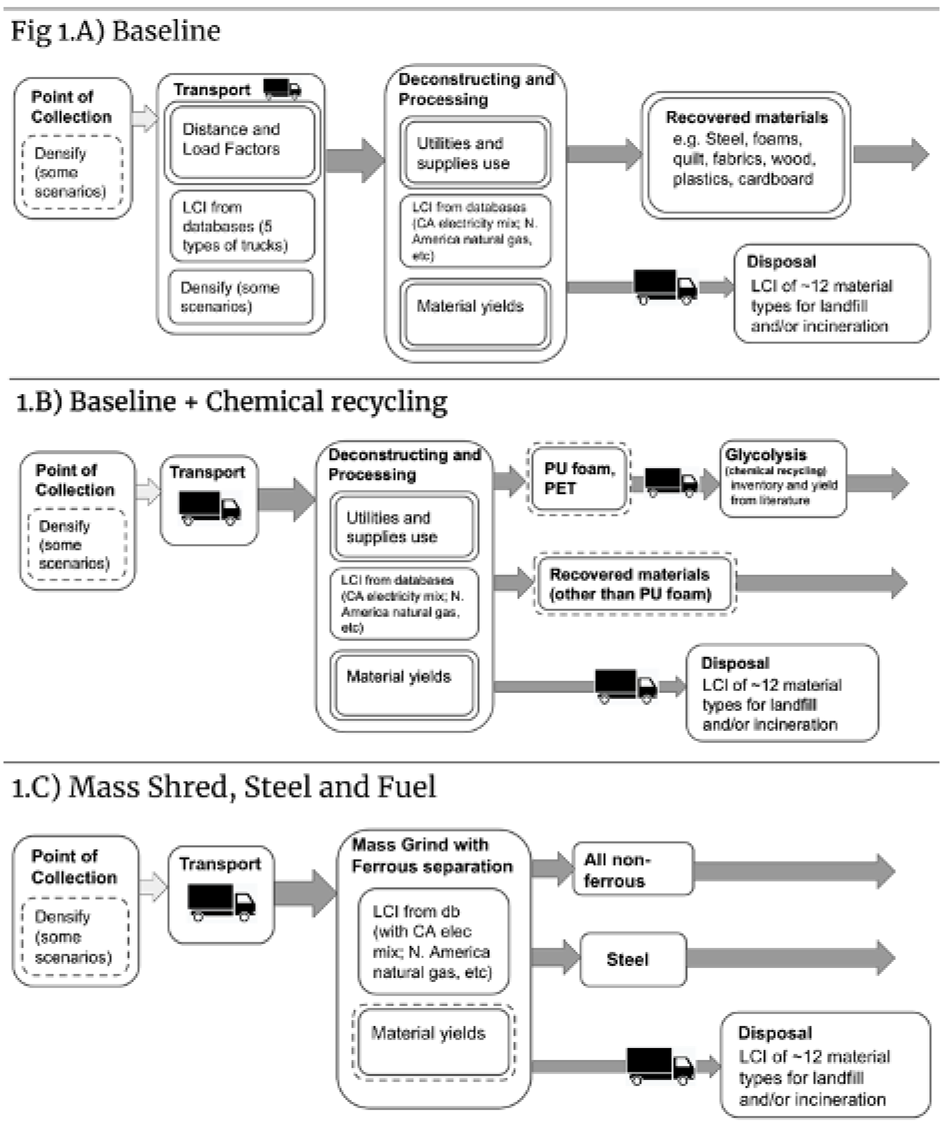
Within each of the pathways shown in Figure 1.3, several alternative scenarios are considered. First, a scenario is developed for each type of sleep product (listed in Table 1.1). Scenarios also represent different uses for the same recovered material (e.g. multiple routes for wood recycling and foam recycling, and pyrolysis and incineration for non-ferrous materials). In addition, a compaction truck scenario is included to quantify the effect of increasing load size for collection.

For the Baseline system, results are shown both at the statewide scale, and at the per-tonne scale. For all other scenarios, results are only shown at the “per tonne” scale.

Table 1.3. Description of the four mattress recycling pathways to be modeled in the study.

Pathway name	Description
Baseline	Based on common current practice in California. Mostly hand-deconstruction and recycling for commodity materials and fuels for energy recovery (will likely include mechanized separation of some materials, e.g. separating pocket coils into steel and fabric)
Baseline + Chemical	As in Baseline, except some material is used as feedstock for depolymerization via chemical recycling (e.g. glycolysis of polyurethane

Recycling	foam)
Shred, Steel, and Fuel	Mass-shred; separate and recycle ferrous; non-ferrous to fuel for electricity generation
Shred, Steel, and Pyrolysis	Mass-shred; separate and recycle ferrous; non-ferrous materials used for pyrolysis to produce crude oil and char



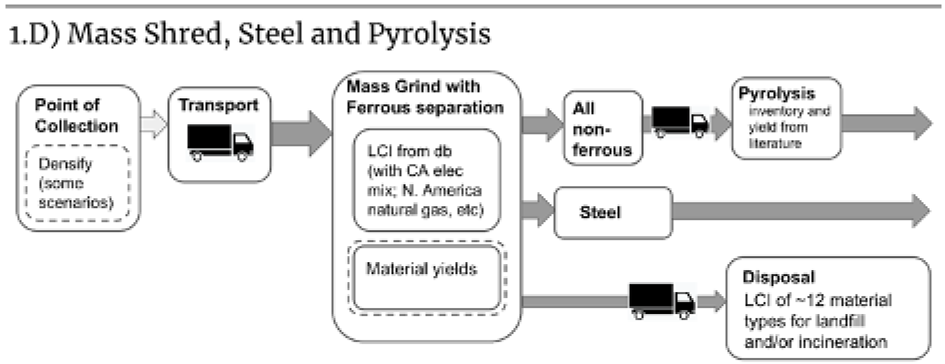


Figure 1.3. Illustrations of the four mattress recycling pathways. Pathways are defined by the types of deconstruction and remanufacturing/recovery processes they employ. Each type of mattress (**Table 1.1**) may produce distinct mixes of recovered materials from each pathway. Boxes represent material flow and transformations. Pathways will be modeled with and without densification at collection, so this process is shown with a dashed border. The double-bordered boxes show processes for which we expect to collect primary data. Panel A) Represents the common current practice of hand-deconstruction with material recovery, and some material sent to disposal. The recovered materials are used as a mix of raw materials and fuel. Panel B) Represents hand-deconstruction as in A), but with some material further processed via chemical recycling (e.g. glycolysis). Other materials are recovered as in A). The pathway in C) represents a mass-shred with steel separation recycling system, where non-ferrous materials are likely used as mattress-derived fuel. The coproduct yield may be informed by data that has been collected by MRC, so this is shown with a dashed double-border. Panel D) is similar to C), but non-ferrous materials are further processed via thermochemical recycling (e.g. pyrolysis) before being marketed. In all figures, final arrows represent marketed material leaving the *recycling system* to its next use. Non-mattress processing inputs (e.g. electricity, natural gas, supplies) are excluded from the figure for clarity, but they will be included in process inventories. LCI = Life Cycle Inventory; PU = polyurethane.

1.2.8 Types and Sources of Data

The data required for modeling the recycling systems includes primary and secondary data. Primary data include:

- Transport distance, truck type, and load factors (# of mattresses per load)
- Mattress counts by type and size
- Material makeup of mattress units by type and size
- Usage of electricity and other utilities, machinery, and supplies during handling, deconstruction and processing
- Amount and kind of products with mattress-derived materials that are delivered to a market
- Amount and kind of mattress-derived material used as fuel
- Amount and kind of mattress-derived material sent to disposal.

Primary data about freight statistics and the fate of mattress-derived materials (whether used as raw materials, fuels, or sent to disposal) is sourced from MRC. Data about the material makeup of mattresses was collected by MRC.

Data to develop an inventory of current deconstruction operations (primary recyclers) were collected via surveys, discussions with recyclers, and site visits, carried out by Scope 3 Consulting. With the data collected, a synthesis model of mattress recycling was developed. Survey data contributed by facilities is aggregated into the synthesis model. No data from individual recyclers/processors has been (nor will be) released by Scope 3 Consulting to MRC nor any other party.

No significant direct emissions to the environment from activities modeled in the study foreground are expected, other than fuel combustion and equipment operation, which are assumed to be well characterized in background databases. No study-specific measurement of combustion emissions or equipment operation was performed.

The primary background database for the model was ecoinvent version 3.8, using the cut-off system model (2021). Ecoinvent is the premier scientific life cycle assessment database worldwide. It includes 17,910 activity models and incorporates data from a wide range of industrial, scientific, and public resources.

For stationary equipment operation powered by diesel, gasoline, and propane, fuel production and combustion were modeled according to the US Life Cycle Inventory database (USLCI), part of the Federal LCA commons. The USLCI database was developed based on US air quality regulations, operator surveys, and refinery data.

The treatment of steel scrap was modeled using the World Steel Association's most recent reference data (World Steel Association, 2021). Their methodology includes a survey-derived model of global steel production, allocated amongst different uses. They also publish a "value of scrap" activity which is a reverse allocation (an induced burden) on the steelmaking process based on their measurement of global scrap consumption. Generating scrap input to this process produces an avoided burden (WorldSteel 2017), which we use to represent the environmental benefit of scrap steel.

1.2.9 LCIA Methodology and Types of Impacts

In an LCA study, results are reported in terms of different categories of environmental effects, such as climate change or water depletion. Each category is represented by a numerical indicator that has a representative reference quantity. Numerical impact scores are computed for each activity in the product life cycle, for each indicator under consideration.

We use the TRACI (version 2.1) life cycle impact assessment methodology to characterize the environmental impacts of the life cycle inventories (Bare, 2012). TRACI was developed by the US EPA, and is more proximate to United States conditions than alternative LCIA methodologies, which tend to focus on European conditions.

Eleven impact categories are included, grouped into “Headline” and “Supporting” indicators (Table 1.4). Descriptions of the impact categories are included in the Appendix. Please refer to (Bare, 2012) for more information. Each indicator’s characterized flows were carefully reviewed for consistency with the emission inventories in ecoinvent (2021), WorldSteel (2021), and US LCI (2021). Impact characterization factors were compared with ReCiPe 2016 to ensure consistency and completeness.

The TRACI fossil depletion methodology is incomplete, so this indicator was not included. Instead, characterization factors were defined to estimate fossil energy use and primary energy use. Similarly, characterization factors were defined to calculate the water use impact.

Table 1.4. Impact categories included in the LCA study. A description of each indicator is included in the Appendix.

Impact Category	Unit	Headline or Supporting?	Area of Protection
Climate Change (GHG emissions)	kg CO_2 eq	Headline	Human & Environmental Health
Respiratory Impacts (Particulate Matter emissions)	kg PM 2.5 eq	Headline	Human Health
Water Use (blue water footprint)	m^3 blue water	Headline	Environmental Health & Natural Resources
Smog Formation	kg O_3 eq	Headline	Human & Environmental Health
Total primary energy demand	MJ	Headline	Natural Resources
Toxicity to Humans (Cancer)	Toxicity Units	Supporting	Human Health
Toxicity to Humans (Non-Cancer)	Toxicity Units	Supporting	Human Health
Ozone Depletion	kg CFC-11 eq	Supporting	Human & Environmental Health
Acidification	kg SO_2 eq	Supporting	Environmental Health
Eutrophication (terrestrial and aquatic)	kg N eq	Supporting	Environmental Health
Fossil Fuel Use	MJ	Supporting	Natural Resources

Biogenic Material Content

The materials in mattresses may contain a mix of bio-based materials and fossil-based materials. Wood and cotton are two obvious bio-based materials in some mattresses. For polyurethane (PU) foam, polyol monomers can be sourced from bio-based materials. In addition to PU foam, mattresses may contain bio-based latex rubber and/or fossil-based synthetic rubber.

For the purposes of climate impact accounting, biogenic carbon is “ignored” in the life cycle inventory. This means that the material production process does not receive a credit for its bio-C content; it also means that the portion of CO_2 released during combustion that is biogenic does not contribute to the GHG emissions impact. The mass fraction of bio-based foam (relative to the total mass of foam) in mattress types will be investigated. The carbon content of rubber is 0.88 (mass fraction, without compounding materials).

1.2.10 Data Quality, Assumptions, and Limitations

We include all flows that we have the capacity to measure or estimate. As with all LCA studies, we inherit the limitations of the data we are able to collect, and the limitations of our background databases. Primary data was collected to model primary deconstruction and post-processing. For the background databases, we consider ecoinvent (2021) implemented with regional electricity grids to be acceptable proxy inventories for the background process.

1.2.11 Reporting and Interpretation

Life cycle impact assessment scores are computed for each scenario under consideration, for each indicator reported in §LCIA Methodology. The indicator scores are interpreted through contribution analysis, in which different activities in the product life cycle are aggregated into stages, whose individual scores add up to the total score. By ranking the contributions of each life cycle stage, we can identify the largest sources of impacts. The following stages are used in the presentation of results:

- Freight for collection (from collection site to recycler)
- Deconstruction (primary recycling, not including shredding of pocket springs)
- Pocket spring shredding
- Foam chopping
- Rebond foam pad manufacture (including material and energy inputs)
- Freight for transport to disposition
- Displaced manufacturing of products
- Displaced freight
- Chemolysis (including material and energy inputs)
- Pyrolysis (including energy inputs)
- Landfill and Incineration

We assess the variability of the results through scenario analysis. As discussed in §Scenarios and Scales, we define a baseline model (CA 2021) that describes the mattress recycling system in 2021. By running the model under alternative scenarios, we can evaluate the effects of the scenario on the indicator scores of various life cycle stages.

The most significant parameter in the life cycle performance of most recycling systems is the assumed displacement rate, as discussed in §Displacement rates. We indicate the sensitivity of the result to the displacement rate assumptions with error bars or “whiskers” on results indicating potentially displaced production.

2 Material Flow Analysis

The life cycle impacts of mattress recycling depend on the types and amounts of materials flowing through the recyclers. In this section, the collection of mattresses, their processing, and transport from recyclers to the next users are described. The raw data used to generate the information in this section was supplied from MRC. Scope 3 reviewed and processed data describing mattress collection and recycling in California for the year 2021. Figure 2.1 shows a high-level overview of the material flow.

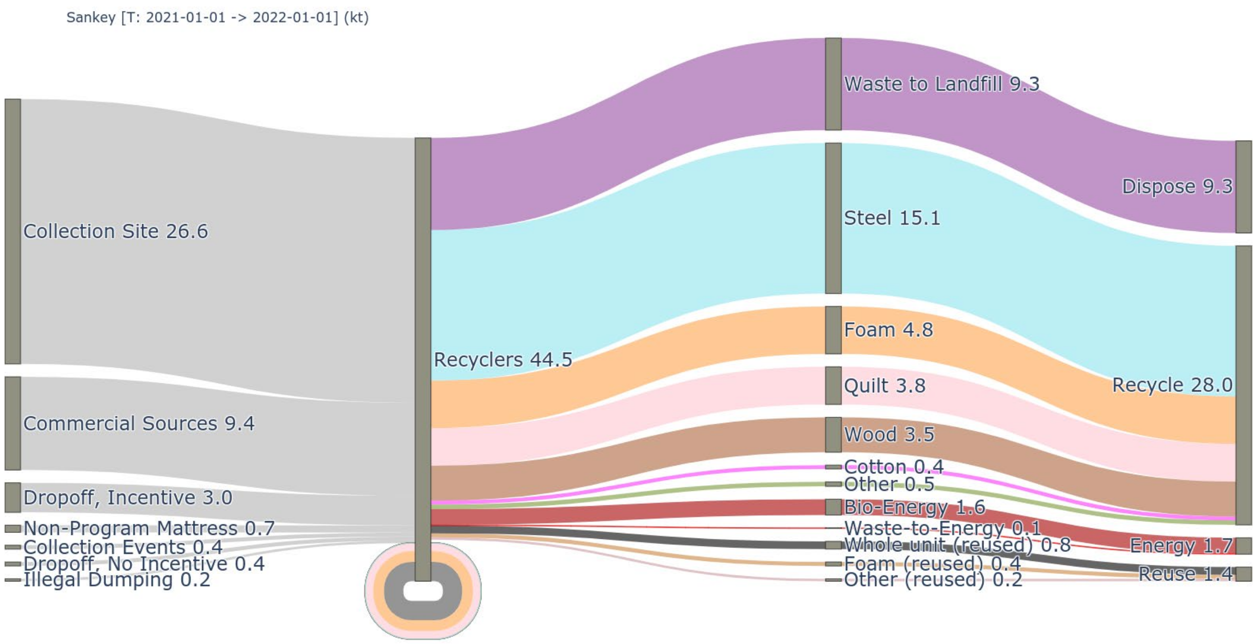


Figure 2.1. Nodes on the left represent different collection types. Material moves through recyclers, where different types of materials are produced as output. The nodes on the right represent different fates (recycled, reused, energy conversion, disposal). The thickness of the lines represents the mass of material (thousand metric tonnes, kt). The “loop” on the Recyclers node indicates mattresses transferred between facilities.

2.1 Highlights

I. According to the data provided to Scope 3, a total of 40,694 tonnes of mattresses (1.63 million units) were received by recyclers
   A. 65.4% from Permanent Collection Sites, 23.0% from other commercial and institutional sites, 7.3% from drop-off with incentive, 1.0% from drop-off without incentive, 1.0% from events, 0.6% from illegal dumping, and 1.8% non-program units
II. Freight for collection is estimated at 3.79 million tonne*kilometers (2.6 M short ton*miles)

    A. 9% of mattresses received by recyclers have an unknown origin location (not including drop-offs); average distance for freight with known collection location was used for these locations.

III. Transfer between recyclers adds 1.20 million tonne*kilometers (0.82 M short ton*miles) of freight

IV. According to the data provided to Scope 3, a total of 40,375 tonnes (44,506 short tons) of materials were output from recycling facilities

    A. 69% to recycling, 23% to disposal, 4% to energy recovery, and 4% to reuse/refurbish

V. Freight from recyclers to disposition vendors is estimated to be 9.7 Mtkm (6.7 million short ton miles)

    A. 59% of recycling output mass has an unknown disposition location (excl. transfers); average distance for materials with known disposition was applied to trips with unknown disposition location.

2.2 Material processing routes

The materials generated by recyclers are shown in Figure 2.2. In many cases, post-deconstruction processing and remanufacturing is required to produce the mix of products included in the model. For example, multiple routes are included for the fate of foam recovered from mattresses.

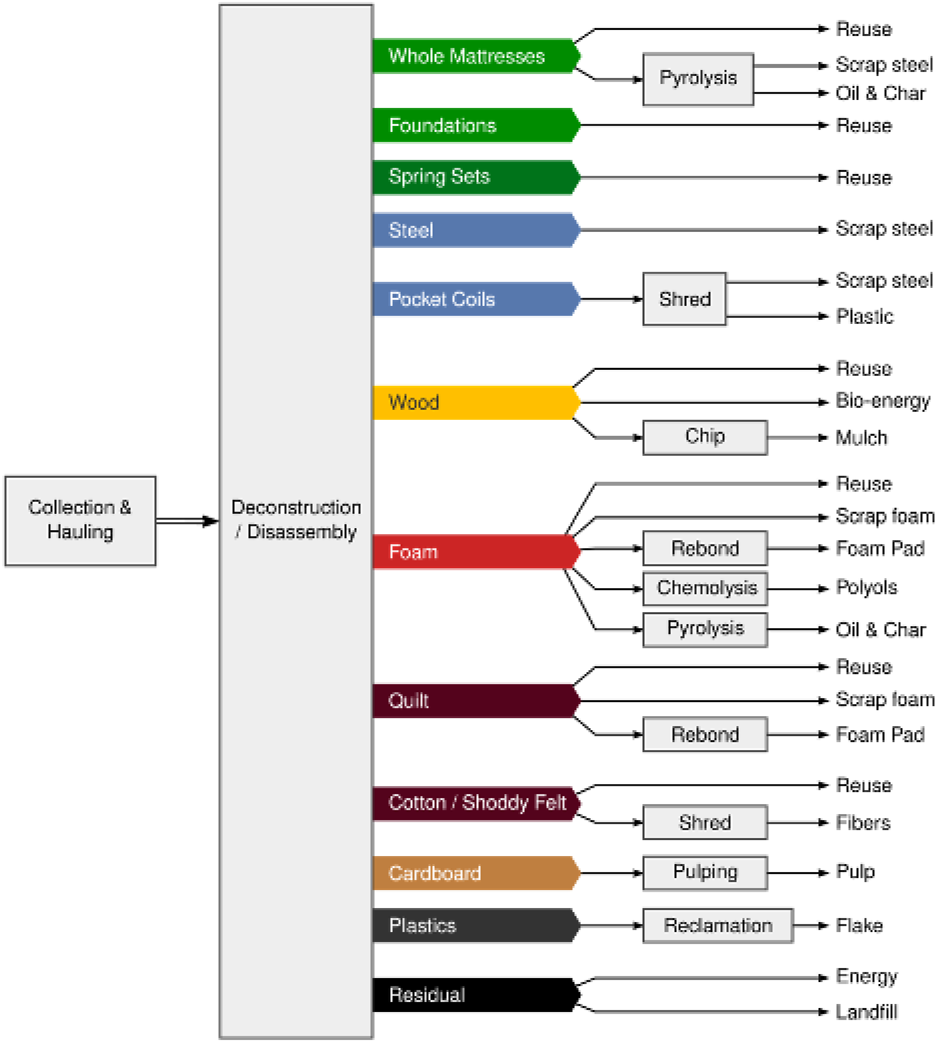


Figure 2.2. System diagram showing reuse and recycling routes. The boxes to the right of Deconstruction/Disassembly represent further processing before the material is sold as a product. For simplicity, not all the processes included in the model are shown. For example, transport from Deconstruction facility to subsequent facilities is not shown, and foam chopping is not shown for the Foam Rebond and Glycolysis pathways, although these are included (see §Other processing).

Table 2.1. The annual mass (k tonne) of mattress-derived material (MDM) that is used in each possible recycling route, for the Baseline Scenario, as well as alternative scenarios. A row represents one possible use of a mattress-derived material. The Primary MDM indicates the form of a material directly after it is recovered from a mattress. The Marketed MDM represents the form of the material that is used in a particular product. Values shown are mass fraction (mass to particular route / mass input).

		k tonne / yr			
Primary MDM	**Marketed MDM**	**Baseline**	**Foam to Chemical Recycling**	**Whole units to Pyrolysis**	**Shred and burn**

Steel	Steel to mill	15.13	15.13	15.13	15.17
	Reuse	0.04	0	0	0
Foam	Rebond pad	4.77	0	0	0
	Scrap	0.00	0	0	0
	Reuse	0.40	0	0	0
	Polyol	0.00	5.18	0	0
Quilt	Rebond pad	3.79	3.79	0	0
	Scrap	0.00	0.00	0	0
	Reuse	0.00	0	0	0
Wood	Mulch	3.51	3.51	0	0
	Reuse	0.20	0.20	0	0
	Energy	1.59	1.59	0	0
Whole mattress	Reuse	0.78	0.78	0	0
	Pyrolysis Oil & Char	0.00	0.00	25.26	0
Cotton	Thread to mill	0.39	0.39	0	0
	Reuse	0.00	0.00	0	0
Shoddy	Plastic to mill	0.22	0.22	0	0
	Scrap	0.00	0.00	0	0
	Reuse	0.00	0.00	0	0
Other fiber & fabric	Thread to mill	0.23	0.23	0	0
	Reuse	0.00	0.00	0	0
Cardboard	Pulp to mill	0.05	0.05	0	0
	Reuse	0.00	0.00	0	0
Plastic	Plastic granulate	0.01	0.01	0	0
Residuals	Landfill	9.26	9.26	0	0
	Energy	0.06	0.06	0	25.26
Total Processed Material		40.43	40.43	40.43	40.43

2.3 Mattress Characterizations

In order to build recycling scenarios for different types of mattresses, it is necessary to estimate the mass of different component materials, for each type of mattress (e.g. no steel will be recovered from an all-foam mattress). To characterize mattress units, we used data from two studies that were undertaken by MRC, independently of this LCA study: the Mattress Composition study, and the Mattress Size and Type Count study.

In the Mattress Composition study, four units of each type and size were manually deconstructed, and the mass of each component was weighed separately. A total of 72 units were deconstructed: The mattress-type units each have 4 sizes; the foundation-type units each have 3 sizes. The average compositions of each mattress type and size are shown in Figure 2.3. In addition to each specific type-size combination, the average composition was calculated for mixes of mattresses: All sizes for a given type; And all sizes and types. The “all sizes and type” average gives the mass composition of an aggregate mattress, composed of all the different types in the system.

To calculate the characteristics of an aggregated average mattress, the Mattress Size and Type study counted and characterized more than 1,000 units by type and size, as defined in Table 1.1; sizes are twin, double, queen, and king.

The average size of a mattress–type unit (pocket coil, tied spring, all foam) and the average size of a foundation-type unit (all wood foundation, other foundation) are necessary to construct scenarios based on a mix of mattress types. Table 2.2 shows the raw area and mass of each mattress type. To create scenarios where one type of mattress is replaced with another (e.g. replace some fraction of pocket coil units with all foam units), we want that swap to be equal-area. The data in Table 2.2 would allow such apples-to-apples scenarios to be constructed.

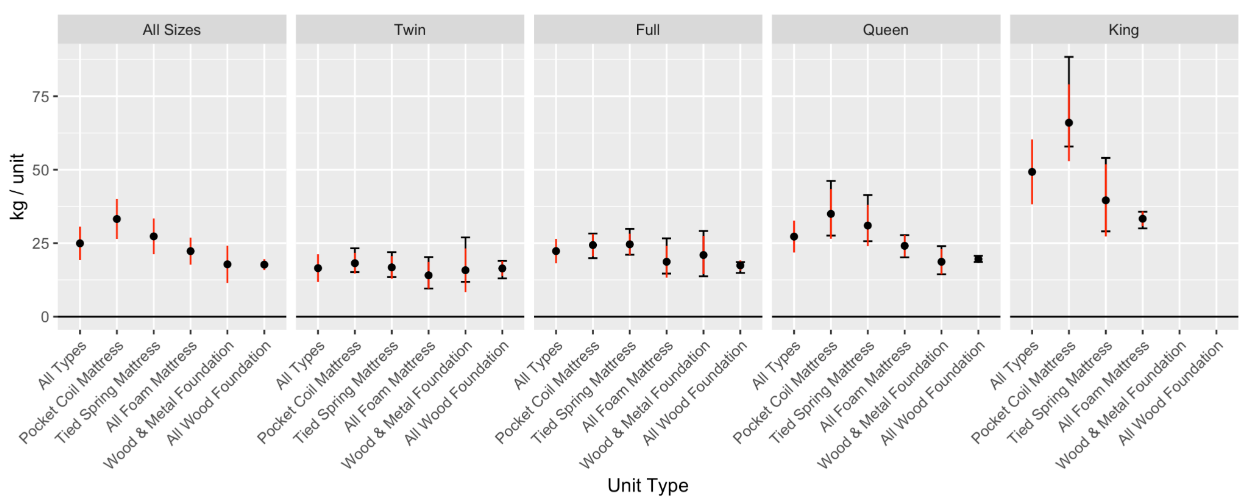


Figure 2.3. The average mass (lbs) of mattresses. Mass data is from the Mattress Decomposition study. Averages are calculated using frequency of types and sizes from the

Mattress Count study. The aggregated, average unit (average across All Types and All Sizes) is 55 lbs, shown at the far left of the figure. Foundations do not exist in King size (far right).

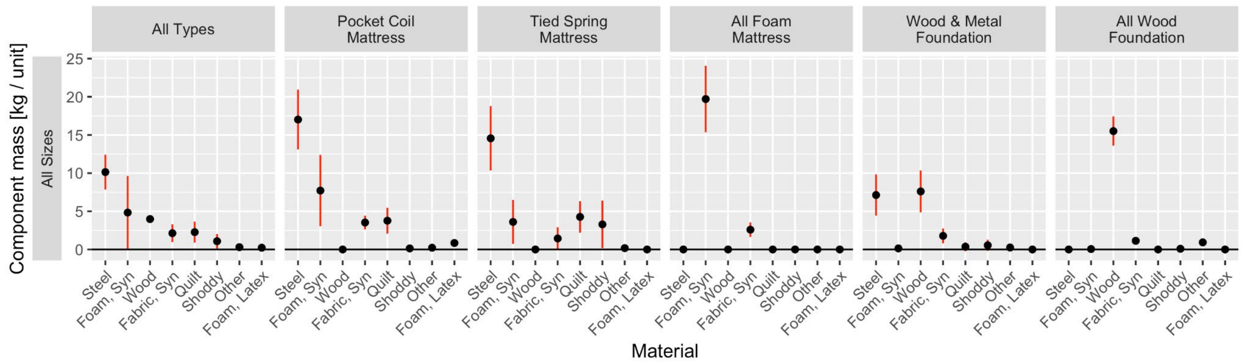


Figure 2.4. Average composition for the five different mattress types, plus the aggregated average unit (left panel).

Table 2.2. Multiplicative factors to convert unit masses to a standard size unit mass.

Type	Size	Area (sq m.)	Mass (kg)	Mass per Area
All Types	All Sizes	2.63	24.95	9.48
Pocket Coil Mattress	All Sizes	2.75	33.23	12.09
Tied Spring Mattress	All Sizes	2.78	27.33	9.84
All Foam Mattress	All Sizes	2.81	22.29	7.94
Wood & Metal Foundation	All Sizes	2.41	17.81	7.4
All Wood Foundation	All Sizes	2.38	17.71	7.45

2.4 Recovery rates for Scenarios

In the Baseline scenario, the mix of outputs from recyclers is known from data. However, in order to estimate the recovery rate for the non-baseline scenarios, we need estimates of the recovery rate for each component with the mattresses. This information comes from MRC's Waste Characterization Study (independent of this LCA study), with the recovery rates shown in Table 2.3.

Table 2.3. Recovery rates for mattress component materials.

Material	Recovery Rate
Steel	99.8%
Wood	97.9%
Foam	79.2%
Cardboard	80.7%

Quilt & Toppers	70.2%
Cotton	38.9%
Other Fiber	6.5%
Felt/Shoddy	9.7%
Plastics	1.6%
Other Non-Recoverable	0%

3 Life Cycle Inventory

This section presents data sources and assumptions used to model the environmental implications of mattress recycling. *Processes* are used as building blocks to construct models of mattress recycling systems. *Inventories* describe the inputs and outputs for processes. These *process inventories* may be “off the shelf” from an LCI data provider, or they may be custom built, based on direct observations and data collection. In both cases, the items (input and output flows) that make up a process inventory are linked to background life cycle data, and environmental impact scores can be calculated. Where possible, we use process inventories from ecoinvent, using the “cutoff” system model (ecoinvent, 2021). The custom processes inventories defined include an aggregated CA Recycling Facility (§3.2), electricity mixes (§3.3), pocket coil shredding, rebond foam pad manufacture, pyrolysis, and chemolysis (§3.4).

The Baseline Scenario models the mattress recycling system in California, calendar year 2021. Additional Scenarios are developed to assess alternative recycling processes and product mixes. Mattress-derived material flows for each Scenario are shown in §Material Processing Routes.

3.1 Freight

Freight includes Collection Transport (truck transport from a collection site to a recycler), Transfers (truck transport between recyclers), and Disposition Transport (from a recycler to a disposition location).

3.1.1 Collection Freight

Mattresses are generated throughout the state and must be marshaled from the point of generation (where it was last used) to a facility for processing. Mattresses may be brought to a collection site, event, or recycling facility by unaffiliated parties (e.g. a consumer or small independent collector), and/or they may be collected by an entity that works with MRC to manage collection and freight to recyclers.

The collection model is based on data at the level of trailer trip. For most trips, the distance is known based on the origination and destination. When the distance is unknown, the average distance of known trips is applied.

A mix of truck-trailer combinations are included in the model. The trailer mix is based on a sample of data, with average load and distance is shown in Table 3.1, along with the relative share of freight for each trailer type. This truck-trailer mix is assumed to apply to all collection freight.

In the Baseline scenario, mattress transport by consumers and independent collectors is excluded. The impacts of this unaffiliated transport are explored in sensitivity cases, where consumer transport is assumed to be 15 km per mattress, and independent collector transport is assumed to be 40 km per vehicle round-trip. The independent collector vehicle is modeled as a pickup truck with a capacity of 10 units per full load.

Table 3.1. Trailer types involved in the mattress collection network, along with total known freight (tkm = tonne * kilometers), average load in tonnes, and the total mass shipped for each trailer type. The data here are for truck loads with known distance and trailer type (a subset of all freight).

Trailer type	Freight (tkm)	tonne / load (avg)	Mass, all loads (tonne)	Fraction of all mass	Fraction of all freight	Distance / load (avg)
53'/48'	1,125,522	2.81	10,273	93%	92%	109.6
28'	41,785	1.74	371	3%	3%	112.6
40' Sea	4,754	1.05	36	0%	0%	132.9
20' Sea	650	1.06	10	0%	0%	67.8
Other	8,388	1.68	159	1%	1%	52.7
Roll-Off	38,827	1.01	248	2%	3%	156.9
All Trailer Types	1,219,925	2.71	11,096	100%	100%	109.9

3.1.2 Disposition Freight

Materials leaving the mattress deconstruction recycling facilities are transported to their next use (disposition) by truck. Distances to some dispositions are unknown, as indicated in Table 3.2. The average distance to the known locations is about 240 km. Truck trips with unknown destinations are assumed to travel the average distance of known trips.

Table 3.2. Freight from recycling facilities to disposition location. To estimate the freight associated with unknown destinations, the average distance of known trips is used.

Trip distance known?	tonne	average distance of known trips (km)	Freight, calculated (Mtkm)
known	16,474	241	3.96
unknown	23,901	NA	5.75

3.1.3 Load factors & LCI model linkages

Mattresses are relatively bulky freight. With an average 53’ trailer load of 110 mattresses, the payload weight is only 2.75 tonnes, compared to a weight capacity of over 30 tonnes for a typical 53’ trailer. This section describes the ecoinvent freight processes used to represent truck transport, and how these were corrected to account for the bulky nature of used mattress freight.

There are seven types of trailers used in the used mattress collection network. The fuel consumption for each trailer type is shown in Table 3.3. The last column also shows the truck class from ecoinvent that is used to model the particular trailer type.

We assume that a truck (with trailer, where applicable) at its maximum rated Gross Vehicle Weight consumes 29% more fuel (per mile) than with an empty load (based on fuel efficiency of 7 MPG for max payload, and 9 MPG for an empty load). In order to calculate the load-specific fuel consumption (shown in Table 3.3), the fuel consumption from the ecoinvent models is adjusted. Table 3.4 shows the default load factors and fuel consumption for each of the ecoinvent truck types.

For material transferred between facilities, we assume that a 53' trailer is used, with the same capacity utilization as in the collection mix, 2.75 tonnes per load.

Table 3.3. Diesel consumption and load factors for the truck freight models. Calculated by adjusting the fuel consumption in the ecoinvent activities (Table 3.4), based on load factor and the difference between fuel consumption at full payload and empty payload (discussed in the text). The 'ecoinvent truck class' column indicates which ecoinvent truck model is applied for each trailer size (ecoinvent processes "transport, freight, lorry [truck class] metric ton, EURO6_RoW_2021_Allocation, cut-off").

Trailer size	Diesel consumption [kg / tkm]	Load factor [t / t]	Diesel consumption [kg / km]	ecoinvent truck class
53'	0.0978	0.092	0.269	>32
28'	0.1100	0.087	0.192	16-32
48'	0.0858	0.105	0.270	>32
Roll-Off	0.1946	0.065	0.191	16-32
40' Sea	0.1539	0.062	0.191	16-32
20' Sea	0.1192	0.081	0.145	7.5-16
Other	0.1459	0.088	0.192	16-32

Table 3.4. Details of the ecoinvent freight activities (ecoinvent, 2021), including fuel consumption per km and per tkm. These parameters are used to calculate the fuel consumption of mattress hauling.

ecoinvent truck class [t]	Diesel consumption [kg / km]	Load Factor [t / t]	Payload max [t]	Fuel consumption [kg / tkm]
3.5-7.5	0.108	0.26	3.7	0.110
7.5-16	0.155	0.34	9.8	0.047
16-32	0.212	0.45	12.8	0.037
>32	0.306	0.59	27.2	0.019

3.1.4 Mattress compaction for collection

To assess the impact of increasing the load factor of mattress collection freight, we include a scenario where mattresses are compacted at the collection locations. For mattress compaction, we model a compression trailer, which will double the capacity of a typical trailer. This type of equipment would reduce the risks of shipping compressed mattresses (since the trailer itself would provide the protective cage). And it would reduce the impacts associated with freight by reducing the number of truck trips required.

The compression of springs can be a dangerous proposition. However, shipping compressed springs is routinely practiced in the mattress manufacturing supply chain, with specialized equipment to protect people from injury.

We assume that the compression and decompression of mattresses would require 25 kW of power for a total of 10 minutes (4.2 kWh shaft energy). This is supplied by diesel fuel burned at 35 percent efficiency in the truck, amounting to 1.1 liters per compaction cycle, and is represented by the same combustion model as used for the transport process. Fuel use per compaction cycle should be measured from actual equipment in the future.

3.2 Primary Mattress Recycling

The primary recycling facilities were surveyed to construct an aggregated facility inventory. These are the recycling facilities that perform the primary deconstruction to recover materials from used mattresses. Survey data was received from facilities that process 72% of the mattresses in CA. Table 3.5 shows the aggregated inventory of the CA primary recycling facilities. This synthetic inventory excludes the shredding of pocket coils (pocket coil shredding is included in §Other processing).

Table 3.5. Aggregated inventory of CA mattress recycling facilities. Amounts represent the amount of an input (item) used per tonne (1000 kg) of scrap mattresses processed.

Item	unit	amount	notes
Scrap mattress (avg. unit)	t	1	mix of sizes and types
Electricity, at user, CA	kwh	36.5	
Natural gas, at user, combusted	m3	0.0	combusted in industrial furnace/boiler
Water, Industrial, at user	kg	555.7	
Propane, combusted	l	2.4	combusted in equipment
Diesel, combusted	l	1.6	combusted in equipment
Gasoline, combusted	l	0.2	combusted in equipment

Knives and Blades	item	0.408	
Wire, baling	kg	1.183	
Lubricating oil	l	0.036	
Grease	kg	0.005	
Shredder blades	item	0.141	
Gloves (PPE)	item	0.474	
Masks (PPE)	item	6.695	
Goggles (PPE)	item	0.466	
Hard Hats (PPE)	item	0.007	
Vests (PPE)	item	0.005	
Boots (PPE)	item	0.003	
Baler (vertical)	item	4.11E-05	5 year lifetime
Baler (horizontal)	item	8.22E-05	5 year lifetime
Shredder	item	0.00E+00	5 year lifetime
Fork lift	item	1.82E-04	5 year lifetime
Separator	item	4.11E-05	5 year lifetime
Cuber	item	3.43E-05	5 year lifetime
Hopper/Dumpster	item	1.77E-04	5 year lifetime

3.2.1 LCI data linkages

To model the environmental impact of the primary recycling, each item in the facility inventory (Table 3.5) is represented by appropriate ecoinvent processes. These assignments are shown in Table 3.6. Some items require a combination of multiple ecoinvent processes (e.g. a steel spring is modeled as steel production plus wire drawing).

Table 3.6. The ecoinvent (2021) activities that represent the supplies and equipment used during recycling. Ecoinvent v3.8 model is used ("Allocation, cut-off by classification"), with either the GLO (global) or RoW (rest of world) region. Electricity generation mixes and linkages to ecoinvent processes are shown in §Electricity.

Item	amount	unit	process name
Propane, combusted in equipment	1	l	Liquefied petroleum gas, combusted in industrial boiler [US LCI]
Diesel, combusted in equipment	1	l	Diesel, combusted in industrial equipment [US LCI]

Gasoline, combusted in equipment	1	l	Gasoline, combusted in equipment [US LCI]
Natural gas, combusted in boiler	1	MJ	heat production, natural gas, at boiler condensing modulating >100kW
Water, Industrial, at user	1	kg	tap water production, conventional treatment
Knives and Blades	1	kg	steel, low-alloyed, hot rolled
	1	kg	hot rolling, steel
Wire, baling	1	kg	wire drawing, steel
	1	kg	steel, low-alloyed
Lubricating oil	1	kg	lubricating oil production
Hydraulic oil	1	kg	lubricating oil production
Grease	1	kg	lubricating oil production
Hopper	0.1	unit	building machine
Baler (vertical)	0.5	unit	building machine
Baler (horizontal)	0.5	unit	building machine
Fork lift	0.33	unit	skidder production
Shredder	1	unit	building machine
Separator	0.25	unit	building machine
Cuber	0.5	unit	building machine
Goggles (PPE)	0.5	g	polycarbonate production
	0.5	g	polyethylene production, high density, granulate
	1	g	thermoforming of plastic sheets
Masks (PPE)	6	g	textile production, nonwoven polyester, needle-punched
Hard Hats (PPE)	1	kg	polyethylene production, high density, granulate
	1	kg	injection moulding
Vests (PPE)	400	g	polyester fibre production, finished
	400	g	textile production, cotton, air jet loom weaving

Boots (PPE)	1	kg	polyester fibre production, finished
	1	kg	textile production, cotton, air jet loom weaving
	0.75	kg	synthetic rubber production
Gloves (PPE)	50	g	polyester fibre production, finished
	50	g	textile production, cotton, air jet loom weaving

3.3 Electricity: Generation mix and LCI linkages

The electricity mix for the state of CA, and for different CA utilities, is shown in Table 3.7. We assume that system losses are 10% of generation, so 1 kWh of delivered electricity requires 1.11 kWh generated. The ecoinvent process models that are used to represent each generation type are shown in Table 3.8.

Table 3.7. Electricity generation mixes for the California state mix (CA), as well as SCE (Southern California Edison), PG&E (Pacific Gas & Electric), and LADWP (Los Angeles Department of Water and Power) utility mixes. The "Unspecified" mix is based on guidance from the California Energy Commission to treat Unspecified power as generated with Natural Gas.

Electricity Source	Unit	CA	SCE	PGE	LADWP	Unspecified
Electricity, Biomass	kWh	2.5%	0.1%	2.6%	0.1%	
Electricity, Geothermal	kWh	4.9%	5.5%	2.6%	9.6%	
Electricity, Hydro (small)	kWh	1.4%	0.8%	1.2%	1.7%	
Electricity, Solar	kWh	13.2%	15.1%	15.9%	14.5%	
Electricity, Wind	kWh	11.1%	9.4%	8.3%	10.8%	
Electricity, Coal	kWh	2.7%	0.0%	0.0%	16.0%	
Electricity, Oil	kWh	0.2%	0.0%	0.0%	0.0%	
Electricity, Hydro (large)	kWh	12.2%	3.3%	10.1%	5.4%	
Electricity, NatGas Combined Cycle	kWh	33.4%	13.7%	14.8%	25.1%	90.0%
Electricity, NatGas Simple Cycle	kWh	3.7%	1.5%	1.6%	2.8%	balance
Electricity, Nuclear	kWh	9.3%	8.4%	42.8%	14.0%	
Electricity, Unspecified	kWh	5.4%	42.3%	0.0%	0.1%	

Table 3.8. ecoinvent (ecoinvent, 2021) processes used to model electricity generation.

Electricity Generation Type	ei Model Name	ei Region

Electricity, Biomass	ecoinvent, v3.8, Allocation, cut-off by classification	US-WECC
Electricity, Geothermal	ecoinvent, v3.8, Allocation, cut-off by classification†	US-WECC
Electricity, Hydro (small)	ecoinvent, v3.8, Allocation, cut-off by classification	US-WECC
Electricity, Solar	ecoinvent, v3.8, Allocation, cut-off by classification	US-WECC
Electricity, Wind	ecoinvent, v3.8, Allocation, cut-off by classification	US-WECC
Electricity, Coal	ecoinvent, v3.8, Allocation, cut-off by classification	US-WECC
Electricity, Oil	ecoinvent, v3.8, Allocation, cut-off by classification	US-WECC
Electricity, Hydro (large)	ecoinvent, v3.8, Allocation, cut-off by classification	US-WECC
Electricity, NatGas Combined Cycle	ecoinvent, v3.8, Allocation, cut-off by classification	US-WECC
Electricity, NatGas Simple Cycle	ecoinvent, v3.8, Allocation, cut-off by classification	US-WECC
Electricity, Nuclear	ecoinvent, v3.8, Allocation, cut-off by classification	US-WECC
† - All impacts are allocated to electricity (i.e. heat cogeneration is ignored)		

3.4 Other processing and manufacturing activities

In this section, inventories are presented that represent activities occurring (or that may occur) outside the MRC-contracted recycling facilities. This includes landfilling and incineration. In addition, the following mattress-derived products may require processing and manufacturing after material leaves a primary recycler:

- Steel from pocketed coils
- Wood chips
- Rebond foam pad
- Pyrolysis oil and char
- Polyol from chemical recycling (glycolysis and acidolysis of PU foam)

This section also presents the inventories of resources required to produce each of these products.

3.4.1 Waste: Landfill and Incineration

Wastes from mattress recycling include a mix of materials. The assumed mix is from the MRC Waste Characterization Study.

Table 3.9. Landfill and incineration processes applied to materials that make up waste flows. For materials without a direct match in the ecoinvent database, proxy processes are defined.

Material name	ei Landfill Process	ei Combustion Process	Biogenic C fraction
Cardboard	treatment of waste paperboard,	treatment of waste paperboard,	1

	sanitary landfill	municipal incineration	
Cotton	treatment of waste graphical paper, sanitary landfill	treatment of waste graphical paper, municipal incineration	1
Fabric, synthetic	treatment of waste polyethylene terephthalate, sanitary landfill	treatment of waste polyethylene terephthalate, municipal incineration	0
Fabric, plant fibers	treatment of waste graphical paper, sanitary landfill	treatment of waste graphical paper, municipal incineration	1
Mixed Non-Woven Fibers	treatment of waste plastic, mixture, sanitary landfill	treatment of waste plastic, mixture, municipal incineration	0
Fibers, synthetic	treatment of waste plastic, mixture, sanitary landfill	treatment of waste plastic, mixture, municipal incineration	0
Foam, latex	treatment of waste wood, untreated, sanitary landfill	treatment of waste wood, untreated, municipal incineration	1
Polyurethane Foam	treatment of waste polyurethane, sanitary landfill	treatment of waste polyurethane, municipal incineration	0
Other Material	treatment of waste plastic, mixture, sanitary landfill	treatment of waste plastic, mixture, municipal incineration	0
Plastic parts	treatment of waste plastic, mixture, sanitary landfill	treatment of waste plastic, mixture, municipal incineration	0
Quilt Panels	treatment of waste plastic, mixture, sanitary landfill	treatment of waste plastic, mixture, municipal incineration	0
Shoddy Felt Pad	treatment of waste plastic, mixture, sanitary landfill	treatment of waste plastic, mixture, municipal incineration	0
Steel springs	treatment of inert waste, sanitary landfill	treatment of scrap steel, municipal incineration	0
Wood	treatment of waste wood, untreated, sanitary landfill	treatment of waste wood, untreated, municipal incineration	1
Fabric, synthetic, woven	treatment of waste plastic, mixture, sanitary landfill	treatment of waste plastic, mixture, municipal incineration	0
Foam, synthetic	treatment of waste polyurethane, sanitary landfill	treatment of waste polyurethane, municipal incineration	0
Other material	treatment of waste plastic, mixture, sanitary landfill	treatment of waste plastic, mixture, municipal incineration	0
Fabric, PP, nonwoven	treatment of waste polypropylene, sanitary landfill	treatment of waste polypropylene, municipal incineration	0
Fabric, PET, nonwoven	treatment of waste polyethylene terephthalate, sanitary landfill	treatment of waste polyethylene terephthalate, municipal incineration	0

Fiber, PP	treatment of waste polypropylene, sanitary landfill	treatment of waste polypropylene, municipal incineration	0
Fiber, PET	treatment of waste polyethylene terephthalate, sanitary landfill	treatment of waste polyethylene terephthalate, municipal incineration	0

3.4.2 Pocketed coil shredding

Table 3.10. Inventory for shredding 1 tonne of pocketed coils. Some data are withheld to protect confidentiality.

Item	in/out	value	unit	notes
Pocketed Coils	in	1	t	
Electricity, at user, CA	in	50	kwh	based on XR2000 specs, and the ecoinvent process "treatment of used glider, passenger car, shredding"
Water, Industrial, at user	in	***	l	
Propane, combusted	in	***	l	
Diesel, combusted	in	***	l	
Gasoline, combusted	in	***	l	
Lubricating oil	in	***	l	
Grease	in	***	l	
Gloves (PPE)	in	***	item	
Masks (PPE)	in	***	item	
Goggles (PPE)	in	***	item	
Hard Hats (PPE)	in	***	item	
Vests (PPE)	in	***	item	
Boots (PPE)	in	***	item	
Shredder	in	***	item	10 tonne machine
Fork lift	in	***	item	
Hopper/Dumpster	in	***	item	
Steel, recycled as scrap	out	0.90		cubed, clean steel
Waste (from pocket coils)	out	0.10		PP fabric scraps

3.4.3 Wood chipping

The recycled wood leaving recyclers is assumed to be subsequently chipped and used as mulch. The wood chipping model is based on the ecoinvent process “wood chips production, softwood, at sawmill” (ecoinvent, 2021), but customized to exclude the raw material input (“slab and siding, softwood, wet, measured as dry mass”) and to utilize a western US power grid.

3.4.4 Rebond Foam pad manufacturing

Table 3.11. Inventory of the rebond foam pad manufacturing process.

Item	in/out	value	unit	Comment
Foam (recycled), Chopped	in	1	kg	Post-consumer polyurethane foam; pre-chopped
Isocyanate (binder)	in	0.070	kg	Based on 16 liters binder per 272 kg (600 lb) foam
Electricity, at user, CA	in	0.040	kWh	assuming 33 kW for 20 minutes to make a 600 lb batch of rebond foam
Heat, natural gas, at user	in	0.387	MJ	assuming 80% steam system efficiency
Water, Industrial, at user	in	0.119	kg	assuming 2x volume of binder (binder density = 1.18 g/cm3)
Rebond capital equipment	in	1.20E-07	items	Model uses 10000 hr equipment lifetime to amortize cost of a 20t piece of equipment
Landfill, PU	out	0.054	kg	Assuming 95% yield
Rebond carpet pad	out	1.017	kg	

3.4.5 Pyrolysis

Table 3.12. Inventory for the whole-mattress pyrolysis process. Where parameters were not reported in the TNO Report (TNO, 2022), other sources were used (Altayeb, 2015; Iribarren et al., 2012; Khoo, 2019).

Item	in/out	value	unit	notes
Scrap mattress (avg. unit)	in	1	kg	includes steel
Pyrolysis Facility	in	3.30E-11	unit	Use "petroleum refinery" as proxy; per mass of input (and petroleum from the proxy)
Heat, natural gas, at user	in	1.500	MJ	TNO Report, Table 9
Electricity, at user, CA	in	0.0442	kwh	Average of Iribarren (2012), Altayeb (2015), and Khoo (2019)
Water, Industrial, at user	in	2	kg	Iribarren, 2012

Water to treatment	out	1.5	kg	Assumption that 75% of water input ends up in the drain
Landfill, pyrolysis sludge	out	0.03204	kg	based on TNO Report, Table 20
Pyrolysis gas, burned onsite	out	3	MJ	TNO Report, Table 9 (Diff b/t "Gross" and "Net" demand; Dry mattress)
Pyrolysis char	out	0.08284	kg	based on TNO Report, Table 20
Pyrolysis oil	out	0.29457	kg	based on TNO Report, Table 20
Steel, recycled as scrap	out	0.398	kg	From deconstruction/count studies

Table 3.13. Inventory for the foam-only pyrolysis process. Where parameters were not reported in the TNO Report (TNO, 2022), other sources were used (Altayeb, 2015; Iribarren et al., 2012; Khoo, 2019).

Item	in/out	value	unit	notes
Foam, recovered	in	1	kg	
Pyrolysis Facility	in	3.30E-11	unit	Use "petroleum refinery" as proxy; per mass of input (and petroleum from the proxy)
Heat, natural gas, at user	in	0.75	MJ	Assumption that supplemental gas amounts to 25% of pyrol gas
Electricity, at user, CA	in	0.04	kwh	Average of Iribarren (2012), Altayeb (2015), and Khoo (2019)
Water, Industrial, at user	in	2.0	kg	Iribarren, 2012
Water to treatment	out	1.5	kg	Assumption that 75% of water input goes to wastewater
Landfill, pyrolysis sludge	out	0.061	kg	based on TNO Report, Table 20
Pyrolysis gas, burned onsite	out	3.0	MJ	All pyrolysis gas produced (TNO Report, Table 20)
Pyrolysis char	out	0.03	kg	based on TNO Report, Table 20
Pyrolysis oil	out	0.81	kg	based on TNO Report, Table 20

3.4.6 Glycolysis of PU foam

Table 3.14. Inventory for the chemical recycling of post-consumer recovered PU foam via glycolysis. The use of diethylene glycol (DEG) as a glycolysis agent is common in the literature, at a DEG:PU ratio of 1.5 by mass (Herrero, 2017; Marson et al., 2021; Simón et al., 2014; Wu et al., 2003). Electricity use is based on (Marson et al., 2021, p. 1722). The rate of evolution of CO_2 from the reaction is from (Borda et al., 2000, Fig.4)

Item Name	in/out	amount	unit	notes
Foam (recycled),	in	1.0	kg	foam recovered from mattresses; pre-chopped

Chopped				
Diethylene glycol	in	1.5	kg	various sources
Diethanolamine	in	0.01	kg	catalyst
Electricity, at user, CA	in	0.08	kwh	(Marson et al., 2021, p1722) [10.1021/acsomega.0c05844]
CO2 emission	out	0.02	kg	(Borda et al., 2000) [10.1016/S0141-3910(00)00030-6]
Polyol, recovered	out	2	kg	

3.4.7 Acidolysis of PU foam

Table 3.15. Inventory for chemical recycling, via acidolysis, of post-consumer recovered PU foam. The ratios of foam, virgin polyol, acids, and catalyst are from the technical documentation brochure of a commercial PU foam recycling process (H&S Anlagentechnik, 2022). Succinic and adipic acid are the acids assumed to be used, based on literature (Gama et al., 2020; Grdadolnik et al., 2022). The fact that two dicarboxylic acids are used in the process was indicated in the brochure (H&S Anlagentechnik, 2022); we assume they are used in equal proportion.

Item Name	in/out	amount	unit	notes
Foam (recycled), Chopped	in	1.00	kg	
Polyol	in	1.05	kg	H&S Anlagentechnik brochure
Succinic acid	in	0.14	kg	H&S Anlagentechnik brochure; assuming equal parts succininc and adipic acids
Adipic acid	in	0.14	kg	H&S Anlagentechnik brochure; assuming equal parts succininc and adipic acids
Diethanolamine	in	0.05	kg	catalyst
Electricity, at user, CA	in	0.07	kwh	(Marson et al., 2021, p1722) [10.1021/acsomega.0c05844]
CO2 emission	out	0.02	kg	(Borda et al., 2000) [10.1016/S0141-3910(00)00030-6]
Water to treatment	out	0.12	kg	
Polyol, recovered	out	2.24	kg	assuming 95% product yield

3.4.8 LCI model linkages (other processing)

Table 3.16. Linkages to the ecoinvent database. The items in the *Activity* column correspond to *Items* in the inventories in the previous sections. The *process name* column provides the ecoinvent process (ecoinvent, 2021) used to model the inventory items.

Activity	amount	amount unit	process name
common			
Water, Industrial, at user	1	kg	tap water production, conventional treatment
Water to treatment	1	kg	treatment of wastewater, average, capacity 1E9l/year
Heat, natural gas, at user	1	MJ	heat production, natural gas, at boiler condensing modulating >100kW
pocket coil shredding			
Shredder (equipment)	1	item	building machine
rebond foam pad			
Isocyanate (binder)	1	kg	market for methylene diphenyl diisocyanate
Rebond equipment	2	item	building machine
pyrolysis			
Pyrolysis Facility	1	item	Petroleum refinery construction
Pyrolysis gas to self-use	1	kg	Refinery gas, burned in furnace (proxy)
chemolysis			
polyol	1	kg	polyol production
adipic acid	1	kg	market for adipic acid
succinic acid	1	kg	market for succinic acid
Diethylene glycol	1	kg	market for diethylene glycol
Diethanolamine	1	kg	market for diethanolamine

3.5 Displaced production and Logistics

Freight transport of mattress-derived products was estimated based on actual product deliveries information reported in ReTRAC. Representative distances were assumed for potentially displaced products based on the best available information in each case (Table 3.17).

Production and logistics of displaced products was avoided according to the assumed displacement rates reported in Table 3.18.

Table 3.17. List of mattress-derived products, and the corresponding potentially displaced products. The column 'Primary MD material?' indicates whether the Mattress-Derived (MD) product is produced directly by CA mattress recyclers ('Yes'), or whether the material requires other processing before being marketed ('No'). The 'Displaced transport' columns indicate transport that is potentially avoided by the supply of the mattress-derived product.

Mattress-derived Product	Primary MD material?	Displaced product	Transport MD to disposition (km, truck)	Displaced transport (km, truck)	Displaced transport (km, ocean)
Steel, recycled as scrap	Yes	Steel, displaced	416	300	1000
Foam, recovered	Yes	Post industrial scrap foam, displaced	0	600	10000
Rebond carpet pad	No	Foam pad, displaced	594	500	0
Quilt, recovered	Yes	Post industrial scrap foam, displaced	0	600	10000
Quilt, recovered	Yes	Foam pad, displaced	640	500	0
Wood mulch, recovered	No	Wood chips, displaced	16	1000	0
Cotton, recovered	Yes	Cotton fiber, displaced	313	300	1000
Shoddy, recovered	Yes	Polypropylene granulate, displaced	45	500	5000
Other fiber, recovered	Yes	Polypropylene granulate, displaced	67	500	5000
Cardboard, recovered	Yes	Wood pulp, displaced	3	500	5000
Plastic, recovered	Yes	Plastic, displaced	1	500	5000
Whole unit, to reuse	Yes	New whole unit, displaced	79	500	0
Foam (reuse)	Yes	Foam pad, displaced	248	500	5000
Wood (reuse)	Yes	Wood, displaced (board)	79	1000	
Steel component (reuse)	Yes	Steel spring, displaced	23	500	5000
Quilt (reuse)	Yes	Quilt, displaced	248	500	5000
Cotton fabric (reuse)	Yes	Cotton fabric, displaced	48	500	5000

Other fabric (reuse)	Yes	Polyester fabric, displaced	48	500	5000
Other (reuse)	Yes	Unknown (reuse)	100	500	5000
Shoddy (reuse)	Yes	Shoddy pad, displaced	48	500	5000
Wood fuel	Yes	Heat, natural gas, displaced	37	0	0
Heat, from wood chips	No	Heat, natural gas, displaced	66		0
Polyol, recovered	No	Polyol, displaced	37	0	5000
Pyrolysis oil	No	Petroleum, displaced	100	500	0
Pyrolysis char	No	Carbon black, displaced	200	500	5000

Table 3.18. Displacement rates for each class of displacement. The Mattress-derived Materials column indicates which materials recovered from mattress are included in each displacement class.

Displacement class	Mattress-derived Materials	Mid (default)	High	Low
Market leaders (scrap-derived product is preferred to virgin product)	Rebond foam pad (from Foam and Quilt)	50%	100%	20%
Fuels & Commodities	Steel, Wood, Cotton, Shoddy, Cardboard, Plastic, Polyols (from foam chemolysis), Crude oil and Char (from pyrolysis), Mulch (from wood), Waste-to-Energy, Biomass Energy	90%	100%	80%
Reuse	All reused (Whole unit, Foam, Wood, Steel)	75%	100%	50%

3.5.1 LCI model linkages and customizations

Each displaced product is modeled using a combination of ecoinvent process inventories, as outlined in Table 3.19.

Table 3.19. Model specification to estimate the impacts of the potentially displaced activities (ecoinvent, 2021). For the “New whole unit” displaced product, the mattress is modeled as a combination of the material composition of an average mattress in CA (see §Mattress Unit Characterizations)

Potentially Displaced Product	ecoinvent Process Model
Steel, displaced	steel production, converter, unalloyed
Steel spring, displaced	wire drawing, steel
	steel, low-alloyed
Quilt, displaced	polyurethane production, flexible foam, TDI-based, high density
	textile production, air jet loom weaving
	polyester fibre production, finished
Foam pad, displaced	polyurethane production, flexible foam, TDI-based, high density
Wood chips, displaced	market for wood chips, wet, measured as dry mass
Wood, displaced (board)	lath, softwood, raw, kiln drying to u=10%
Cotton fabric, displaced	textile production, cotton, air jet loom weaving
Fibers (mix), displaced	market for fibre, cotton
	market for waste polyethylene terephthalate, for recycling, sorted
	market for polyethylene terephthalate, granulate, amorphous
New spring mattress, displaced	mattress production, polyurethane foam
New foam mattress, displaced	mattress production, pocket spring
New whole unit, displaced	(various processes)
Polyol, displaced	polyol production
Petroleum, displaced	market for petroleum
Carbon black, displaced	carbon black production

Table 3.120. Activities based on customized ecoinvnet inventories.

Custom Activity	ei Process	Customization Applied
Textile weaving (process only)	textile production, cotton, air jet loom weaving	Exclude “yarn, cotton”
Needle punching	textile production, nonwoven polyester, needle-punched	Exclude “fibre, polyester”
Fibre, PP	polyester fibre production, finished	Replace “polyethylene terephthalate, granulate, amorphous” with “polypropylene, granulate”

4 Life Cycle Impact Assessment

This section describes the modeled environmental impacts associated with used mattress management in California. The results presented have two types of contributions: incurred impacts (positive-valued contributions) and potentially displaced impacts (negative-valued contributions).

- Incurred environmental impacts result from the actions taken within the mattress recycling system. These include emissions from transportation of mattresses from collection centers to processors, direct emissions from facility operations, upstream emissions from materials and equipment used by processors, and emissions from electricity generation. Impacts are also modeled for the transport of the mattress-derived products to their next use in the market (disposition).

- Potentially displaced impacts represent emissions associated with the production of products that compete with mattress-derived products in the marketplace, and so are potentially avoided by mattress recycling. There is considerable uncertainty about displacement rates (see §Study Scope).

The sum of these positive and negative impact scores indicates the potential net environmental impacts that could occur if mattress-derived products are displacing primary products as assumed. In the figures below, when the net totals are shown, uncertainty ranges are also shown, based on the displacement rates in §Displaced Production.

There are 11 impact categories included in the model (descriptions of each in §Appendix).

4.1 Results: California state-wide, 2021

The results in this section represent the Mattress recycling system in California, circa 2021, plus the potentially displaced products. During 2021 MRC operations in California, 1.63 million mattress units were delivered to primary recyclers. Assuming an average of 25 kg / mattress (55 lb), this amounts to 40.7 thousand tonnes (kt) of mattresses. The outputs from the recyclers were 40.4 kt.

Figure 4.1 shows the impacts of mattress recycling activities, including the impacts that could potentially be avoided if the recycled materials displace virgin material production. Figure (A) shows the Headline indicators; Figure (B) shows the Supporting indicators. In each figure, the bars on the far right show the Net total impacts, a combination of the incurred impacts from the recycling system plus the potentially avoided (negative) impacts associated with the displaced products. In the figures, activities are grouped into stages (x-axis). Detailed results for the baseline scenario, where the stage groups are dis-aggregated, are shown in §Baseline Incurred Impacts.

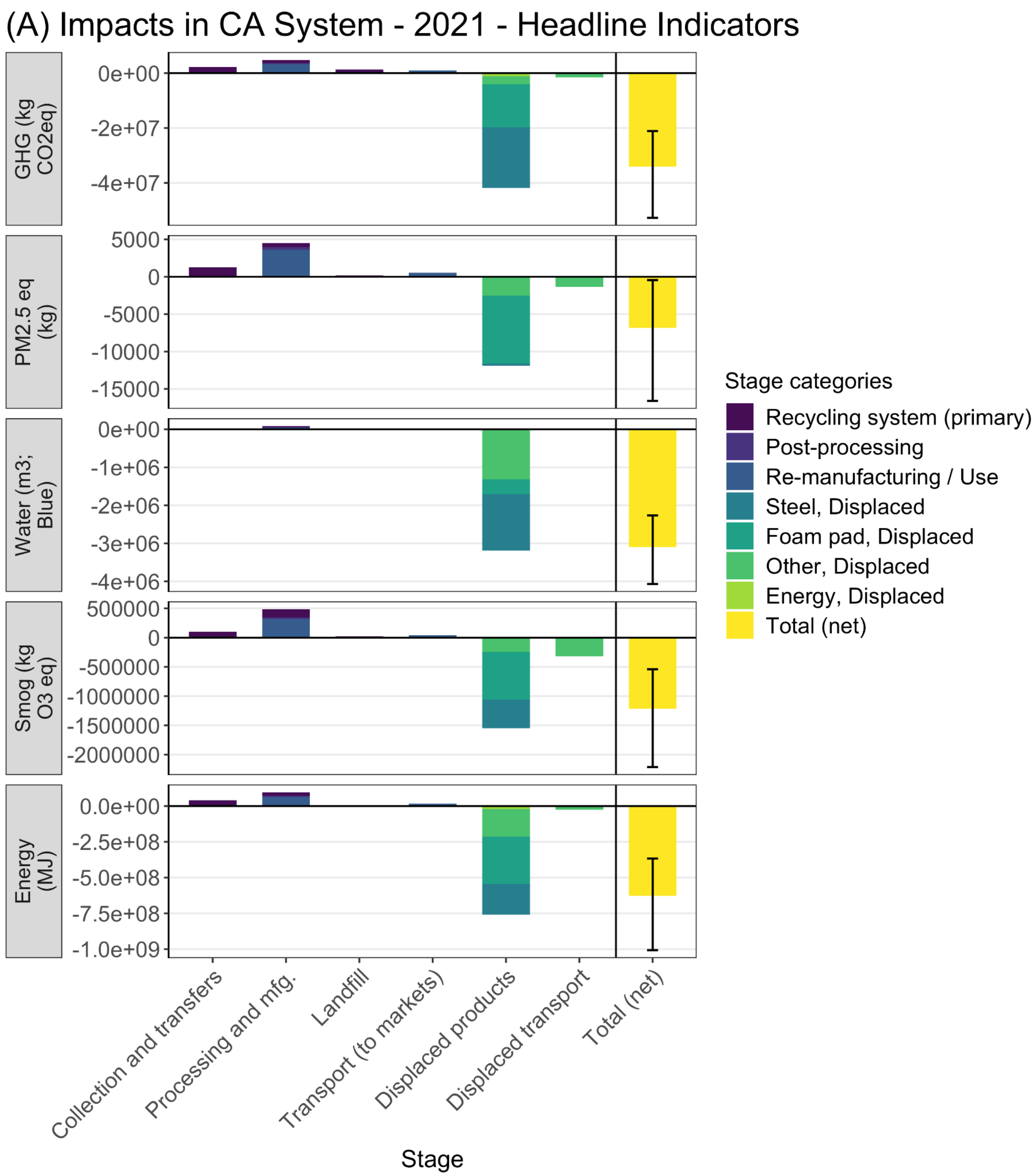
Figure 4.1(A) shows that the potentially avoided impacts from displaced production exceed the incurred impacts in all headline indicators, although the particulates indicator (PM2.5eq) approaches break-even with the most pessimistic displacement rates. Benefits for Climate impact (GHG), Water use, and Primary energy demand appear to be particularly significant. The "processing and manufacturing" stage is dominated by the foam rebond activity (see §Baseline Incurred Impacts). Nonetheless, the potentially avoided impacts due to displaced production of primary (virgin) polyurethane foam are larger in magnitude, and so rebond foam appears to be a beneficial use of recovered foam. The generation of steel scrap also provides benefits. For the Water use indicator, displaced textile production is significant (included in the "Other, Displaced" category), in addition to the displaced steel. Impacts from collection and transport are generally smaller than impacts from production activities.

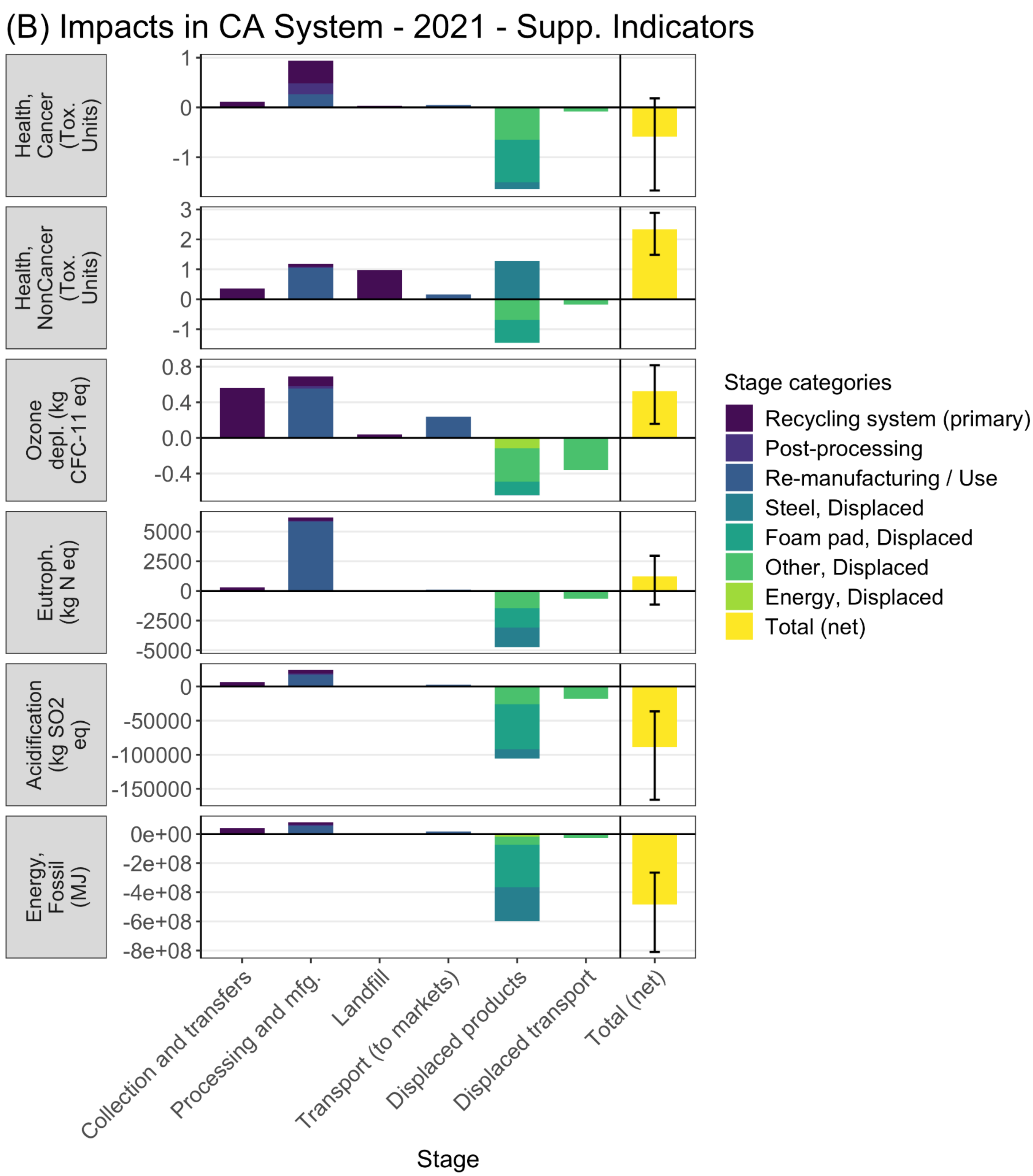
In Figure 4.1(B), the results show that the avoided impacts from displaced production are greater in magnitude than incurred impacts in three out of six supporting indicators, although one of those (health-cancer) is marginal.

In the other three categories (health-noncancer, ozone depletion, eutrophication), the incurred impacts of recycling exceed the magnitude of the avoided impacts of the potentially displaced products. The production of methylene diphenyl diisocyanate (MDI, required for the rebond process) is a major contributor in every impact category (not shown). In the health-noncancer case, steel recycling actually generates an incurred impact, driven by emissions of mercury and zinc that are modeled to increase under steel recycling (ecoinvent, 2021; World Steel Association, 2021). In cases like this, recycled material has a higher impact than its primary (virgin) alternative.

Landfill impacts are also significant. In the Eutrophication impact category, the rebond process is dominant (due to MDI production). In Ozone depletion, impacts are due to MDI production, as well as heavy truck transport and electricity production. In Health-cancer, production of heavy equipment for recycling is the largest contributor, followed by MDI production, due to emissions of mercury, nitrobenzene, and formaldehyde (not shown).

Figure 4.1. Impacts of mattress recycling activities, and of the potentially displaced products. These results represent the recycling and management of 1.6 million used mattresses in California during calendar year 2021 Each panel shows results for one type of indicator (Greenhouse gas impact at the top); each panel has a distinct y-axis. Different stages in the system are shown along the horizontal axis. The error bars show the Total (net) impact for the higher and lower displacement rates.





(B) Impacts in CA System - 2021 - Supp. Indicators
Health, Cancer (Tox. Units)
Health, NonCancer (Tox. Units)
Ozone depl. (kg CFC-11 eq)
Eutroph. (kg N eq)
Acidification (kg SO2 eq)
Energy, Fossil (MJ)
Stage categories
Recycling system (primary)
Post-processing
Re-manufacturing / Use
Steel, Displaced
Foam pad, Displaced
Other, Displaced
Energy, Displaced
Total (net)
Collection and transfers
Processing and mfg.
Landfill
Transport (to markets)
Displaced products
Displaced transport
Total (net)
Stage

4.2 Impacts per tonne of mattresses

The results in this section show impacts per tonne of mattresses recycled. Results for multiple scenarios are included (see §Scenarios and Scales for an explanation of each scenario). Scenarios are defined by the mix of mattress types, the recycling activities included, and the products that are assumed to be displaced.

4.2.1 System Scenarios

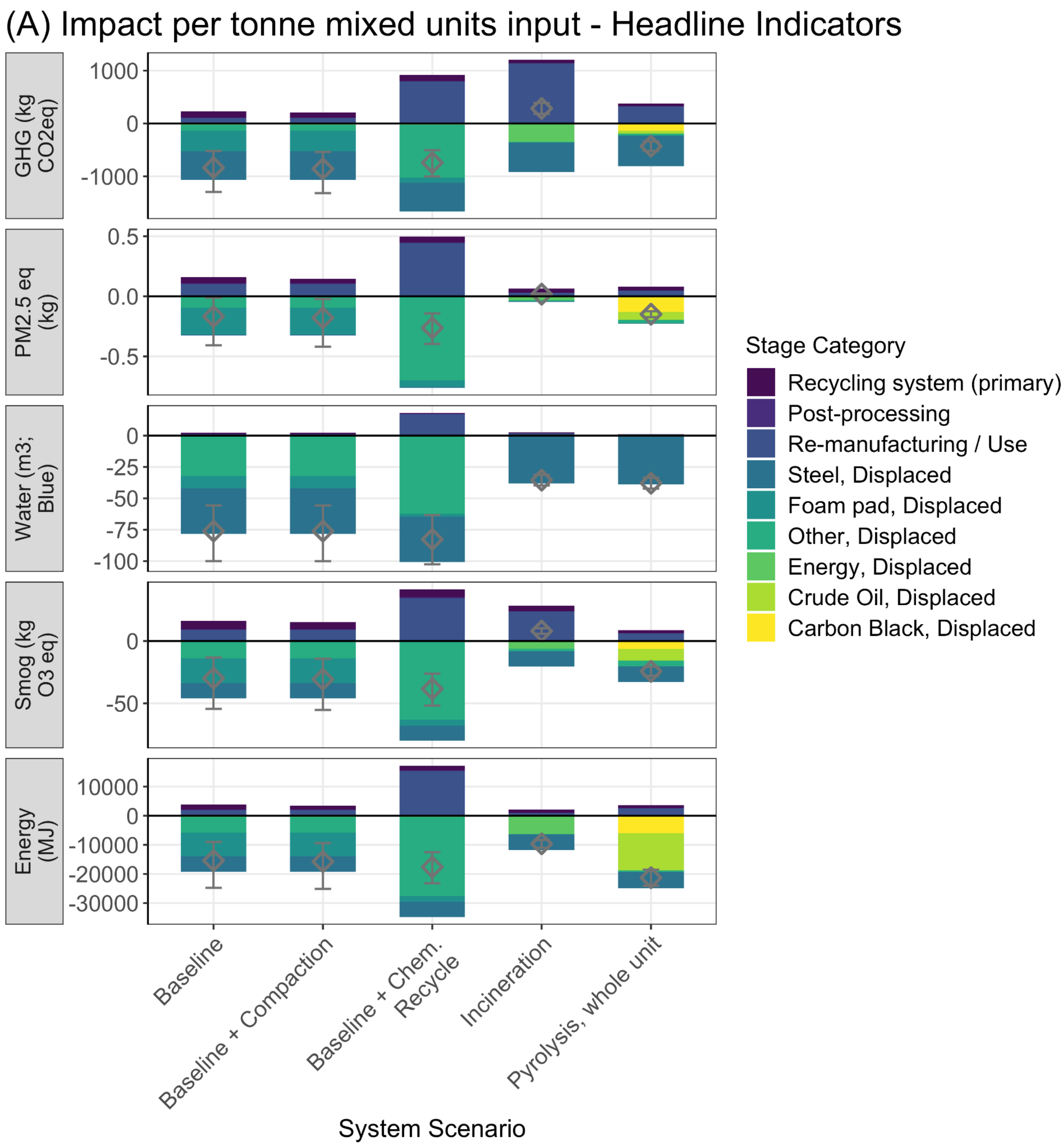
Results for six different recycling scenarios are shown in Figure 4.2. These scenarios all use the Baseline mix of collected mattress unit types and sizes.

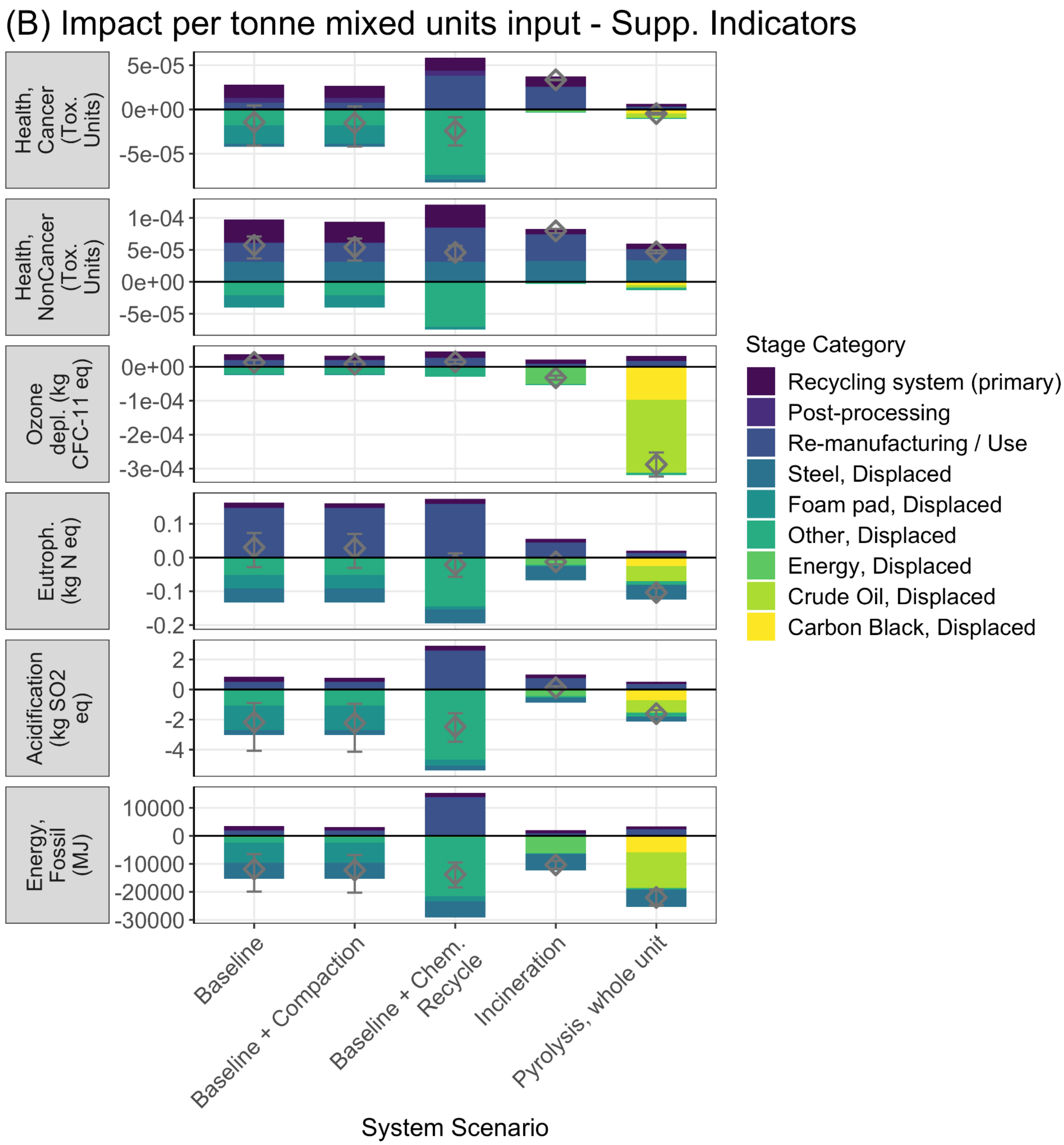
The results for the Headline indicators are shown in Figure 4.2(A). In the compaction scenario, impacts from mattress collection are reduced, but that has a small effect on the overall system. In the case where all foam is chemically recycled rather than used for rebond, both incurred and avoided impacts increase substantially (driven by upstream chemicals production), although the net effect is one of slight improvement. The incineration case shows an increase in climate change, particulate, and smog impacts in exchange for energy (and potentially cost) savings. The results suggest that pyrolysis with steel recovery is a possible materials management strategy to avoid impacts.

The results in figure 4.2(B) show supporting indicators for the management scenarios. These results largely mirror the CA 2021 scenario. In particular, the incurred impacts from MDI production in the rebond process dominate the health categories, along with steel recycling in the health-noncancer category. In eutrophication and ozone depletion, the chemical recycling route approaches break-even, but only pyrolysis shows likely benefits. Acidification mirrors the other categories driven by air emissions (climate change, particulates, and smog). All routes show reductions in fossil energy demand.

No management routes show potential improvement in the health-noncancer category. The incurred impacts in this indicator are driven by multiple stages. The largest contributor is the steel recycling credit, which indicates an increase in zinc and mercury emissions resulting from the use of steel scrap. Other contributors are the landfill process, the wood combustion process, and the production of methylene diphenyl diisocyanate (MDI) for rebond foam.

Figure 4.2. Impacts of six used mattress management system scenarios. The scenario on the far left represents the Baseline (CA 2021).

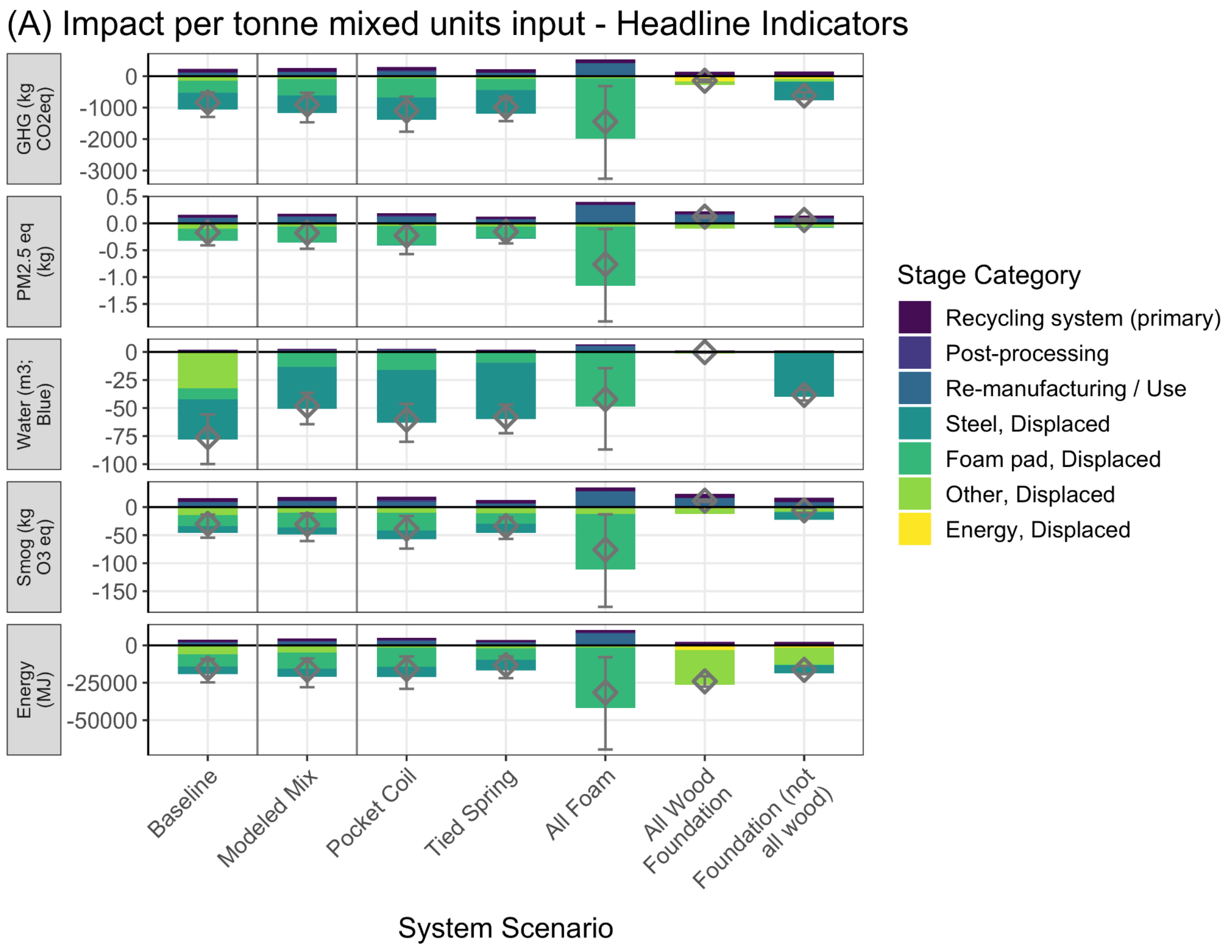


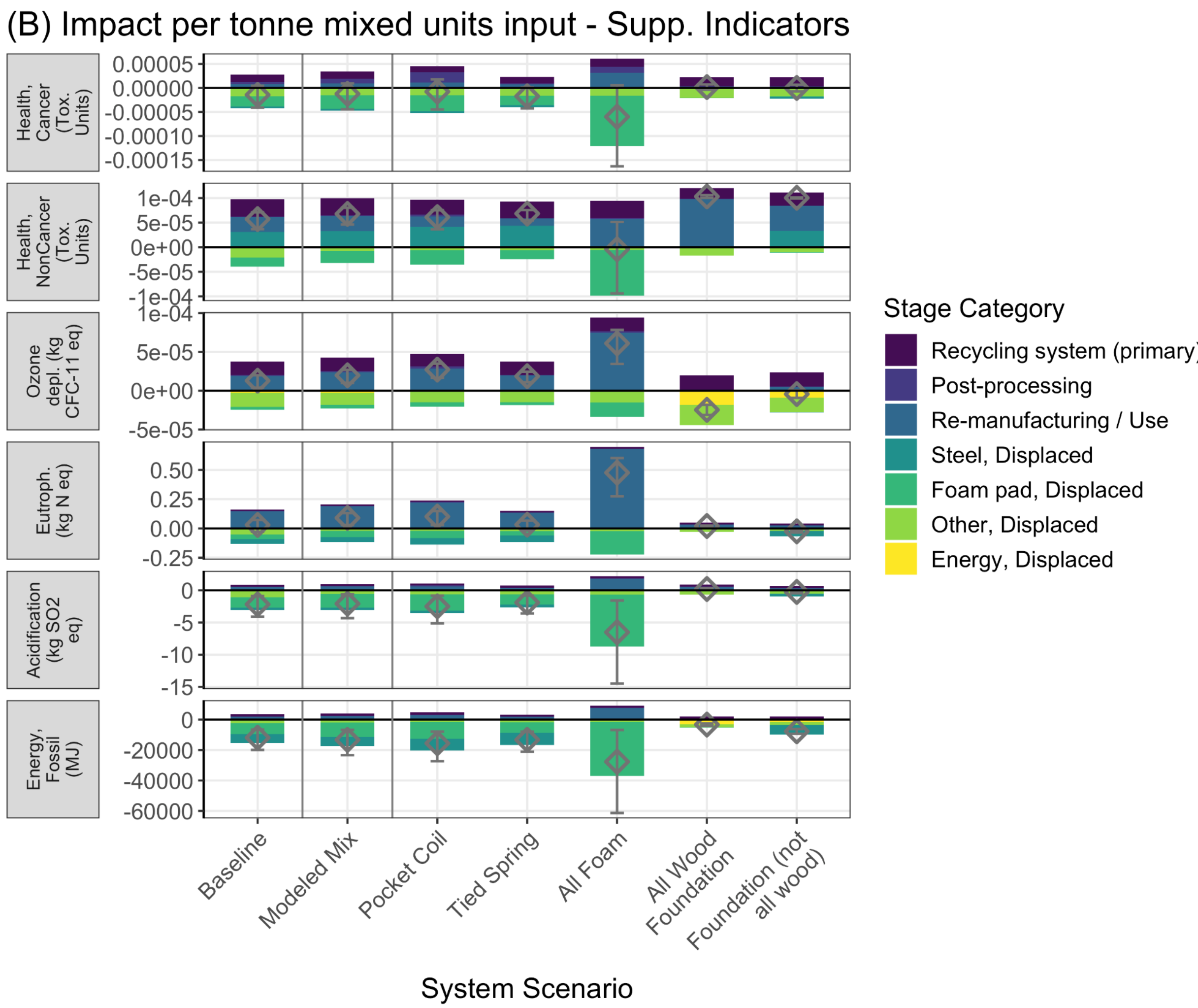


4.2.2 Results by Mattress Type

The impacts and potential benefits of recycling different mattress types are shown in Figure 4.3. Both innerspring mattress types are similar, with pocket coils performing slightly better (owing to their higher foam content). Foam mattresses show larger potential benefits but also proportionately larger uncertainty (due to the large range for the displacement rate for rebond foam pad). Recycling of wood foundations is mixed, showing large reductions in primary energy demand (due to avoided forestry activity), but increased or marginally increased smog and particulate emissions.

Figure 4.3. Impacts of recycling six different types of used mattress types. The Baseline scenario (far left) is included for comparison. For all other scenarios, the uses (dispositions) of recovered materials are as in the Baseline, but the relative amounts of the materials are determined by the makeup of each type of mattress (see §Mattress Unit Characterizations). The "Modeled Mix" scenario is similar to the "Baseline" scenario, but the mix of material outputs is based on the makeup of the mix of mattresses (not on the material outputs reported in ReTRAC).



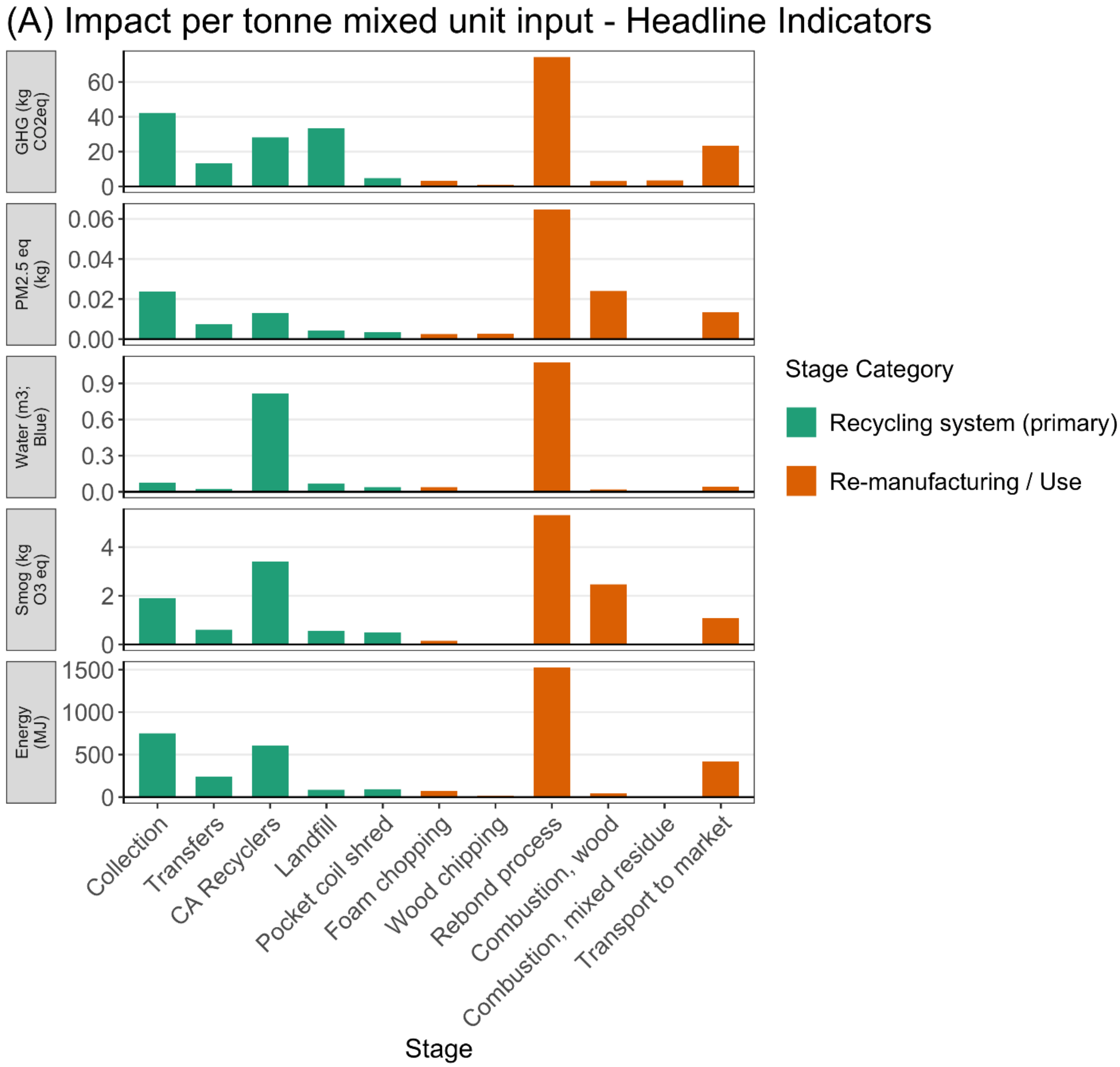


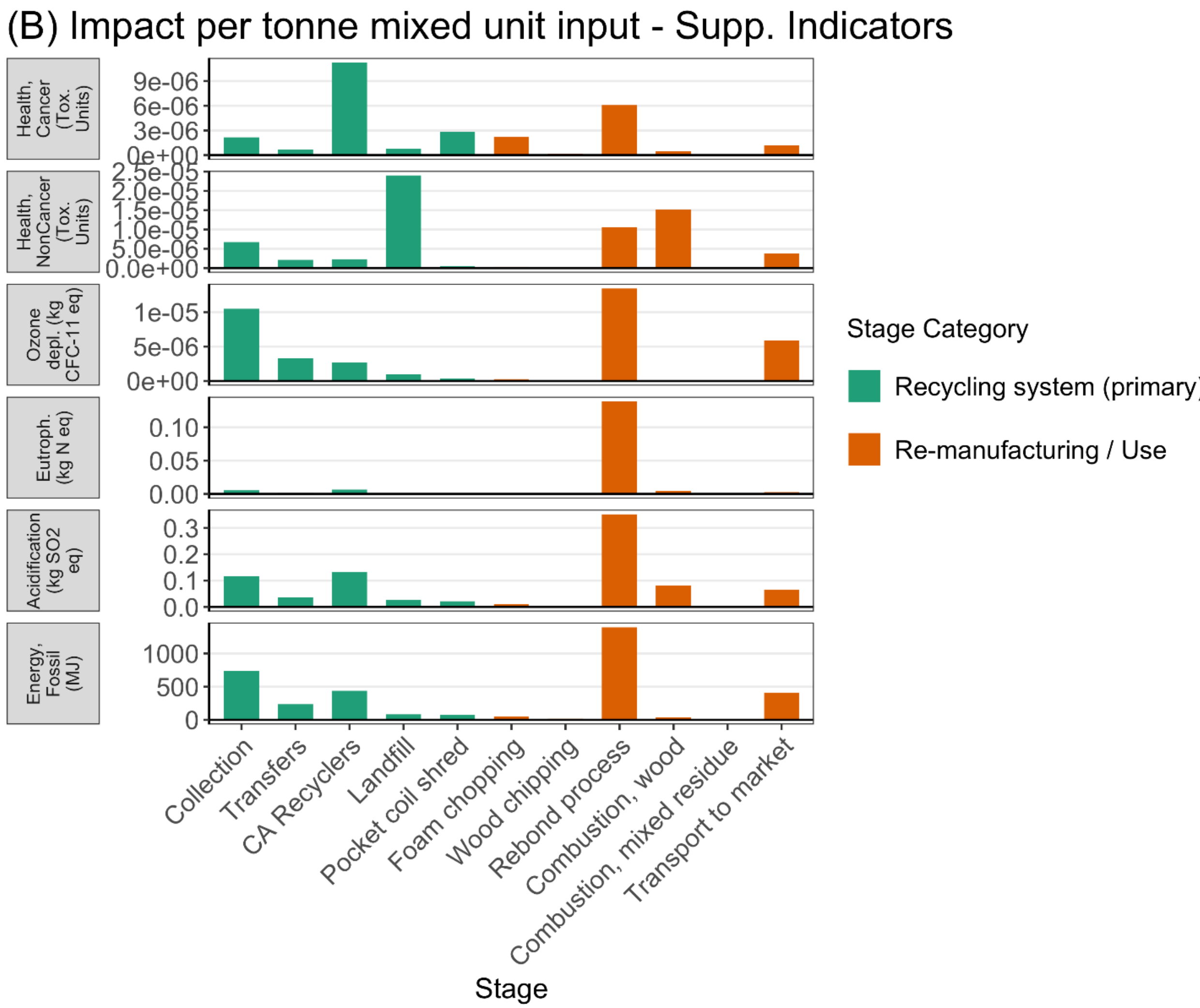
4.2.3 Baseline Incurred Impacts

The charts in this section show only the activities in the mattress recycling system that lead to incurred impacts. Impacts are grouped into Primary recycling activities (including collection, transfers, deconstruction, and landfill), Post-processing (shredding and chopping), Re-manufacturing / Use (downstream manufacturing), and transport of recycled products to markets.

The results show that the rebond process is the dominant source of impacts for every headline indicator, and for 4 out of 6 supporting indicators. As discussed above, this impact is primarily driven by the production of MDI used in the rebond process. The collection and deconstruction (CA Recyclers) stage is also important in several of the impact categories.

Figure 4.4. Incurred impacts in the recycling system. These results exclude the potentially avoided impacts associated with displaced products.

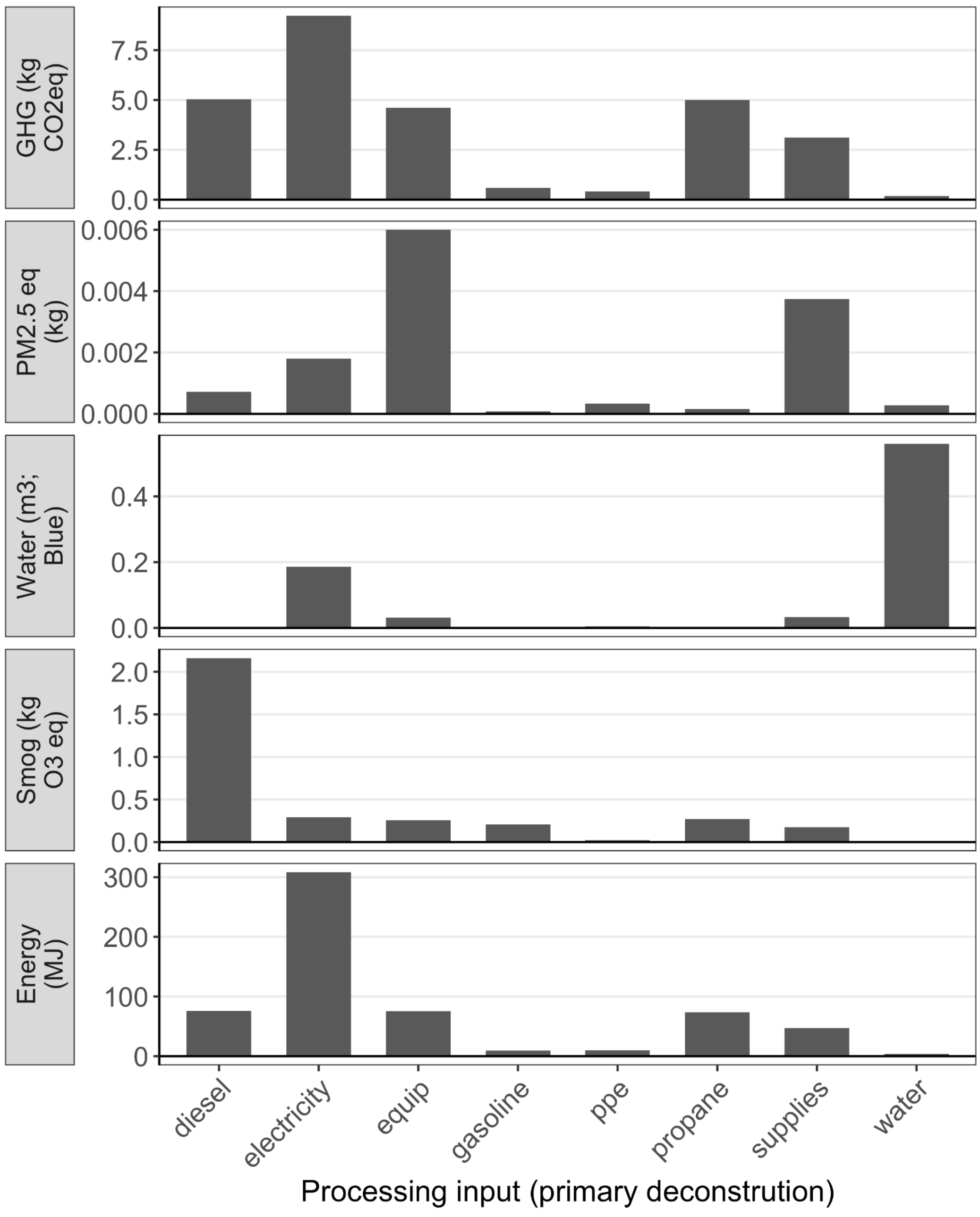


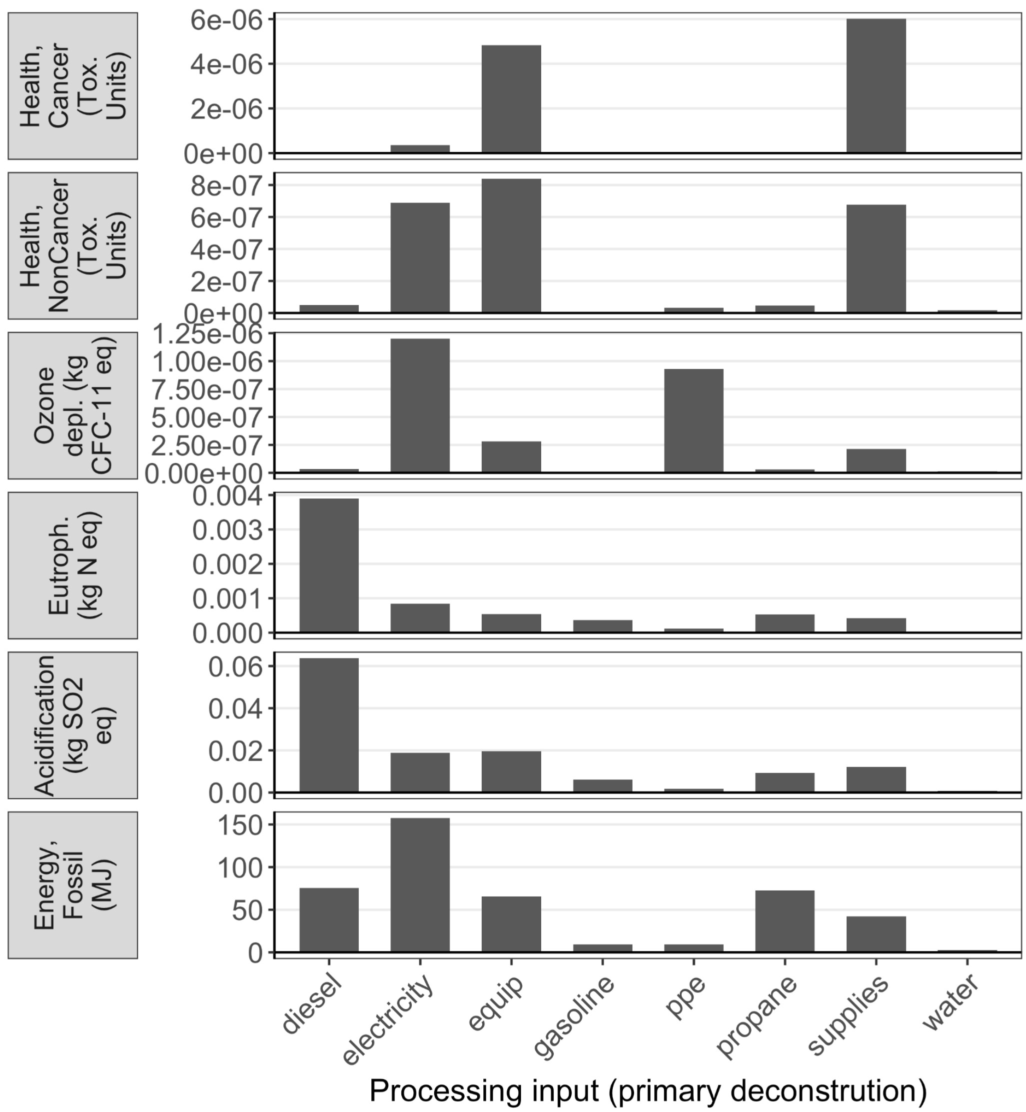


4.2.4 CA Processors

Figure 4.5 shows a stage contribution analysis of the California mattress recycling facilities for all eleven indicators. The charts show that different activities are significant for different indicators. Electricity use is perhaps the most important stage, along with diesel use and equipment manufacturing. Both electricity use and diesel use can be addressed through management interventions such as installing or purchasing clean energy, using cleaner-burning equipment, and electrifying heavy equipment.

Figure 4.5. Impacts of activities during primary mattress deconstruction. These impacts do not include pocket coil chopping or foam shredding (see next section). The charts show the impact of processing one tonne of mixed mattress units.





4.3 Material Disposition Routes

The results in this section show comparative impacts for different uses of a given material. The results do not include the impacts of collection or deconstruction. Thus, they should be used to compare among the options, but should not be understood as complete life cycle impacts.

4.3.1 Foam Routes

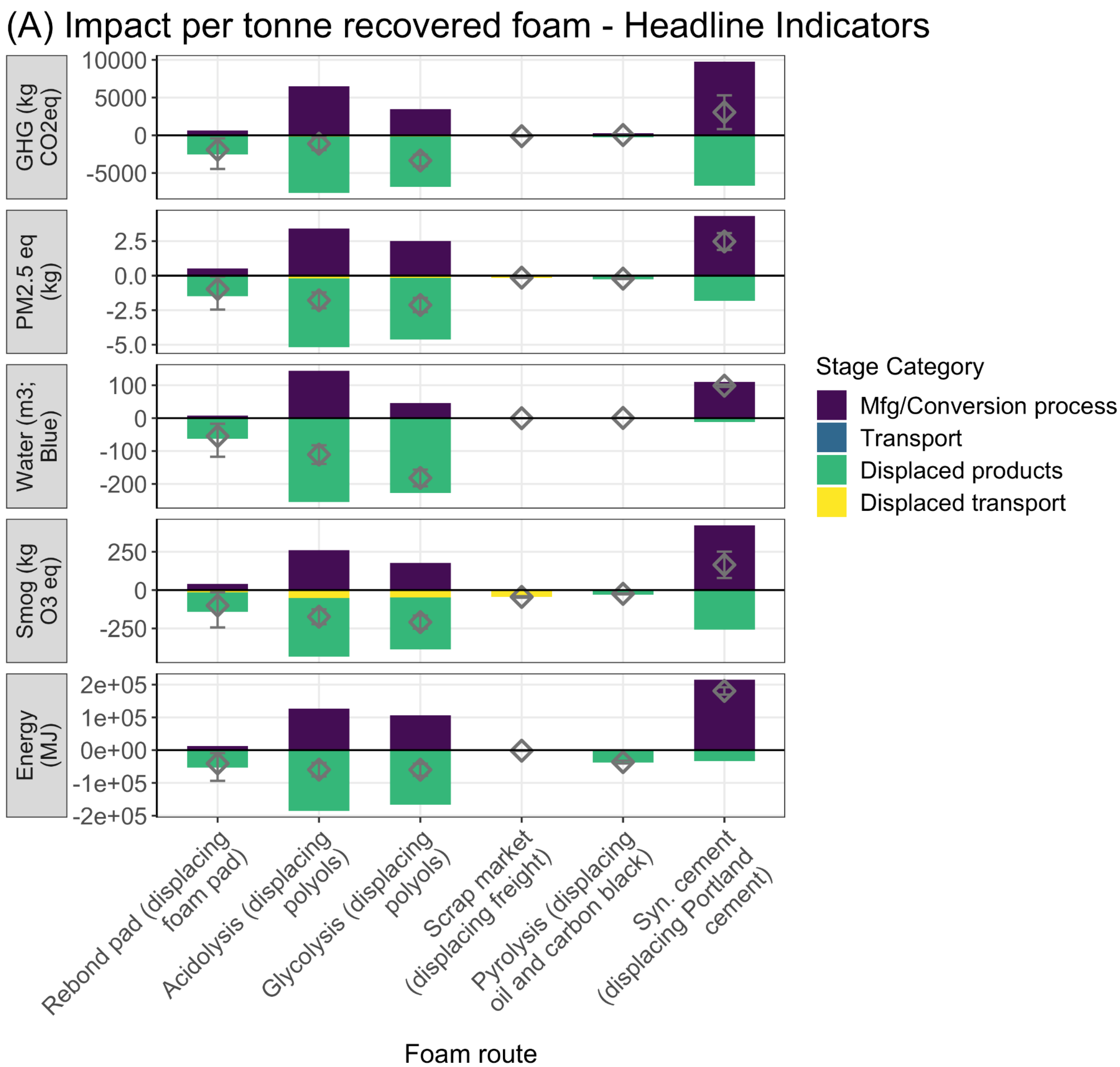
The foam recycling system includes six possible disposition fates. In the baseline case, the default assumption is that recycled foam is shredded and used to create pads in a rebond process. Rebond foam is assumed to displace new polyurethane foam.

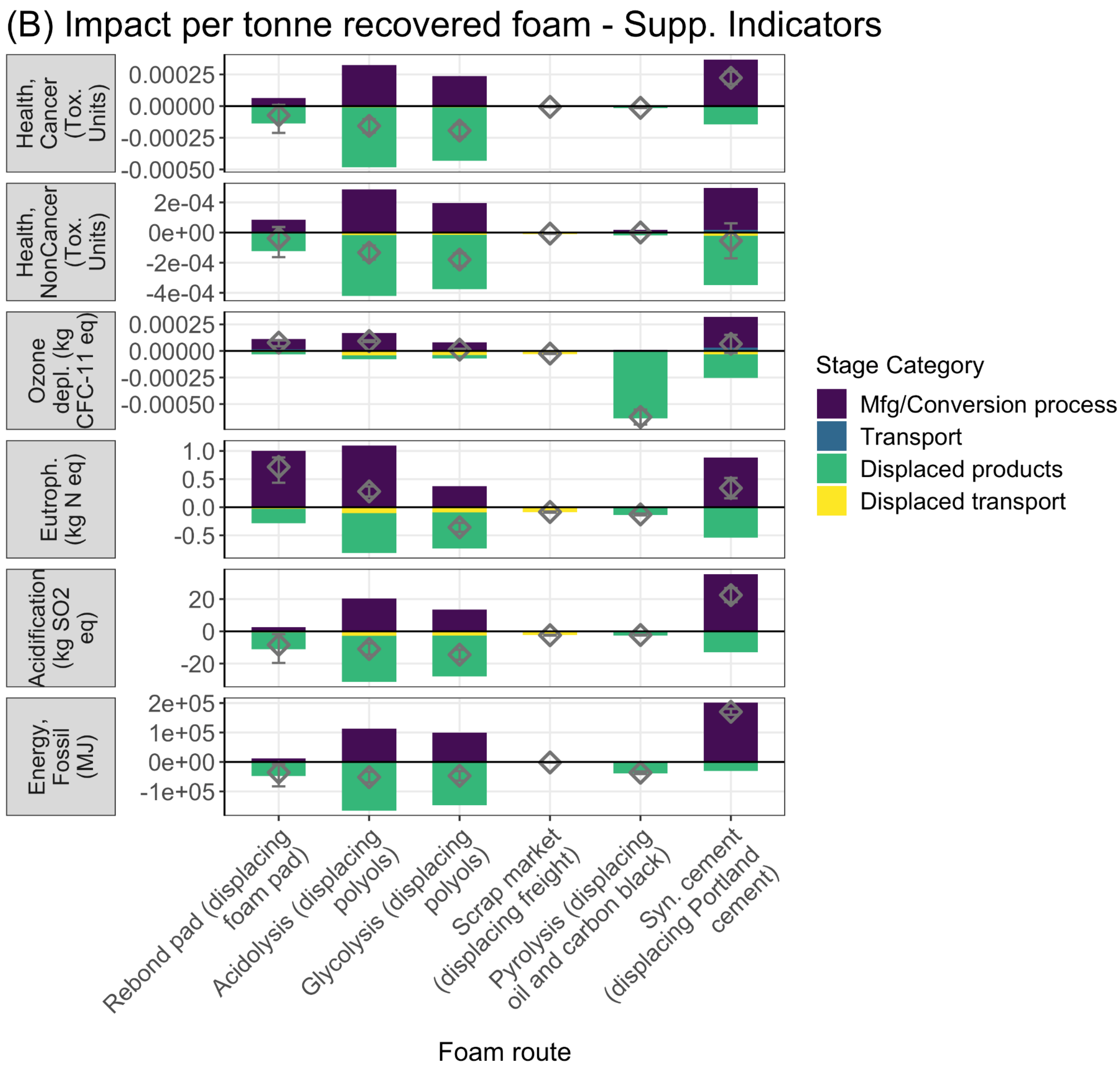
Two chemical recycling processes (acidolysis and glycolysis) were modeled, with the acidolysis process based on actual commercial scale facilities (§Acidolysis), and the glycolysis process based on literature reports of lab experiments (§Glycolysis). In both chemical recycling routes, the output of the process is reclaimed polyols. The Scrap market scenario represents foam that is sold as scrap and does not displace any primary production, only transport of other industrial foam scrap. Foam used as a pyrolysis feedstock would generate pyrolysis oil and char, which could displace crude oil and carbon black.

The results (Figure 4.6) show that rebond, along with both chemical recycling routes, are the best performers in most categories. Rebond shows improvement in all five headline indicators and three out of six supporting indicators. Inferior performance in health-noncancer, ozone depletion, and eutrophication can be attributed to MDI production as discussed above.

Chemical recycling via the acidolysis route shows an improvement in 4 out of 5 headline indicators (marginal on global warming) and 4 of 6 supporting indicators (impacts increase in ozone depletion and eutrophication). Adverse scores are again due to upstream chemical production of adipic acid and succinic acid. The glycolysis route is superior, showing improvement in all 5 headline indicators and 5 of 6 supporting indicators. However, this scenario is based on lab-scale studies, while the acidolysis scenario is based on commercial-scale installations.

Figure 4.6. Impacts of the different foam disposition routes. These results do not include impacts from Collection or Primary deconstruction. They represent the use of one tonne of recovered foam.



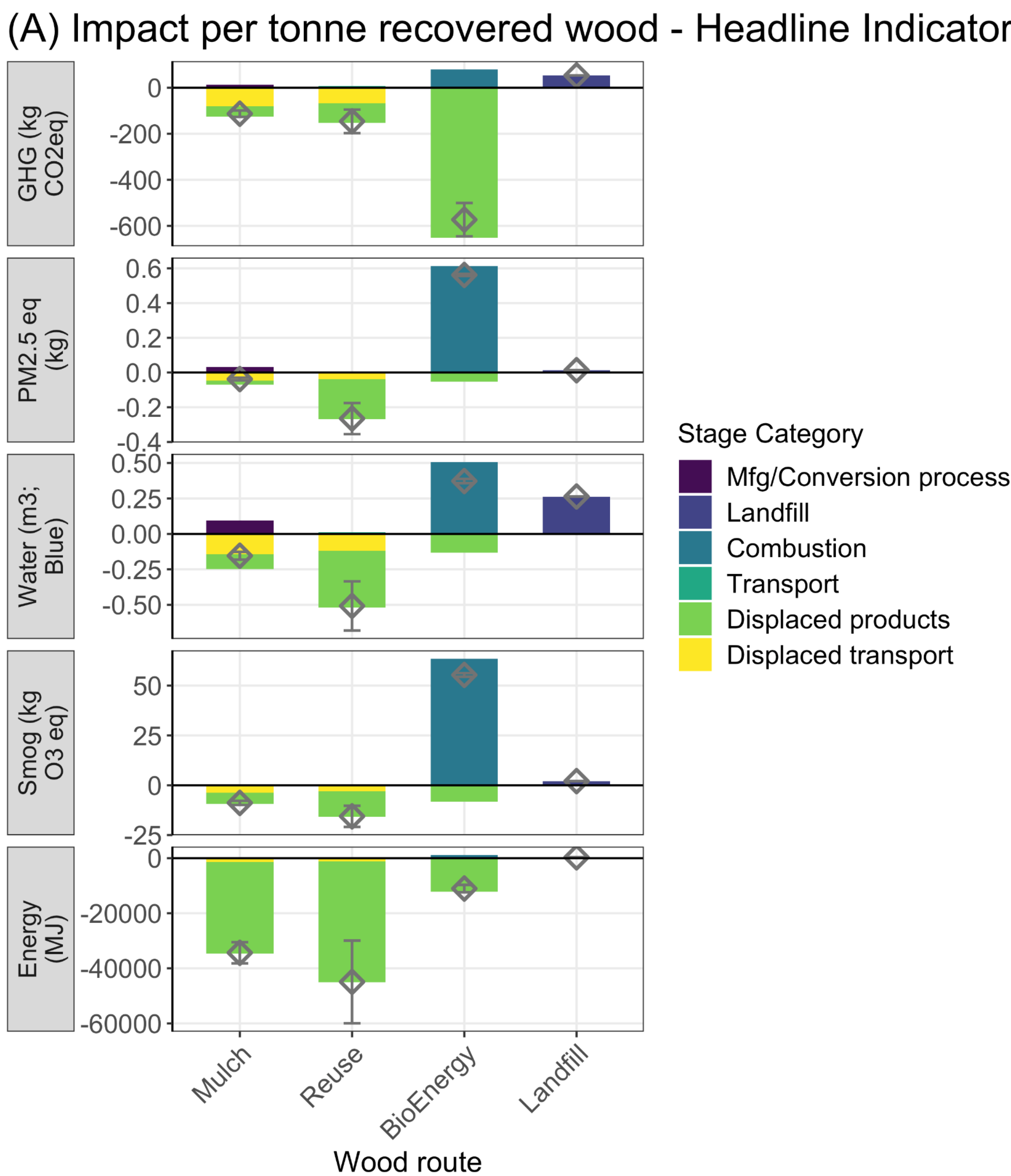


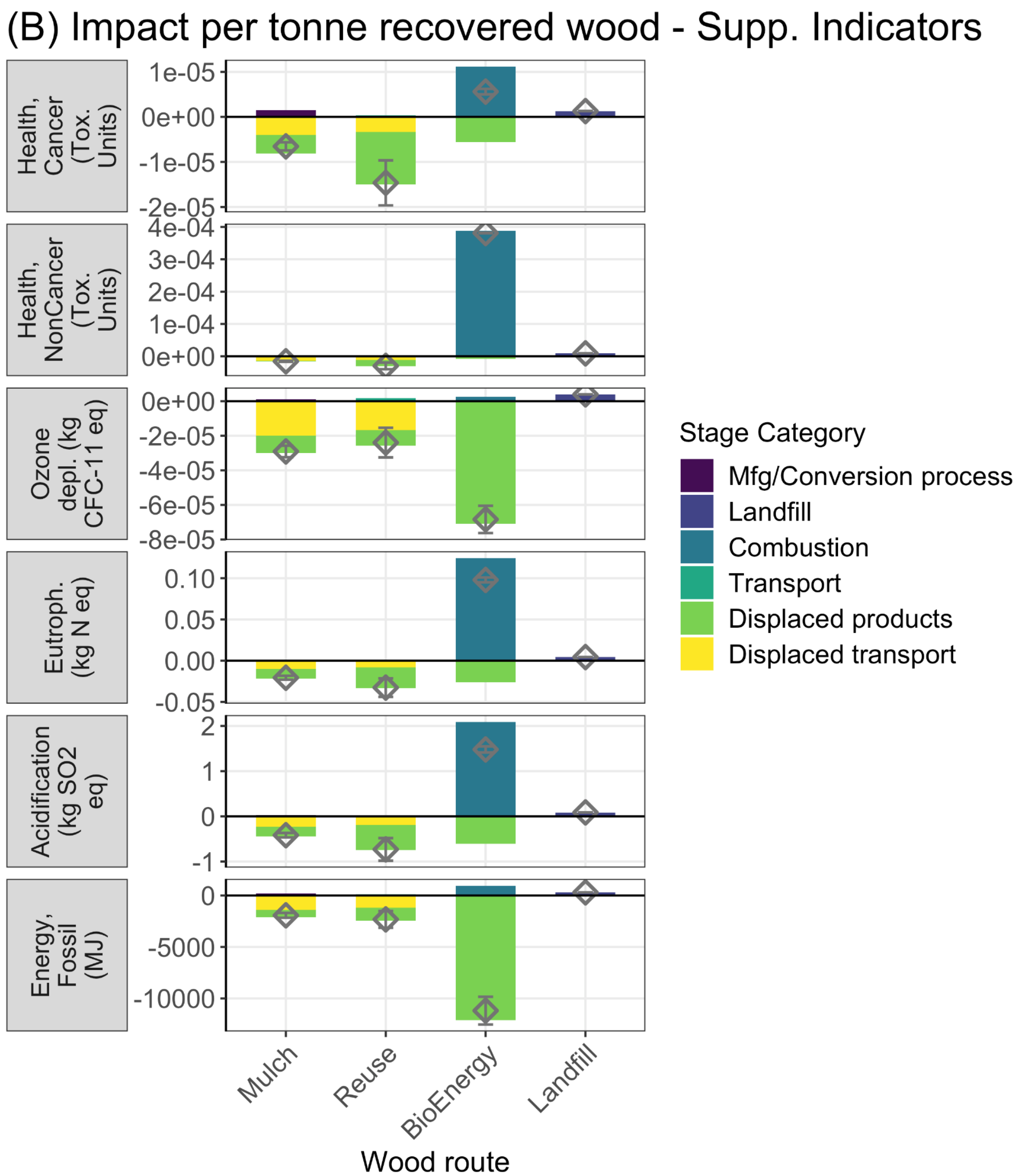
4.3.2 Wood Routes

Wood recovered from mattress recycling originates in foundations, which are between 25 and 60 percent wood according to the deconstruction study. We modeled four different end-of-life fates for wood: recycling as mulch, direct reuse as whole boards, combustion for bio-energy to displace natural gas, and disposal in landfill.

The results show that the recycling and reuse routes both show the potential for benefits in every indicator (five baseline plus six supporting). In contrast, combustion for bio-energy shows a mix of potential benefits and incurred emissions. The substantial reduction in GHG emissions is a result of the methodological assumption that bio-based fuels are carbon neutral. Other than climate change, air-pollution-related indicators show an increase in impacts over the displaced natural gas process. Wood in landfill is considered to be fairly inert, with less than 2 percent of the wood breaking down over a 100 year time-scale, resulting in comparatively low incurred impacts. The BioEnergy route shows net increases in seven out of 11 indicators, mainly driven by direct emissions from wood combustion.

Figure 4.7. Impacts of different wood disposition routes. These results do not include impacts from Collection or Primary deconstruction. They represent the use of one tonne of recovered wood.



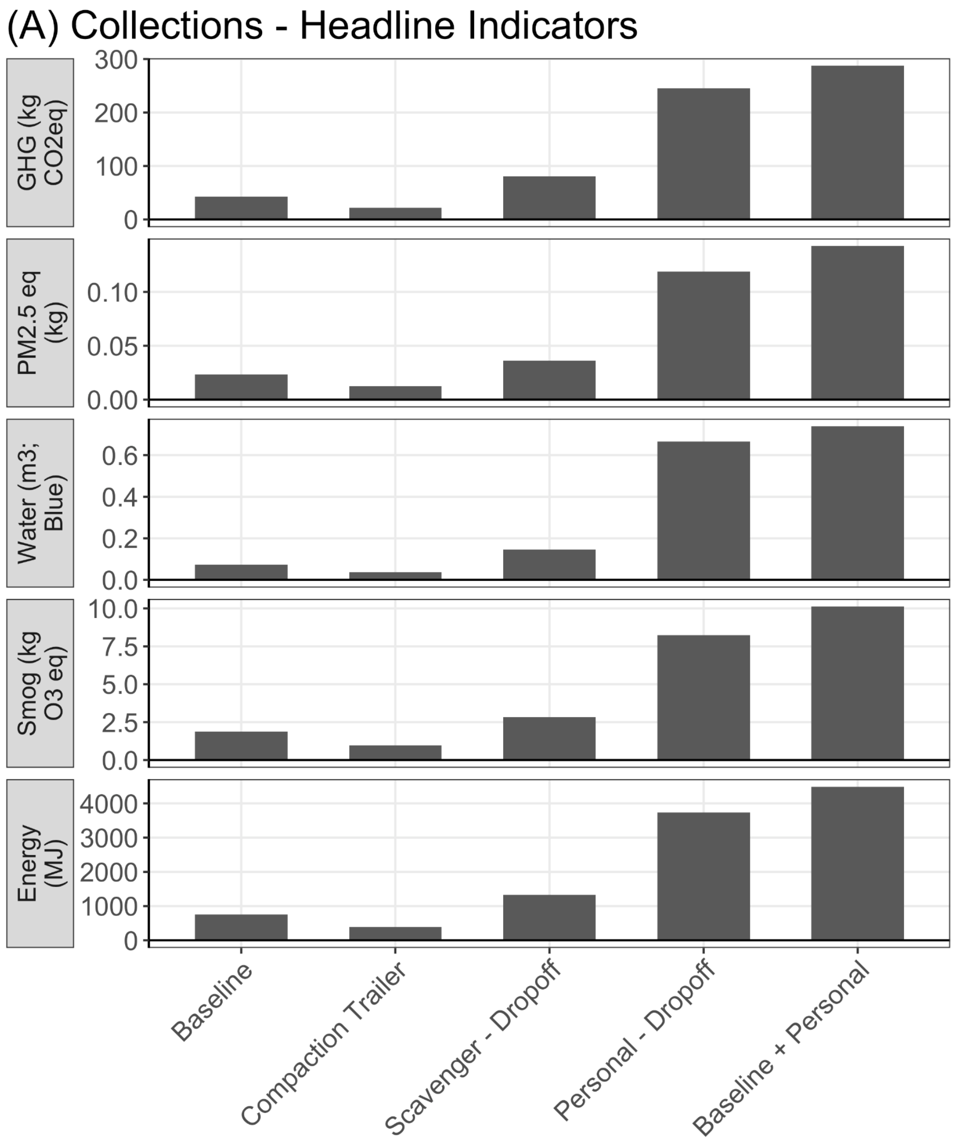


4.4 Collection Scenarios

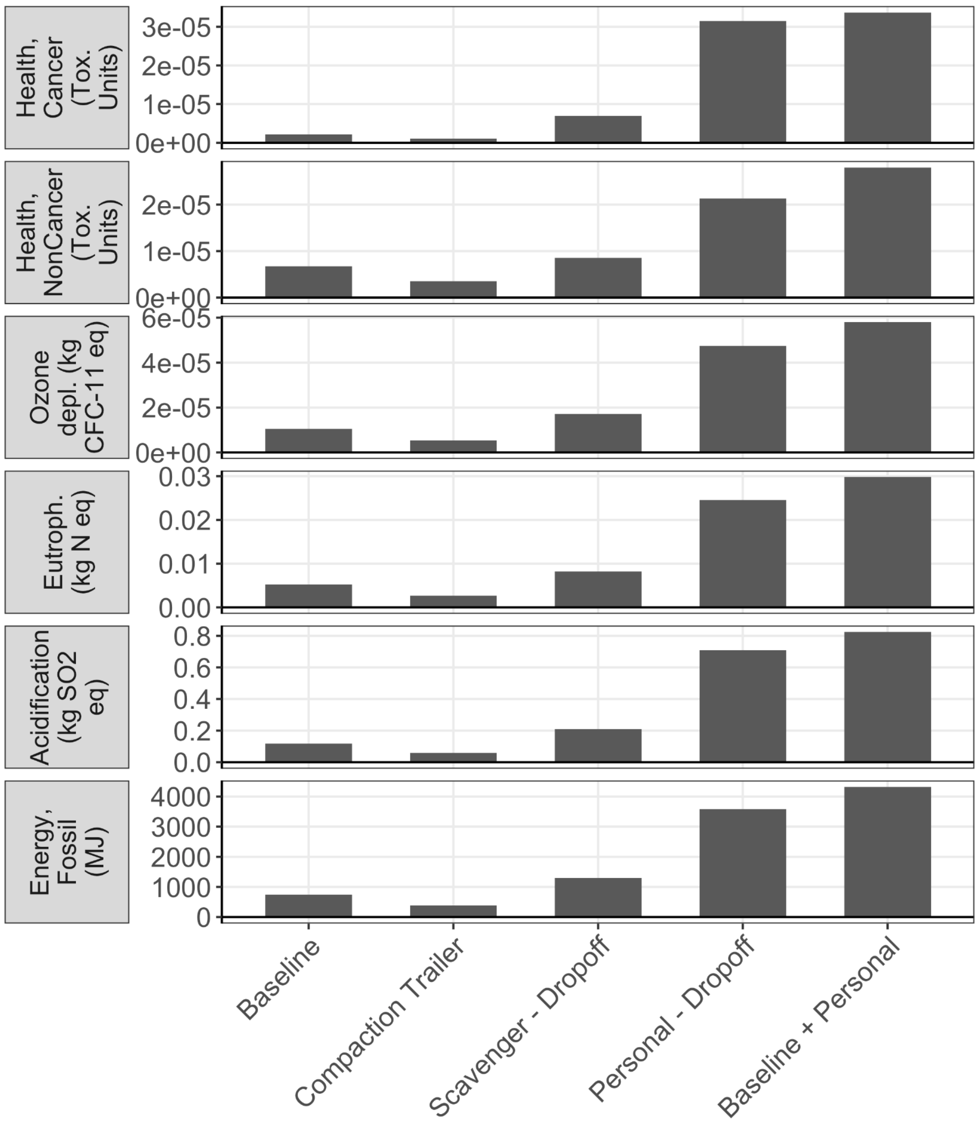
This section discusses the comparative impacts of different mattress collection methods. In the Baseline case, collection burdens arise from the transport of mattresses in bulk from collection points to processors using a mix of trailer trucks that is representative of MRC's material flow data. In the Baseline case, delivery of mattresses to collection points by the consumer are outside the scope of the study. The compaction case is the same as the Baseline, except that compaction trailers can carry twice the number of mattresses, and are assumed to be used at every collection point. In the scavenger case, mattresses are collected by private pickup trucks, traveling 4 km per mattress on a round-trip journey delivering truckloads of mattresses to processors. In the personal dropoff case, private vehicles are used to deliver single mattresses directly to processors, traveling a round trip of 15 km. In the "Baseline + Personal" case, the consumers are assumed to deliver mattresses to collection points instead, with baseline collection impacts still required.

The results report impacts per tonne of mattresses collected through each route. They show that private transport is the most significant source of impacts and any interventions that avoid private vehicle use are advantageous.

Figure 4.8. Impacts associated with different collection scenarios.



(B) Collections - Supp. Indicators



5 Life Cycle Interpretation

This study was carried out with two main objectives: to estimate the environmental impacts of the current (baseline) conditions for mattress recycling in California, and to understand the advantages and disadvantages of alternative management scenarios. In both cases, the incurred impacts of mattress recycling were compared against the potentially avoided impacts of displaced production.

5.1 Overall Results - Baseline

The results indicate that mattress recycling is beneficial according to all five headline indicators (global warming potential, particulates, water depletion, smog, and primary energy demand) and two out of six supporting indicators (fossil energy demand and acidification). In these indicators, the finding is robust even under the most pessimistic assumptions regarding product displacement. In two of six supporting indicators (human health - cancer and eutrophication), mattress recycling is marginal (net results near zero within the bounds of uncertainty about displacement). In two supporting indicators (human health - non-cancer and ozone depletion), mattress recycling results in increased impacts in comparison to the displaced products.

The major drivers of the incurred impacts included rebond foam pad production, reverse logistics, and the activity of California recyclers. Within the rebond activity, production of methylene diphenyl diisocyanate (MDI) was the major driver. The major drivers for avoided impacts were steel recycling and avoided polyurethane foam production.

5.2 Overall Results - Scenarios

The scenarios modeled in the study revealed several important findings about mattress end of life management.

- Impacts from collection and reverse logistics impacts make up a somewhat large share of incurred impacts. This is in contrast to many other recycling systems, and can largely be explained by the low density of mattresses during collection. We estimated that a 53' trailer containing a full load of 110 average units is utilizing only 9% of its hauling capacity (by weight).
- Any bulk collection process is far superior (lower in impacts) to the return of mattresses to drop-off locations by consumers in private vehicles.
- Of the scenarios considered, incineration of mattresses with energy recovery has the worst performance in all but two impact categories (Ozone depletion and Eutrophication).
- The environmental performance of foam chemical recycling depends strongly on the technology and the assumed application. Chemolysis generally performs well in comparison to virgin polyol production. Impacts of chemical recycling pathways were largely driven by upstream chemical production, and not from direct emissions or energy use.
- Combustion of wood for bio-energy led to significant avoided impacts in the global warming indicator, driven by the assumption that wood fuel is carbon-neutral in comparison to displaced fuels. In other indicators, bio-energy was more mixed, and reuse and recycling were preferable.

5.3 Potential Data Quality Issues

The overall quality of data used in the study foreground is judged to be very high, due to the fact that data describing logistics, mattress composition, the mix of mattress types, and the activities of California processors all came from primary sources. Foreground models for production activities, including rebond foam pad, chemical recycling of polyurethane foam, and pyrolysis were developed specifically for the study and are judged to be medium-high quality.

Many models used to describe background activities are proxy models, and some data quality issues affect the validity of the results.

- In the scrap steel process, which was prepared by the WorldSteel Association, the utilization of scrap steel leads to an increase in certain heavy metal emissions, leading to a large positive score in the human health - non-cancer indicator. This finding cannot be validated without access to the details of the WorldSteel model. However, it is consistent with the assumption of increased electricity production to power electric arc furnaces, if that electricity is supplied using coal and other polluting fuels. It is important to note that the "Value of Scrap" process being used represents a globally-averaged activity. Because a considerable share of scrap steel collected in the US is utilized domestically, it is possible that a US-specific model of scrap recycling would show different results.
- Several activities describing polymer production in ecoinvent are adapted from the eco-profiles database published by PlasticsEurope. This database includes several processes that have been aggregated for confidentiality, including the processes for production of virgin polyols and toluene diisocyanate (TDI). These aggregated processes appear to include a less comprehensive set of emissions than the dis-aggregated process models such as MDI, which make use of ecoinvent's internal models. As a result, direct comparisons between these activities may be inconsistent or misleading. We believe this discrepancy is responsible for the apparent poor performance of rebond foam in comparison to primary foam in the eutrophication, ozone depletion, and human health - non-cancer indicators in §Foam Routes.
- Water depletion is unevenly represented in life cycle inventory databases. The current study includes inventory data from USLCI and WorldSteel, as well as ecoinvent. Because of differences in the methodology accounting for water depletion in these databases, the quality of the water depletion indicator is lower than that of the other indicators. The large avoided water depletion score resulting from scrap steel recycling may be overstated, and the water depletion associated with the production of fuels burned in mattress recycling facilities may be understated.
- Capital equipment used at recycling facilities made a somewhat large contribution to the impacts of these facilities. This equipment was modeled using a set of simple proxy processes in ecoinvent and further investigation may be appropriate.
- The study used generic combustion models for diesel and propane burned in mobile equipment in processing facilities. Due to the significance of emissions from combustion equipment in these facilities for employee health, it would be appropriate to investigate the degree to which the models are representative of conditions at recyclers.

References

Altayeb, R. K. (2015). *Liquid fuel production from pyrolysis of waste tires: Process simulation, exergetic analysis, and life cycle assessment* [Masters]. American University of Sharjah.

Bare, J. (2012). *Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) TRACI version 2.1* (EPA/600/R-12/554). US Environmental Protection Agency. https://nepis.epa.gov/Adobe/PDF/P100HN53.pdf

Borda, J., Pásztor, G., & Zsuga, M. (2000). Glycolysis of polyurethane foams and elastomers. *Polymer Degradation and Stability*, *68*(3), 419–422. https://doi.org/10.1016/S0141-3910(00)00030-6

Earles, J. M., & Halog, A. (2011). Consequential life cycle assessment: A review. *The International Journal of Life Cycle Assessment*, *16*(5), 445–453. https://doi.org/10.1007/s11367-011-0275-9

ecoinvent. (2021). *Ecoinvent, v3.8, Allocation, cut-off by classification*.

Ekvall, T., & Weidema, B. P. (2004). System boundaries and input data in consequential life cycle inventory analysis. *The International Journal of Life Cycle Assessment*, *9*(3), 161–171. https://doi.org/10.1007/BF02994190

Gama, N., Godinho, B., Marques, G., Silva, R., Barros-Timmons, A., & Ferreira, A. (2020). Recycling of polyurethane scraps via acidolysis. *Chemical Engineering Journal*, *395*, 125102. https://doi.org/10.1016/j.cej.2020.125102

Grdadolnik, M., Drinčić, A., Oreški, A., Onder, O. C., Utroša, P., Pahovnik, D., & Žagar, E. (2022). Insight into Chemical Recycling of Flexible Polyurethane Foams by Acidolysis. *ACS Sustainable Chemistry & Engineering*, *10*(3), 1323–1332. https://doi.org/10.1021/acssuschemeng.1c07911

Guinee, J. B. (2002). Handbook on life cycle assessment operational guide to the ISO standards. *The International Journal of Life Cycle Assessment*, *7*(5), 311, BF02978897. https://doi.org/10.1007/BF02978897

Haugen, H. H., Furuvik, N. C. I., & Moldestad, B. M. E. (2016). *Characterization of biomass wood*. 257–269. https://doi.org/10.2495/EQ160241

Herrero, D. S. (2017). *Glycolysis process for polyurethane waste recycling* [Doctoral]. Universidad de Castilla–La Mancha.

H&S Anlagentechnik. (2022). *Your specialist for PUR: recycling, blending, storing*. https://www.hs-anlagentechnik.de/files/pdf/broschuere.pdf

Iribarren, D., Dufour, J., & Serrano, D. P. (2012). Preliminary assessment of plastic waste valorization via sequential pyrolysis and catalytic reforming. *Journal of Material Cycles and Waste Management*, *14*(4), 301–307. https://doi.org/10.1007/s10163-012-0069-6

ISO 14044. (2006). *14044: Environmental Management—Life Cycle Assessment—Requirements and guidelines*.

Khoo, H. H. (2019). LCA of plastic waste recovery into recycled materials, energy and fuels in Singapore. *Resources, Conservation and Recycling*, *145*, 67–77. https://doi.org/10.1016/j.resconrec.2019.02.010

Marson, A., Masiero, M., Modesti, M., Scipioni, A., & Manzardo, A. (2021). Life Cycle Assessment of Polyurethane Foams from Polyols Obtained through Chemical Recycling. *ACS Omega*, *6*(2), 1718–1724. https://doi.org/10.1021/acsomega.0c05844

Simón, D., Borreguero, A. M., de Lucas, A., & Rodríguez, J. F. (2014). Glycolysis of flexible polyurethane wastes containing polymeric polyols. *Polymer Degradation and Stability*, *109*, 115–121. https://doi.org/10.1016/j.polymdegradstab.2014.07.009

TNO. (2022). *Feasibility mattress recycling – TNO measurement campaign*.

US LCI. (2021). *U.S. Life Cycle Inventory Database (Q1)*. National Renewable Energy Laboratory. www.lcacommons.gov/nrel/search

USEPA. (2014). *Emission Factors for Greenhouse Gas Inventories*. US Environmental Protection Agency. https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

World Steel Association. (2021). *Life cycle inventory methodology report for steel products (2017); with 2021 reference data*. https://www.worldsteel.org/en/dam/jcr:6eefabf4-f562-4868-b919-f232280fd8b9/LCI+methodology+report_2017_vfinal.pdf

Wu, C.-H., Chang, C.-Y., Cheng, C.-M., & Huang, H.-C. (2003). Glycolysis of waste flexible polyurethane foam. *Polymer Degradation and Stability*, *80*(1), 103–111. https://doi.org/10.1016/S0141-3910(02)00390-7

Zink, T., Geyer, R., & Startz, R. (2018). Toward Estimating Displaced Primary Production from Recycling: A Case Study of U.S. Aluminum. *Journal of Industrial Ecology*, *22*(2), 314–326. https://doi.org/10.1111/jiec.12557

Appendix

A1 Descriptions of Impact Categories

A1.1 Headline Indicators

Global Climate Change (kg CO_2 equivalent)
Global warming is an average increase in the temperature of the atmosphere near the Earth's surface and in the troposphere, attributable to the release of carbon dioxide and other substances from industrial processes, including combustion of fuels. TRACI 2.1 utilizes global warming potentials (GWPs) for the calculation of the potency of greenhouse gases consistent with the guidance of the United Nations Framework Convention on Climate Change (UNFCCC) (UNFCCC -The United Nations Framework Convention on Climate Change 2003). The indicator uses GWPs with 100-year time horizons.

Particulate Matter formation (kg PM2.5 equivalent)
Particulate matter is a collection of small particles in ambient air which have the ability to cause negative human health effects including respiratory illness and death. Particulate matter may be emitted as particulates, or may be the product of chemical reactions in the air (secondary particulates). The most common precursors to secondary particulates are sulfur dioxide (SO2) and nitrogen oxides (NOx). The method for calculation of human health impacts includes the modeling of the fate and exposure into intake fractions (i.e., that portion of the emitted substance, which is expected to be inhaled by a human being).

Water use (cubic meters of water)
To assess water use by the product system, we will follow the methodology of the Global Water Footprint Standard (Hoekstra et al., 2011). We will estimate "blue water footprint," which reports consumptive use of surface and ground water throughout the product supply chain, including actions that result in the transfer of water between reservoirs. The blue water footprint is reported in units of physical volume of water consumed, and does not reflect water scarcity or any other spatial or geographic factors of water use. Blue water also excludes natural rainwater for irrigation ("green water") and ignores the emission of pollutants or contaminants into water ("gray water").

Photochemical Smog Formation (kg O_3 equivalent)
Ground level ozone is created by various chemical reactions, which occur between nitrogen oxides (NOx) and volatile organic compounds (VOCs) in sunlight. Human health effects can result in a variety of respiratory issues including increasing symptoms of bronchitis, asthma, and emphysema. Smog creation potential is modeled using the Maximum Incremental Reactivity (MIR) method.

Primary Energy Demand (MJ net calorific value)

This indicator reports the total amount of energy extracted from the natural environment in any form that was required to bring about the modeled activities. While the environmental impacts of energy production are accounted for by using the other methods, the primary energy demand can be used to express the relative energy efficiency of different scenarios regardless of the source of energy used. Primary energy obtained from renewable sources was counted on a one-to-one basis. Energy content assigned to different fuels is reported in Table A1.1 below.

Table A1.1. Heating values used to quantify fossil fuel use. (Haugen et al., 2016; USEPA, 2014)

Fuel Type	**Heating Value (MJ/kg)**	
	Higher	**Lower**
Lignite	16.5	16.0
Hard Coal	28.0	27.2
Crude Oil	45.0	42.1
Natural Gas	50.0	45.5
Methane	55.0	50.0
Bitumen	43.0	41.0
Shale	10.0	9.5
Peat	9.3	8.9
Biomass (byproducts)	12.1	10.1
Biomass (wood)	18.0	15.0
	Heating Value (MJ/m3)	
Wood, standing (MJ/m3)	8000-12000	

A1.2 Supporting Indicators

Human Health, Cancer and Non-cancer (Comparative toxicity units)
Under the Life Cycle Initiative of the United Nations Environment Program (UNEP) / Society of Environmental Toxicology and Chemistry (SETAC), various international multimedia toxicity model developers created a global consensus model known as USEtox (Rosenbaum et al, 2008). The USEtox model adopted many of the best features of earlier models and was used to develop human health cancer and noncancer toxicity potentials for over 3000 substances including organic and inorganic substances. In the current report, human health cancer and non-cancer (including physical damage, cardiovascular diseases, reproductive harm, and other

adverse effects) impact scores are included. These indicators are best interpreted in relative terms and used as a basis for comparison among alternatives.

Acidification (kg SO_2 equivalent)
Acidification is the increasing concentration of hydrogen ion (H+) within a local environment, as the result of the release of acids such as sulfur dioxide. Acidifying emissions are often emitted to air as byproducts of combustion, and can travel long distances before later deposition in the form of acid rain or other precipitation. Acidification can cause damage to human property and also adversely affect the health of ecosystems. Acidification as an indicator is often correlated to fossil fuel consumption, particularly coal, so it often closely tracks other indicators such as global warming potential and primary energy demand.

Stratospheric Ozone Depletion (kg CFC-11 equivalent)
High concentrations of ozone in the upper atmosphere provide an absorptive layer that protects the Earth from solar radiation. The presence of certain human-created compounds known as chlorofluorocarbons (or CFCs) can cause stratospheric ozone to be depleted into oxygen, which lacks this protective characteristic. Because CFCs persist for long periods in the upper atmosphere, small amounts of emission can have compounding effects. The problem of ozone depletion was largely addressed by the Montreal Protocol of 1987, under which these compounds were phased out in favor of less-harmful alternatives.

Eutrophication (kg N equivalent)
Many processes result in the deposition of nitrogen or phosphorus into soil or water, which can lead to an overabundance of algae and other microorganisms that deplete aqueous oxygen and have other unintended effects. Eutrophication can occur from combustion emissions or from runoff of excessive fertilizers applied to agricultural land. Because of the low prominence of agriculture in the present LCA, eutrophication is not regarded as a prominent indicator.

Fossil Fuel Use (MJ net calorific value)
Fossil fuel use is quantified in energy units (MJ). This indicator is useful to assess the degree to which a product or process depends on the use of fossil fuels, a limited and depletable resource. Representative heating values were assumed for each of the fuel classes listed in Table A1.1 in the previous section.

A2 Descriptions of recycling routes

A2.1 Routes included in baseline scenario

Steel, recycled, to Scrap market
Steel recovered from mattresses and foundations is assumed to be shipped to brokers, from which point it is sold to steelmakers. This includes steel recovered from foundations, Bonnell springs, and pocketed coils. The benefit of scrap steel recycling is estimated using the World

Steel Association's value of scrap model (World Steel Association, 2021), which reflects the reduction in environmental burdens associated with the increased use of scrap steel.

Foam, recycled
Foam to recycling is modeled as a mix of multiple pathways. In the baseline scenario, 100% of the foam is used to manufacture rebond foam pad, which displaces a new (virgin) frothed polyurethane foam pad. In this case, the mattress-derived foam is chopped, mixed with adhesive, compressed, cooked, and sliced. This mattress-derived rebond then potentially displaces the manufacture of virgin high-density frothed foam, which would be suitable as a carpet pad.

In addition to the rebond manufacturing process, additional foam use routes include chemolysis and pyrolysis.

Quilt, recycled
Quilt, as a mix of foam and fiber, is assumed to either displace post-industrial scrap foam, or to be used as an ingredient in Rebond Foam Carpet pad (as with the Foam, recycled).

Wood, recycled
Recycled wood is chipped and used to displace softwood landscaping mulch.

Shoddy, recycled; Other fiber, recycled
Fibers recovered from shoddy and other fiber are assumed to be used as an ingredient in a similar non-woven pad. We assume these recycled fibers displace a mix of materials: 10% cotton fiber, 50% scrap fiber, and 40% PET granulate (by mass).

Cardboard, recycled
Used as an ingredient for paper manufacturing, potentially displacing paper pulp.

Plastic, recycled
Recycled plastic potentially displaces virgin polypropylene granulate.

Whole Mattresses and Foundations, reused
In this route, a recovered mattress or foundation is used to displace the production of a new unit. The displaced product will include a mix of innerspring and foam mattresses (and foundations) that matches the mattress size and type mix for a given scenario.

Foam, reused
High-quality foam recovered from mattresses may be reused as-is (not chopped and rebonded) in bedding, furniture, or other applications. This potentially displaces the production of virgin (prime) PU foam.

Wood, reused

Whole wood boards that are recovered from deconstruction are assumed to displace the equivalent weight in new sawn lumber.

Steel component (i.e. spring assembly), reused
A complete innerspring set extracted from a recovered mattress can be re-used inside of a new mattress, displacing the production of an equivalent amount of steel wire. No refurbishing impacts are assigned.

Quilt, reused
If quilt is reused as-is, it would displace a mix of foam production and woven synthetic fabric production.

Cotton, reused
If cotton is reused as-is, it would displace production of new cotton fabric.

Other fabric, reused
Reused fabric could displace new polyester fabric production.

Shoddy pad, reused
Shoddy pad is made mostly with recycled fibers. Thus, reuse of shoddy is assumed to displace the fabrication (not including raw material) of a non-woven synthetic pad.

Wood, to energy
Recycled wood is burned for energy recovery, potentially displacing combustion of natural gas. Because wood contains only biogenic carbon, the CO_2 emissions from wood combustion are excluded from GWP.

Waste, to energy
Waste (residuals) from recycling is burned for energy recovery, potentially displacing natural gas. The mix of material in the waste stream determines the biogenic C fraction of the fuel.

A2.2 Routes in Additional Scenarios

Foam glycolysis
In this scenario, recycled foam undergoes chemical recycling to produce polyols, which displace virgin polyol production.

Foam Acidolysis
In this scenario, recycled foam undergoes chemical recycling to produce polyols, which displace virgin polyol production.

Pyrolysis

Pyrolysis is included for Foam and for Whole units. The pyrolysis gas is used in the process, and pyrolysis oil and char are the mattress-derived products, which may displace crude oil and black carbon, respectively.

Foam Scrap
The Scrap route represents the displacement of transcontinental transport for scrap foam. Post-industrial scrap does not carry any impacts from manufacture. However, since scrap material markets are global, we assume that a locally generated and used material that enters a scrap market would displace the import of scrap material.

A3 Tabular Data: Incurred, Displaced, and Net total

Data for Figure ES.1. and Figure 4.1: Overall results of the LCA study. Impacts of recycling and managing 1.6 million mattress recycling in CA (yr2021).

Scenario	Impact Type	Incurred, Displaced	result	result_lo	result_hi
Baseline (CA 2021)	GHG (kt CO2eq)	Incurred	9.4	9.4	9.4
Baseline (CA 2021)	GHG (kt CO2eq)	Displaced	-43.4	-62.1	-30.5
Baseline (CA 2021)	GHG (kt CO2eq)	Net	-34.0	-52.7	-21.1
Baseline (CA 2021)	PM2.5eq (t)	Incurred	6.5	6.5	6.5
Baseline (CA 2021)	PM2.5eq (t)	Displaced	-13.3	-23.1	-6.9
Baseline (CA 2021)	PM2.5eq (t)	Net	-6.8	-16.6	-0.5
Baseline (CA 2021)	Water (k m3; Blue)	Incurred	89.9	89.9	89.9
Baseline (CA 2021)	Water (k m3; Blue)	Displaced	-3,185.6	-4,159.1	-2,355.7
Baseline (CA 2021)	Water (k m3; Blue)	Net	-3,095.6	-4,069.2	-2,265.7
Baseline (CA 2021)	Smog (t O3 eq)	Incurred	653.1	653.1	653.1
Baseline (CA 2021)	Smog (t O3 eq)	Displaced	-1,867.0	-2,866.6	-1,193.2
Baseline (CA 2021)	Smog (t O3 eq)	Net	-1,213.9	-2,213.5	-540.2
Baseline (CA 2021)	Energy (TJ)	Incurred	157.0	157.0	157.0
Baseline (CA 2021)	Energy (TJ)	Displaced	-783.7	-1,165.1	-523.8
Baseline (CA 2021)	Energy (TJ)	Net	-626.7	-1,008.1	-366.8
Baseline (CA 2021)	Health, Cancer (Tox. Units)	Incurred	1.1	1.1	1.1
Baseline (CA 2021)	Health, Cancer (Tox. Units)	Displaced	-1.7	-2.8	-1.0

Baseline (CA 2021)	Health, Cancer (Tox. Units)	Net	-0.6	-1.7	0.2
Baseline (CA 2021)	Health, NonCancer (Tox. Units)	Incurred	2.7	2.7	2.7
Baseline (CA 2021)	Health, NonCancer (Tox. Units)	Displaced	-0.3	-1.2	0.2
Baseline (CA 2021)	Health, NonCancer (Tox. Units)	Net	2.3	1.5	2.9
Baseline (CA 2021)	Ozone depl. (kg CFC-11 eq)	Incurred	1.5	1.5	1.5
Baseline (CA 2021)	Ozone depl. (kg CFC-11 eq)	Displaced	-1.0	-1.4	-0.7
Baseline (CA 2021)	Ozone depl. (kg CFC-11 eq)	Net	0.5	0.2	0.8
Baseline (CA 2021)	Eutroph. (t N eq)	Incurred	6.6	6.6	6.6
Baseline (CA 2021)	Eutroph. (t N eq)	Displaced	-5.4	-7.8	-3.7
Baseline (CA 2021)	Eutroph. (t N eq)	Net	1.2	-1.1	3.0
Baseline (CA 2021)	Acidification (t SO2 eq)	Incurred	34.5	34.5	34.5
Baseline (CA 2021)	Acidification (t SO2 eq)	Displaced	-123.0	-200.5	-71.0
Baseline (CA 2021)	Acidification (t SO2 eq)	Net	-88.5	-166.0	-36.5
Baseline (CA 2021)	Energy, Fossil (TJ)	Incurred	141.3	141.3	141.3
Baseline (CA 2021)	Energy, Fossil (TJ)	Displaced	-625.3	-951.6	-406.5
Baseline (CA 2021)	Energy, Fossil (TJ)	Net	-484.0	-810.3	-265.2

Data for Figure 4.5: Impacts of primary recycling facilities (one tonne of mattress processed)

Impact Type	diesel	electr-icity	equip	gasoline	ppe	prop-ane	supplies	water	total
GHG (kg CO2eq)	5.0	9.2	4.6	0.6	0.4	5.0	3.1	0.2	28.2
PM2.5 eq (kg)	7.1E-04	1.8E-03	6.0E-03	8.0E-05	3.3E-04	1.5E-04	3.7E-03	2.9E-04	1.3E-02
Water (m3; Blue)	0.00	0.19	0.03	0.00	0.01	0.00	0.03	0.56	0.82
Energy (MJ)	76.4	308.5	75.3	9.5	10.4	73.6	46.9	3.5	604.0
Smog (kg O3 eq)	2.16	0.29	0.26	0.21	0.02	0.27	0.18	0.01	3.39

Health, Cancer (Tox. Units)	4.5E-10	3.5E-07	4.8E-06	5.7E-11	3.6E-08	3.9E-10	6.0E-06	2.5E-08	1.1E-05
Health, NonCancer (Tox. Units)	4.9E-08	6.9E-07	8.4E-07	6.1E-09	3.2E-08	4.7E-08	6.8E-07	1.7E-08	2.4E-06
Acidification (kg SO2 eq)	0.06	0.02	0.02	0.01	0.00	0.01	0.01	0.00	0.13
Ozone depl. (kg CFC-11 eq)	3.3E-08	1.2E-06	2.8E-07	4.1E-09	9.3E-07	3.2E-08	2.1E-07	1.3E-08	2.7E-06
Eutroph. (kg N eq)	3.9E-03	8.4E-04	5.4E-04	3.7E-04	1.2E-04	5.3E-04	4.2E-04	1.9E-05	6.7E-03
Energy, Fossil (MJ)	75.6	157.5	65.7	9.4	9.3	72.8	42.1	2.8	435.2

Data for Figure 4.2: Impacts of recycling one tonne of mattresses; four system scenarios

Scenario	**Impact Type**	**Incurred, Displaced**	**result**	**result_lo**	**result_hi**
Baseline	GHG (t CO2eq)	Incurred	0.230	0.230	0.230
Baseline	GHG (t CO2eq)	Displaced	-1.066	-1.526	-0.749
Baseline	GHG (t CO2eq)	Net	-0.836	-1.296	-0.519
Baseline	PM2.5 eq (kg)	Incurred	0.159	0.159	0.159
Baseline	PM2.5 eq (kg)	Displaced	-0.327	-0.567	-0.170
Baseline	PM2.5 eq (kg)	Net	-0.168	-0.408	-0.011
Baseline	Water (m3; Blue)	Incurred	2.210	2.210	2.210
Baseline	Water (m3; Blue)	Displaced	-78.275	-102.197	-57.883
Baseline	Water (m3; Blue)	Net	-76.065	-99.987	-55.673
Baseline	Smog (kg O3 eq)	Incurred	16.048	16.048	16.048
Baseline	Smog (kg O3 eq)	Displaced	-45.876	-70.437	-29.320
Baseline	Smog (kg O3 eq)	Net	-29.828	-54.389	-13.273
Baseline	Energy (GJ)	Incurred	3.858	3.858	3.858
Baseline	Energy (GJ)	Displaced	-19.257	-28.629	-12.870
Baseline	Energy (GJ)	Net	-15.399	-24.771	-9.012

Baseline	Health, Cancer (Tox. Units)	Incurred	0.000	0.000	0.000
Baseline	Health, Cancer (Tox. Units)	Displaced	0.000	0.000	0.000
Baseline	Health, Cancer (Tox. Units)	Net	0.000	0.000	0.000
Baseline	Health, NonCancer (Tox. Units)	Incurred	0.000	0.000	0.000
Baseline	Health, NonCancer (Tox. Units)	Displaced	0.000	0.000	0.000
Baseline	Health, NonCancer (Tox. Units)	Net	0.000	0.000	0.000
Baseline	Ozone depl. (g CFC-11 eq)	Incurred	0.038	0.038	0.038
Baseline	Ozone depl. (g CFC-11 eq)	Displaced	-0.025	-0.034	-0.018
Baseline	Ozone depl. (g CFC-11 eq)	Net	0.013	0.004	0.020
Baseline	Eutroph. (kg N eq)	Incurred	0.163	0.163	0.163
Baseline	Eutroph. (kg N eq)	Displaced	-0.133	-0.191	-0.090
Baseline	Eutroph. (kg N eq)	Net	0.030	-0.028	0.073
Baseline	Acidification (kg SO2 eq)	Incurred	0.849	0.849	0.849
Baseline	Acidification (kg SO2 eq)	Displaced	-3.022	-4.926	-1.746
Baseline	Acidification (kg SO2 eq)	Net	-2.174	-4.078	-0.897
Baseline	Energy, Fossil (GJ)	Incurred	3.471	3.471	3.471
Baseline	Energy, Fossil (GJ)	Displaced	-15.365	-23.382	-9.988
Baseline	Energy, Fossil (GJ)	Net	-11.894	-19.910	-6.517
Baseline w/ Compaction	GHG (t CO2eq)	Incurred	0.210	0.210	0.210
Baseline w/ Compaction	GHG (t CO2eq)	Displaced	-1.066	-1.526	-0.749
Baseline w/ Compaction	GHG (t CO2eq)	Net	-0.857	-1.317	-0.540
Baseline w/ Compaction	PM2.5 eq (kg)	Incurred	0.148	0.148	0.148
Baseline w/ Compaction	PM2.5 eq (kg)	Displaced	-0.327	-0.567	-0.170
Baseline w/ Compaction	PM2.5 eq (kg)	Net	-0.179	-0.419	-0.022
Baseline w/ Compaction	Water (m3; Blue)	Incurred	2.174	2.174	2.174
Baseline w/ Compaction	Water (m3; Blue)	Displaced	-78.275	-102.197	-57.883
Baseline w/ Compaction	Water (m3; Blue)	Net	-76.101	-100.023	-55.709
Baseline w/ Compaction	Smog (kg O3 eq)	Incurred	15.141	15.141	15.141
Baseline w/ Compaction	Smog (kg O3 eq)	Displaced	-45.876	-70.437	-29.320
Baseline w/ Compaction	Smog (kg O3 eq)	Net	-30.735	-55.296	-14.180

Baseline w/ Compaction	Energy (GJ)	Incurred	3.492	3.492	3.492
Baseline w/ Compaction	Energy (GJ)	Displaced	-19.257	-28.629	-12.870
Baseline w/ Compaction	Energy (GJ)	Net	-15.765	-25.137	-9.378
Baseline w/ Compaction	Health, Cancer (Tox. Units)	Incurred	0.000	0.000	0.000
Baseline w/ Compaction	Health, Cancer (Tox. Units)	Displaced	0.000	0.000	0.000
Baseline w/ Compaction	Health, Cancer (Tox. Units)	Net	0.000	0.000	0.000
Baseline w/ Compaction	Health, NonCancer (Tox. Units)	Incurred	0.000	0.000	0.000
Baseline w/ Compaction	Health, NonCancer (Tox. Units)	Displaced	0.000	0.000	0.000
Baseline w/ Compaction	Health, NonCancer (Tox. Units)	Net	0.000	0.000	0.000
Baseline w/ Compaction	Ozone depl. (g CFC-11 eq)	Incurred	0.033	0.033	0.033
Baseline w/ Compaction	Ozone depl. (g CFC-11 eq)	Displaced	-0.025	-0.034	-0.018
Baseline w/ Compaction	Ozone depl. (g CFC-11 eq)	Net	0.008	-0.001	0.015
Baseline w/ Compaction	Eutroph. (kg N eq)	Incurred	0.160	0.160	0.160
Baseline w/ Compaction	Eutroph. (kg N eq)	Displaced	-0.133	-0.191	-0.090
Baseline w/ Compaction	Eutroph. (kg N eq)	Net	0.028	-0.031	0.070
Baseline w/ Compaction	Acidification (kg SO2 eq)	Incurred	0.792	0.792	0.792
Baseline w/ Compaction	Acidification (kg SO2 eq)	Displaced	-3.022	-4.926	-1.746
Baseline w/ Compaction	Acidification (kg SO2 eq)	Net	-2.230	-4.135	-0.954
Baseline w/ Compaction	Energy, Fossil (GJ)	Incurred	3.112	3.112	3.112
Baseline w/ Compaction	Energy, Fossil (GJ)	Displaced	-15.365	-23.382	-9.988
Baseline w/ Compaction	Energy, Fossil (GJ)	Net	-12.253	-20.270	-6.876
Baseline w/ Chem. Recycle	GHG (t CO2eq)	Incurred	0.923	0.923	0.923
Baseline w/ Chem. Recycle	GHG (t CO2eq)	Displaced	-1.664	-1.925	-1.426
Baseline w/ Chem. Recycle	GHG (t CO2eq)	Net	-0.741	-1.003	-0.503
Baseline w/ Chem. Recycle	PM2.5 eq (kg)	Incurred	0.499	0.499	0.499
Baseline w/ Chem. Recycle	PM2.5 eq (kg)	Displaced	-0.762	-0.896	-0.642

Baseline w/ Chem. Recycle	PM2.5 eq (kg)	Net	-0.263	-0.397	-0.143
Baseline w/ Chem. Recycle	Water (m3; Blue)	Incurred	18.171	18.171	18.171
Baseline w/ Chem. Recycle	Water (m3; Blue)	Displaced	-100.802	-120.681	-81.508
Baseline w/ Chem. Recycle	Water (m3; Blue)	Net	-82.631	-102.510	-63.337
Baseline w/ Chem. Recycle	Smog (kg O3 eq)	Incurred	41.623	41.623	41.623
Baseline w/ Chem. Recycle	Smog (kg O3 eq)	Displaced	-79.984	-93.489	-67.804
Baseline w/ Chem. Recycle	Smog (kg O3 eq)	Net	-38.361	-51.866	-26.181
Baseline w/ Chem. Recycle	Energy (GJ)	Incurred	17.219	17.219	17.219
Baseline w/ Chem. Recycle	Energy (GJ)	Displaced	-34.831	-40.397	-29.760
Baseline w/ Chem. Recycle	Energy (GJ)	Net	-17.612	-23.178	-12.540
Baseline w/ Chem. Recycle	Health, Cancer (Tox. Units)	Incurred	0.000	0.000	0.000
Baseline w/ Chem. Recycle	Health, Cancer (Tox. Units)	Displaced	0.000	0.000	0.000
Baseline w/ Chem. Recycle	Health, Cancer (Tox. Units)	Net	0.000	0.000	0.000
Baseline w/ Chem. Recycle	Health, NonCancer (Tox. Units)	Incurred	0.000	0.000	0.000
Baseline w/ Chem. Recycle	Health, NonCancer (Tox. Units)	Displaced	0.000	0.000	0.000
Baseline w/ Chem. Recycle	Health, NonCancer (Tox. Units)	Net	0.000	0.000	0.000
Baseline w/ Chem. Recycle	Ozone depl. (g CFC-11 eq)	Incurred	0.045	0.045	0.045
Baseline w/ Chem. Recycle	Ozone depl. (g CFC-11 eq)	Displaced	-0.030	-0.036	-0.024
Baseline w/ Chem. Recycle	Ozone depl. (g CFC-11 eq)	Net	0.015	0.009	0.020
Baseline w/ Chem. Recycle	Eutroph. (kg N eq)	Incurred	0.175	0.175	0.175

Baseline w/ Chem. Recycle	Eutroph. (kg N eq)	Displaced	-0.195	-0.232	-0.162
Baseline w/ Chem. Recycle	Eutroph. (kg N eq)	Net	-0.021	-0.057	0.013
Baseline w/ Chem. Recycle	Acidification (kg SO2 eq)	Incurred	2.916	2.916	2.916
Baseline w/ Chem. Recycle	Acidification (kg SO2 eq)	Displaced	-5.387	-6.390	-4.489
Baseline w/ Chem. Recycle	Acidification (kg SO2 eq)	Net	-2.471	-3.474	-1.573
Baseline w/ Chem. Recycle	Energy, Fossil (GJ)	Incurred	15.411	15.411	15.411
Baseline w/ Chem. Recycle	Energy, Fossil (GJ)	Displaced	-29.161	-33.815	-24.944
Baseline w/ Chem. Recycle	Energy, Fossil (GJ)	Net	-13.750	-18.404	-9.533
Incineration	GHG (t CO2eq)	Incurred	1.203	1.203	1.203
Incineration	GHG (t CO2eq)	Displaced	-0.918	-1.020	-0.816
Incineration	GHG (t CO2eq)	Net	0.285	0.183	0.387
Incineration	PM2.5 eq (kg)	Incurred	0.065	0.065	0.065
Incineration	PM2.5 eq (kg)	Displaced	-0.047	-0.052	-0.042
Incineration	PM2.5 eq (kg)	Net	0.018	0.012	0.023
Incineration	Water (m3; Blue)	Incurred	2.580	2.580	2.580
Incineration	Water (m3; Blue)	Displaced	-38.075	-42.306	-33.845
Incineration	Water (m3; Blue)	Net	-35.496	-39.726	-31.265
Incineration	Smog (kg O3 eq)	Incurred	28.587	28.587	28.587
Incineration	Smog (kg O3 eq)	Displaced	-20.543	-22.826	-18.261
Incineration	Smog (kg O3 eq)	Net	8.044	5.761	10.326
Incineration	Energy (GJ)	Incurred	2.173	2.173	2.173
Incineration	Energy (GJ)	Displaced	-11.811	-13.123	-10.498
Incineration	Energy (GJ)	Net	-9.638	-10.951	-8.326
Incineration	Health, Cancer (Tox. Units)	Incurred	0.000	0.000	0.000
Incineration	Health, Cancer (Tox. Units)	Displaced	0.000	0.000	0.000
Incineration	Health, Cancer (Tox. Units)	Net	0.000	0.000	0.000

Incineration	Health, NonCancer (Tox. Units)	Incurred	0.000	0.000	0.000
Incineration	Health, NonCancer (Tox. Units)	Displaced	0.000	0.000	0.000
Incineration	Health, NonCancer (Tox. Units)	Net	0.000	0.000	0.000
Incineration	Ozone depl. (g CFC-11 eq)	Incurred	0.022	0.022	0.022
Incineration	Ozone depl. (g CFC-11 eq)	Displaced	-0.054	-0.060	-0.048
Incineration	Ozone depl. (g CFC-11 eq)	Net	-0.032	-0.038	-0.026
Incineration	Eutroph. (kg N eq)	Incurred	0.055	0.055	0.055
Incineration	Eutroph. (kg N eq)	Displaced	-0.068	-0.075	-0.060
Incineration	Eutroph. (kg N eq)	Net	-0.012	-0.020	-0.005
Incineration	Acidification (kg SO2 eq)	Incurred	0.991	0.991	0.991
Incineration	Acidification (kg SO2 eq)	Displaced	-0.866	-0.963	-0.770
Incineration	Acidification (kg SO2 eq)	Net	0.125	0.028	0.221
Incineration	Energy, Fossil (GJ)	Incurred	1.994	1.994	1.994
Incineration	Energy, Fossil (GJ)	Displaced	-12.336	-13.707	-10.965
Incineration	Energy, Fossil (GJ)	Net	-10.342	-11.713	-8.972
Pyrolysis, whole unit	GHG (t CO2eq)	Incurred	0.376	0.376	0.376
Pyrolysis, whole unit	GHG (t CO2eq)	Displaced	-0.806	-0.895	-0.716
Pyrolysis, whole unit	GHG (t CO2eq)	Net	-0.429	-0.519	-0.340
Pyrolysis, whole unit	PM2.5 eq (kg)	Incurred	0.080	0.080	0.080
Pyrolysis, whole unit	PM2.5 eq (kg)	Displaced	-0.229	-0.254	-0.203
Pyrolysis, whole unit	PM2.5 eq (kg)	Net	-0.149	-0.174	-0.124
Pyrolysis, whole unit	Water (m3; Blue)	Incurred	1.065	1.065	1.065
Pyrolysis, whole unit	Water (m3; Blue)	Displaced	-38.976	-43.307	-34.645
Pyrolysis, whole unit	Water (m3; Blue)	Net	-37.911	-42.241	-33.580
Pyrolysis, whole unit	Smog (kg O3 eq)	Incurred	8.626	8.626	8.626
Pyrolysis, whole unit	Smog (kg O3 eq)	Displaced	-32.917	-36.574	-29.259
Pyrolysis, whole unit	Smog (kg O3 eq)	Net	-24.291	-27.948	-20.633
Pyrolysis, whole unit	Energy (GJ)	Incurred	3.597	3.597	3.597
Pyrolysis, whole unit	Energy (GJ)	Displaced	-24.895	-27.661	-22.129
Pyrolysis, whole unit	Energy (GJ)	Net	-21.298	-24.064	-18.532

Pyrolysis, whole unit	Health, Cancer (Tox. Units)	Incurred	0.000	0.000	0.000
Pyrolysis, whole unit	Health, Cancer (Tox. Units)	Displaced	0.000	0.000	0.000
Pyrolysis, whole unit	Health, Cancer (Tox. Units)	Net	0.000	0.000	0.000
Pyrolysis, whole unit	Health, NonCancer (Tox. Units)	Incurred	0.000	0.000	0.000
Pyrolysis, whole unit	Health, NonCancer (Tox. Units)	Displaced	0.000	0.000	0.000
Pyrolysis, whole unit	Health, NonCancer (Tox. Units)	Net	0.000	0.000	0.000
Pyrolysis, whole unit	Ozone depl. (g CFC-11 eq)	Incurred	0.031	0.031	0.031
Pyrolysis, whole unit	Ozone depl. (g CFC-11 eq)	Displaced	-0.319	-0.354	-0.284
Pyrolysis, whole unit	Ozone depl. (g CFC-11 eq)	Net	-0.288	-0.323	-0.252
Pyrolysis, whole unit	Eutroph. (kg N eq)	Incurred	0.021	0.021	0.021
Pyrolysis, whole unit	Eutroph. (kg N eq)	Displaced	-0.125	-0.138	-0.111
Pyrolysis, whole unit	Eutroph. (kg N eq)	Net	-0.104	-0.117	-0.090
Pyrolysis, whole unit	Acidification (kg SO2 eq)	Incurred	0.524	0.524	0.524
Pyrolysis, whole unit	Acidification (kg SO2 eq)	Displaced	-2.130	-2.366	-1.893
Pyrolysis, whole unit	Acidification (kg SO2 eq)	Net	-1.606	-1.843	-1.369
Pyrolysis, whole unit	Energy, Fossil (GJ)	Incurred	3.376	3.376	3.376
Pyrolysis, whole unit	Energy, Fossil (GJ)	Displaced	-25.369	-28.188	-22.550
Pyrolysis, whole unit	Energy, Fossil (GJ)	Net	-21.994	-24.812	-19.175

Data for Figure 4.3: Impacts of recycling one tonne of mattresses; five types of mattresses, and one mix of types

Scenario	Impact Type	Incurred, Displaced	result	result_lo	result_hi
Modeled Mix	GHG (t CO2eq)	Incurred	0.26	0.26	0.26
Modeled Mix	GHG (t CO2eq)	Displaced	-1.17	-1.73	-0.79
Modeled Mix	GHG (t CO2eq)	Net	-0.90	-1.47	-0.53
Modeled Mix	PM2.5 eq (kg)	Incurred	0.18	0.18	0.18
Modeled Mix	PM2.5 eq (kg)	Displaced	-0.36	-0.66	-0.17
Modeled Mix	PM2.5 eq (kg)	Net	-0.18	-0.47	0.01
Modeled Mix	Water (m3; Blue)	Incurred	2.61	2.61	2.61

Modeled Mix	Water (m3; Blue)	Displaced	-50.70	-67.01	-39.01
Modeled Mix	Water (m3; Blue)	Net	-48.10	-64.40	-36.41
Modeled Mix	Smog (kg O3 eq)	Incurred	18.10	18.10	18.10
Modeled Mix	Smog (kg O3 eq)	Displaced	-48.80	-78.63	-29.46
Modeled Mix	Smog (kg O3 eq)	Net	-30.70	-60.52	-11.36
Modeled Mix	Energy (GJ)	Incurred	4.50	4.50	4.50
Modeled Mix	Energy (GJ)	Displaced	-20.91	-32.44	-13.29
Modeled Mix	Energy (GJ)	Net	-16.41	-27.93	-8.79
Modeled Mix	Health, Cancer (Tox. Units)	Incurred	3.4E-05	3.4E-05	3.4E-05
Modeled Mix	Health, Cancer (Tox. Units)	Displaced	-4.7E-05	-7.9E-05	-2.5E-05
Modeled Mix	Health, Cancer (Tox. Units)	Net	-1.2E-05	-4.4E-05	9.6E-06
Modeled Mix	Health, NonCancer (Tox. Units)	Incurred	6.7E-05	6.7E-05	6.7E-05
Modeled Mix	Health, NonCancer (Tox. Units)	Displaced	3.1E-07	-2.1E-05	1.3E-05
Modeled Mix	Health, NonCancer (Tox. Units)	Net	6.8E-05	4.6E-05	8.0E-05
Modeled Mix	Ozone depl. (g CFC-11 eq)	Incurred	0.04	0.04	0.04
Modeled Mix	Ozone depl. (g CFC-11 eq)	Displaced	-0.02	-0.03	-0.02
Modeled Mix	Ozone depl. (g CFC-11 eq)	Net	0.02	0.01	0.03
Modeled Mix	Eutroph. (kg N eq)	Incurred	0.21	0.21	0.21
Modeled Mix	Eutroph. (kg N eq)	Displaced	-0.12	-0.18	-0.08
Modeled Mix	Eutroph. (kg N eq)	Net	0.09	0.03	0.13
Modeled Mix	Acidification (kg SO2 eq)	Incurred	0.98	0.98	0.98
Modeled Mix	Acidification (kg SO2 eq)	Displaced	-3.06	-5.31	-1.63
Modeled Mix	Acidification (kg SO2 eq)	Net	-2.08	-4.33	-0.65
Modeled Mix	Energy, Fossil (GJ)	Incurred	4.04	4.04	4.04
Modeled Mix	Energy, Fossil (GJ)	Displaced	-17.36	-27.39	-10.78
Modeled Mix	Energy, Fossil (GJ)	Net	-13.32	-23.35	-6.74
Pocket Coil	GHG (t CO2eq)	Incurred	0.29	0.29	0.29
Pocket Coil	GHG (t CO2eq)	Displaced	-1.39	-2.05	-0.94
Pocket Coil	GHG (t CO2eq)	Net	-1.10	-1.76	-0.65

Pocket Coil	PM2.5 eq (kg)	Incurred	0.19	0.19	0.19
Pocket Coil	PM2.5 eq (kg)	Displaced	-0.41	-0.76	-0.20
Pocket Coil	PM2.5 eq (kg)	Net	-0.22	-0.57	-0.01
Pocket Coil	Water (m3; Blue)	Incurred	2.81	2.81	2.81
Pocket Coil	Water (m3; Blue)	Displaced	-63.25	-82.91	-49.06
Pocket Coil	Water (m3; Blue)	Net	-60.44	-80.10	-46.25
Pocket Coil	Smog (kg O3 eq)	Incurred	18.61	18.61	18.61
Pocket Coil	Smog (kg O3 eq)	Displaced	-57.30	-92.48	-34.54
Pocket Coil	Smog (kg O3 eq)	Net	-38.69	-73.87	-15.94
Pocket Coil	Energy (GJ)	Incurred	5.15	5.15	5.15
Pocket Coil	Energy (GJ)	Displaced	-21.10	-34.24	-12.58
Pocket Coil	Energy (GJ)	Net	-15.94	-29.09	-7.43
Pocket Coil	Health, Cancer (Tox. Units)	Incurred	4.5E-05	4.5E-05	4.5E-05
Pocket Coil	Health, Cancer (Tox. Units)	Displaced	-5.3E-05	-9.0E-05	-2.7E-05
Pocket Coil	Health, Cancer (Tox. Units)	Net	-7.6E-06	-4.5E-05	1.8E-05
Pocket Coil	Health, NonCancer (Tox. Units)	Incurred	5.6E-05	5.6E-05	5.6E-05
Pocket Coil	Health, NonCancer (Tox. Units)	Displaced	5.7E-06	-1.9E-05	2.0E-05
Pocket Coil	Health, NonCancer (Tox. Units)	Net	6.1E-05	3.6E-05	7.5E-05
Pocket Coil	Ozone depl. (g CFC-11 eq)	Incurred	0.05	0.05	0.05
Pocket Coil	Ozone depl. (g CFC-11 eq)	Displaced	-0.02	-0.03	-0.01
Pocket Coil	Ozone depl. (g CFC-11 eq)	Net	0.03	0.02	0.03
Pocket Coil	Eutroph. (kg N eq)	Incurred	0.24	0.24	0.24
Pocket Coil	Eutroph. (kg N eq)	Displaced	-0.14	-0.21	-0.09
Pocket Coil	Eutroph. (kg N eq)	Net	0.10	0.03	0.15
Pocket Coil	Acidification (kg SO2 eq)	Incurred	1.07	1.07	1.07
Pocket Coil	Acidification (kg SO2 eq)	Displaced	-3.56	-6.21	-1.88
Pocket Coil	Acidification (kg SO2 eq)	Net	-2.49	-5.14	-0.81
Pocket Coil	Energy, Fossil (GJ)	Incurred	4.62	4.62	4.62
Pocket Coil	Energy, Fossil (GJ)	Displaced	-20.18	-31.97	-12.48

Pocket Coil	Energy, Fossil (GJ)	Net	-15.56	-27.35	-7.86
Tied Spring	GHG (t CO2eq)	Incurred	0.22	0.22	0.22
Tied Spring	GHG (t CO2eq)	Displaced	-1.20	-1.65	-0.88
Tied Spring	GHG (t CO2eq)	Net	-0.98	-1.43	-0.66
Tied Spring	PM2.5 eq (kg)	Incurred	0.13	0.13	0.13
Tied Spring	PM2.5 eq (kg)	Displaced	-0.28	-0.50	-0.14
Tied Spring	PM2.5 eq (kg)	Net	-0.15	-0.37	-0.02
Tied Spring	Water (m3; Blue)	Incurred	2.02	2.02	2.02
Tied Spring	Water (m3; Blue)	Displaced	-59.98	-74.42	-48.90
Tied Spring	Water (m3; Blue)	Net	-57.96	-72.40	-46.88
Tied Spring	Smog (kg O3 eq)	Incurred	12.66	12.66	12.66
Tied Spring	Smog (kg O3 eq)	Displaced	-46.42	-69.46	-30.98
Tied Spring	Smog (kg O3 eq)	Net	-33.76	-56.80	-18.32
Tied Spring	Energy (GJ)	Incurred	3.64	3.64	3.64
Tied Spring	Energy (GJ)	Displaced	-16.90	-25.54	-11.08
Tied Spring	Energy (GJ)	Net	-13.25	-21.90	-7.44
Tied Spring	Health, Cancer (Tox. Units)	Incurred	2.3E-05	2.3E-05	2.3E-05
Tied Spring	Health, Cancer (Tox. Units)	Displaced	-4.0E-05	-6.6E-05	-2.2E-05
Tied Spring	Health, Cancer (Tox. Units)	Net	-1.7E-05	-4.3E-05	9.2E-07
Tied Spring	Health, NonCancer (Tox. Units)	Incurred	4.9E-05	4.9E-05	4.9E-05
Tied Spring	Health, NonCancer (Tox. Units)	Displaced	1.9E-05	5.4E-06	2.6E-05
Tied Spring	Health, NonCancer (Tox. Units)	Net	6.8E-05	5.5E-05	7.6E-05
Tied Spring	Ozone depl. (g CFC-11 eq)	Incurred	0.04	0.04	0.04
Tied Spring	Ozone depl. (g CFC-11 eq)	Displaced	-0.02	-0.03	-0.01
Tied Spring	Ozone depl. (g CFC-11 eq)	Net	0.02	0.01	0.02
Tied Spring	Eutroph. (kg N eq)	Incurred	0.15	0.15	0.15
Tied Spring	Eutroph. (kg N eq)	Displaced	-0.12	-0.17	-0.08
Tied Spring	Eutroph. (kg N eq)	Net	0.03	-0.02	0.07
Tied Spring	Acidification (kg SO2 eq)	Incurred	0.72	0.72	0.72

Tied Spring	Acidification (kg SO2 eq)	Displaced	-2.63	-4.32	-1.53
Tied Spring	Acidification (kg SO2 eq)	Net	-1.90	-3.59	-0.81
Tied Spring	Energy, Fossil (GJ)	Incurred	3.31	3.31	3.31
Tied Spring	Energy, Fossil (GJ)	Displaced	-16.59	-24.43	-11.26
Tied Spring	Energy, Fossil (GJ)	Net	-13.28	-21.12	-7.95
All Foam	GHG (t CO2eq)	Incurred	0.54	0.54	0.54
All Foam	GHG (t CO2eq)	Displaced	-1.98	-3.80	-0.86
All Foam	GHG (t CO2eq)	Net	-1.44	-3.26	-0.32
All Foam	PM2.5 eq (kg)	Incurred	0.40	0.40	0.40
All Foam	PM2.5 eq (kg)	Displaced	-1.16	-2.22	-0.50
All Foam	PM2.5 eq (kg)	Net	-0.76	-1.82	-0.10
All Foam	Water (m3; Blue)	Incurred	6.61	6.61	6.61
All Foam	Water (m3; Blue)	Displaced	-48.75	-93.58	-21.06
All Foam	Water (m3; Blue)	Net	-42.14	-86.98	-14.46
All Foam	Smog (kg O3 eq)	Incurred	35.38	35.38	35.38
All Foam	Smog (kg O3 eq)	Displaced	-111.25	-213.15	-48.24
All Foam	Smog (kg O3 eq)	Net	-75.87	-177.77	-12.86
All Foam	Energy (GJ)	Incurred	10.27	10.27	10.27
All Foam	Energy (GJ)	Displaced	-41.80	-79.91	-18.20
All Foam	Energy (GJ)	Net	-31.53	-69.64	-7.93
All Foam	Health, Cancer (Tox. Units)	Incurred	6.1E-05	6.1E-05	6.1E-05
All Foam	Health, Cancer (Tox. Units)	Displaced	-1.2E-04	-2.2E-04	-5.5E-05
All Foam	Health, Cancer (Tox. Units)	Net	-6.0E-05	-1.6E-04	5.6E-06
All Foam	Health, NonCancer (Tox. Units)	Incurred	9.4E-05	9.4E-05	9.4E-05
All Foam	Health, NonCancer (Tox. Units)	Displaced	-9.9E-05	-1.9E-04	-4.3E-05
All Foam	Health, NonCancer (Tox. Units)	Net	-4.3E-06	-9.4E-05	5.1E-05
All Foam	Ozone depl. (g CFC-11 eq)	Incurred	0.09	0.09	0.09
All Foam	Ozone depl. (g CFC-11 eq)	Displaced	-0.03	-0.06	-0.02
All Foam	Ozone depl. (g CFC-11 eq)	Net	0.06	0.03	0.08

All Foam	Eutroph. (kg N eq)	Incurred	0.70	0.70	0.70
All Foam	Eutroph. (kg N eq)	Displaced	-0.22	-0.42	-0.10
All Foam	Eutroph. (kg N eq)	Net	0.48	0.27	0.60
All Foam	Acidification (kg SO2 eq)	Incurred	2.21	2.21	2.21
All Foam	Acidification (kg SO2 eq)	Displaced	-8.72	-16.70	-3.78
All Foam	Acidification (kg SO2 eq)	Net	-6.51	-14.50	-1.57
All Foam	Energy, Fossil (GJ)	Incurred	9.28	9.28	9.28
All Foam	Energy, Fossil (GJ)	Displaced	-36.96	-70.65	-16.09
All Foam	Energy, Fossil (GJ)	Net	-27.67	-61.36	-6.81
All Wood Foundation	GHG (t CO2eq)	Incurred	0.14	0.14	0.14
All Wood Foundation	GHG (t CO2eq)	Displaced	-0.28	-0.33	-0.24
All Wood Foundation	GHG (t CO2eq)	Net	-0.15	-0.19	-0.10
All Wood Foundation	PM2.5 eq (kg)	Incurred	0.22	0.22	0.22
All Wood Foundation	PM2.5 eq (kg)	Displaced	-0.10	-0.12	-0.08
All Wood Foundation	PM2.5 eq (kg)	Net	0.12	0.10	0.14
All Wood Foundation	Water (m3; Blue)	Incurred	1.47	1.47	1.47
All Wood Foundation	Water (m3; Blue)	Displaced	-1.61	-2.03	-1.24
All Wood Foundation	Water (m3; Blue)	Net	-0.14	-0.56	0.23
All Wood Foundation	Smog (kg O3 eq)	Incurred	23.82	23.82	23.82
All Wood Foundation	Smog (kg O3 eq)	Displaced	-12.37	-14.44	-10.41
All Wood Foundation	Smog (kg O3 eq)	Net	11.44	9.38	13.40
All Wood Foundation	Energy (GJ)	Incurred	2.34	2.34	2.34
All Wood Foundation	Energy (GJ)	Displaced	-26.39	-29.90	-22.92
All Wood Foundation	Energy (GJ)	Net	-24.05	-27.55	-20.58
All Wood Foundation	Health, Cancer (Tox. Units)	Incurred	2.3E-05	2.3E-05	2.3E-05
All Wood Foundation	Health, Cancer (Tox. Units)	Displaced	-2.1E-05	-2.7E-05	-1.6E-05
All Wood Foundation	Health, Cancer (Tox. Units)	Net	1.9E-06	-3.7E-06	7.4E-06
All Wood Foundation	Health, NonCancer (Tox. Units)	Incurred	1.2E-04	1.2E-04	1.2E-04
All Wood Foundation	Health, NonCancer (Tox. Units)	Displaced	-1.7E-05	-2.0E-05	-1.4E-05

All Wood Foundation	Health, NonCancer (Tox. Units)	Net	1.0E-04	1.0E-04	1.1E-04
All Wood Foundation	Ozone depl. (g CFC-11 eq)	Incurred	0.02	0.02	0.02
All Wood Foundation	Ozone depl. (g CFC-11 eq)	Displaced	-0.04	-0.05	-0.04
All Wood Foundation	Ozone depl. (g CFC-11 eq)	Net	-0.02	-0.03	-0.02
All Wood Foundation	Eutroph. (kg N eq)	Incurred	0.05	0.05	0.05
All Wood Foundation	Eutroph. (kg N eq)	Displaced	-0.03	-0.03	-0.03
All Wood Foundation	Eutroph. (kg N eq)	Net	0.02	0.02	0.03
All Wood Foundation	Acidification (kg SO2 eq)	Incurred	0.90	0.90	0.90
All Wood Foundation	Acidification (kg SO2 eq)	Displaced	-0.70	-0.82	-0.58
All Wood Foundation	Acidification (kg SO2 eq)	Net	0.20	0.08	0.32
All Wood Foundation	Energy, Fossil (GJ)	Incurred	2.00	2.00	2.00
All Wood Foundation	Energy, Fossil (GJ)	Displaced	-5.25	-6.08	-4.46
All Wood Foundation	Energy, Fossil (GJ)	Net	-3.25	-4.08	-2.46
Foundation (not all wood)	GHG (t CO2eq)	Incurred	0.15	0.15	0.15
Foundation (not all wood)	GHG (t CO2eq)	Displaced	-0.77	-0.88	-0.66
Foundation (not all wood)	GHG (t CO2eq)	Net	-0.62	-0.73	-0.51
Foundation (not all wood)	PM2.5 eq (kg)	Incurred	0.15	0.15	0.15
Foundation (not all wood)	PM2.5 eq (kg)	Displaced	-0.09	-0.11	-0.06
Foundation (not all wood)	PM2.5 eq (kg)	Net	0.06	0.04	0.08
Foundation (not all wood)	Water (m3; Blue)	Incurred	1.46	1.46	1.46
Foundation (not all wood)	Water (m3; Blue)	Displaced	-39.77	-44.73	-35.00
Foundation (not all wood)	Water (m3; Blue)	Net	-38.31	-43.27	-33.54
Foundation (not all wood)	Smog (kg O3 eq)	Incurred	16.48	16.48	16.48
Foundation (not all wood)	Smog (kg O3 eq)	Displaced	-22.27	-26.23	-18.74

Foundation (not all wood)	Smog (kg O3 eq)	Net	-5.79	-9.75	-2.26
Foundation (not all wood)	Energy (GJ)	Incurred	2.46	2.46	2.46
Foundation (not all wood)	Energy (GJ)	Displaced	-18.87	-21.72	-16.17
Foundation (not all wood)	Energy (GJ)	Net	-16.40	-19.26	-13.70
Foundation (not all wood)	Health, Cancer (Tox. Units)	Incurred	2.2E-05	2.2E-05	2.2E-05
Foundation (not all wood)	Health, Cancer (Tox. Units)	Displaced	-2.2E-05	-2.9E-05	-1.5E-05
Foundation (not all wood)	Health, Cancer (Tox. Units)	Net	5.2E-08	-7.2E-06	6.9E-06
Foundation (not all wood)	Health, NonCancer (Tox. Units)	Incurred	7.8E-05	7.8E-05	7.8E-05
Foundation (not all wood)	Health, NonCancer (Tox. Units)	Displaced	2.2E-05	2.3E-05	2.1E-05
Foundation (not all wood)	Health, NonCancer (Tox. Units)	Net	1.0E-04	1.0E-04	9.9E-05
Foundation (not all wood)	Ozone depl. (g CFC-11 eq)	Incurred	0.02	0.02	0.02
Foundation (not all wood)	Ozone depl. (g CFC-11 eq)	Displaced	-0.03	-0.03	-0.02
Foundation (not all wood)	Ozone depl. (g CFC-11 eq)	Net	0.00	-0.01	0.00
Foundation (not all wood)	Eutroph. (kg N eq)	Incurred	0.04	0.04	0.04
Foundation (not all wood)	Eutroph. (kg N eq)	Displaced	-0.07	-0.08	-0.06
Foundation (not all wood)	Eutroph. (kg N eq)	Net	-0.02	-0.03	-0.01
Foundation (not all wood)	Acidification (kg SO2 eq)	Incurred	0.68	0.68	0.68
Foundation (not all wood)	Acidification (kg SO2 eq)	Displaced	-0.93	-1.15	-0.75
Foundation (not all wood)	Acidification (kg SO2 eq)	Net	-0.25	-0.47	-0.07
Foundation (not all wood)	Energy, Fossil (GJ)	Incurred	2.15	2.15	2.15

Foundation (not all wood)	Energy, Fossil (GJ)	Displaced	-9.86	-11.50	-8.35
Foundation (not all wood)	Energy, Fossil (GJ)	Net	-7.71	-9.35	-6.20

Data for Figure 4.6: Foam routes, processing one tonne of recovered foam (not including collection or primary recycling)

Scenario	Impact Type	Incurred/ Displaced	result	result_lo	result_hi
Rebond pad (displacing foam pad)	GHG (kg CO2eq)	Incurred	611.22	611.22	611.22
Rebond pad (displacing foam pad)	GHG (kg CO2eq)	Displaced	-2,538.23	-5,076.46	-1,015.29
Rebond pad (displacing foam pad)	GHG (kg CO2eq)	Net	-1,927.01	-4,465.24	-404.07
Rebond pad (displacing foam pad)	PM2.5 eq (kg)	Incurred	0.51	0.51	0.51
Rebond pad (displacing foam pad)	PM2.5 eq (kg)	Displaced	-1.48	-2.97	-0.59
Rebond pad (displacing foam pad)	PM2.5 eq (kg)	Net	-0.97	-2.45	-0.08
Rebond pad (displacing foam pad)	Water (m3; Blue)	Incurred	8.09	8.09	8.09
Rebond pad (displacing foam pad)	Water (m3; Blue)	Displaced	-62.79	-125.58	-25.12
Rebond pad (displacing foam pad)	Water (m3; Blue)	Net	-54.70	-117.49	-17.03
Rebond pad (displacing foam pad)	Smog (kg O3 eq)	Incurred	41.62	41.62	41.62
Rebond pad (displacing foam pad)	Smog (kg O3 eq)	Displaced	-142.38	-284.77	-56.95
Rebond pad (displacing foam pad)	Smog (kg O3 eq)	Net	-100.77	-243.15	-15.34
Rebond pad (displacing foam pad)	Energy (MJ)	Incurred	12,437.67	12,437.67	12,437.67
Rebond pad (displacing foam pad)	Energy (MJ)	Displaced	-53,103.59	-106,207.19	-21,241.44
Rebond pad (displacing foam pad)	Energy (MJ)	Net	-40,665.93	-93,769.52	-8,803.77

Rebond pad (displacing foam pad)	Health, Cancer (Tox. Units)	Incurred	6.51E-05	6.51E-05	6.51E-05
Rebond pad (displacing foam pad)	Health, Cancer (Tox. Units)	Displaced	-1.38E-04	-2.77E-04	-5.53E-05
Rebond pad (displacing foam pad)	Health, Cancer (Tox. Units)	Net	-7.32E-05	-2.12E-04	9.75E-06
Rebond pad (displacing foam pad)	Health, NonCancer (Tox. Units)	Incurred	8.66E-05	8.66E-05	8.66E-05
Rebond pad (displacing foam pad)	Health, NonCancer (Tox. Units)	Displaced	-1.25E-04	-2.49E-04	-4.99E-05
Rebond pad (displacing foam pad)	Health, NonCancer (Tox. Units)	Net	-3.82E-05	-1.63E-04	3.67E-05
Rebond pad (displacing foam pad)	Ozone depl. (kg CFC-11 eq)	Incurred	1.12E-04	1.12E-04	1.12E-04
Rebond pad (displacing foam pad)	Ozone depl. (kg CFC-11 eq)	Displaced	-3.40E-05	-6.80E-05	-1.36E-05
Rebond pad (displacing foam pad)	Ozone depl. (kg CFC-11 eq)	Net	7.78E-05	4.38E-05	9.82E-05
Rebond pad (displacing foam pad)	Eutroph. (kg N eq)	Incurred	1.00	1.00	1.00
Rebond pad (displacing foam pad)	Eutroph. (kg N eq)	Displaced	-0.28	-0.56	-0.11
Rebond pad (displacing foam pad)	Eutroph. (kg N eq)	Net	0.72	0.43	0.89
Rebond pad (displacing foam pad)	Acidification (kg SO2 eq)	Incurred	2.74	2.74	2.74
Rebond pad (displacing foam pad)	Acidification (kg SO2 eq)	Displaced	-11.16	-22.33	-4.47
Rebond pad (displacing foam pad)	Acidification (kg SO2 eq)	Net	-8.43	-19.59	-1.73
Rebond pad (displacing foam pad)	Energy, Fossil (MJ)	Incurred	11,302.84	11,302.84	11,302.84
Rebond pad (displacing foam pad)	Energy, Fossil (MJ)	Displaced	-46,953.75	-93,907.49	-18,781.50
Rebond pad (displacing foam pad)	Energy, Fossil (MJ)	Net	-35,650.91	-82,604.66	-7,478.66
Acidolysis (displacing polyols)	GHG (kg CO2eq)	Incurred	6,513.60	6,513.60	6,513.60
Acidolysis (displacing polyols)	GHG (kg CO2eq)	Displaced	-7,630.65	-8,478.50	-6,782.80
Acidolysis (displacing polyols)	GHG (kg CO2eq)	Net	-1,117.05	-1,964.90	-269.20
Acidolysis (displacing polyols)	PM2.5 eq (kg)	Incurred	3.41	3.41	3.41

Acidolysis (displacing polyols)	PM2.5 eq (kg)	Displaced	-5.19	-5.77	-4.62
Acidolysis (displacing polyols)	PM2.5 eq (kg)	Net	-1.78	-2.36	-1.20
Acidolysis (displacing polyols)	Water (m3; Blue)	Incurred	144.16	144.16	144.16
Acidolysis (displacing polyols)	Water (m3; Blue)	Displaced	-254.84	-283.15	-226.52
Acidolysis (displacing polyols)	Water (m3; Blue)	Net	-110.68	-138.99	-82.36
Acidolysis (displacing polyols)	Smog (kg O3 eq)	Incurred	259.65	259.65	259.65
Acidolysis (displacing polyols)	Smog (kg O3 eq)	Displaced	-433.16	-481.29	-385.03
Acidolysis (displacing polyols)	Smog (kg O3 eq)	Net	-173.51	-221.64	-125.38
Acidolysis (displacing polyols)	Energy (MJ)	Incurred	126,347.40	126,347.40	126,347.40
Acidolysis (displacing polyols)	Energy (MJ)	Displaced	-185,881.85	-206,535.39	-165,228.31
Acidolysis (displacing polyols)	Energy (MJ)	Net	-59,534.45	-80,187.99	-38,880.91
Acidolysis (displacing polyols)	Health, Cancer (Tox. Units)	Incurred	3.26E-04	3.26E-04	3.26E-04
Acidolysis (displacing polyols)	Health, Cancer (Tox. Units)	Displaced	-4.82E-04	-5.36E-04	-4.29E-04
Acidolysis (displacing polyols)	Health, Cancer (Tox. Units)	Net	-1.56E-04	-2.10E-04	-1.03E-04
Acidolysis (displacing polyols)	Health, NonCancer (Tox. Units)	Incurred	2.87E-04	2.87E-04	2.87E-04
Acidolysis (displacing polyols)	Health, NonCancer (Tox. Units)	Displaced	-4.20E-04	-4.67E-04	-3.73E-04
Acidolysis (displacing polyols)	Health, NonCancer (Tox. Units)	Net	-1.33E-04	-1.80E-04	-8.63E-05
Acidolysis (displacing polyols)	Ozone depl. (kg CFC-11 eq)	Incurred	1.71E-04	1.71E-04	1.71E-04
Acidolysis (displacing polyols)	Ozone depl. (kg CFC-11 eq)	Displaced	-7.86E-05	-8.74E-05	-6.99E-05
Acidolysis (displacing polyols)	Ozone depl. (kg CFC-11 eq)	Net	9.24E-05	8.37E-05	1.01E-04
Acidolysis (displacing polyols)	Eutroph. (kg N eq)	Incurred	1.10	1.10	1.10
Acidolysis (displacing polyols)	Eutroph. (kg N eq)	Displaced	-0.82	-0.91	-0.73
Acidolysis (displacing polyols)	Eutroph. (kg N eq)	Net	0.28	0.19	0.37
Acidolysis (displacing polyols)	Acidification (kg SO2 eq)	Incurred	20.36	20.36	20.36
Acidolysis (displacing polyols)	Acidification (kg SO2 eq)	Displaced	-31.33	-34.81	-27.85

Acidolysis (displacing polyols)	Acidification (kg SO2 eq)	Net	-10.96	-14.45	-7.48
Acidolysis (displacing polyols)	Energy, Fossil (MJ)	Incurred	113,087.81	113,087.81	113,087.81
Acidolysis (displacing polyols)	Energy, Fossil (MJ)	Displaced	-164,567.68	-182,852.98	-146,282.38
Acidolysis (displacing polyols)	Energy, Fossil (MJ)	Net	-51,479.87	-69,765.17	-33,194.57
Glycolysis (displacing polyols)	GHG (kg CO2eq)	Incurred	3,472.69	3,472.69	3,472.69
Glycolysis (displacing polyols)	GHG (kg CO2eq)	Displaced	-6,813.08	-7,570.09	-6,056.07
Glycolysis (displacing polyols)	GHG (kg CO2eq)	Net	-3,340.39	-4,097.40	-2,583.39
Glycolysis (displacing polyols)	PM2.5 eq (kg)	Incurred	2.51	2.51	2.51
Glycolysis (displacing polyols)	PM2.5 eq (kg)	Displaced	-4.64	-5.15	-4.12
Glycolysis (displacing polyols)	PM2.5 eq (kg)	Net	-2.12	-2.64	-1.61
Glycolysis (displacing polyols)	Water (m3; Blue)	Incurred	45.61	45.61	45.61
Glycolysis (displacing polyols)	Water (m3; Blue)	Displaced	-227.53	-252.81	-202.25
Glycolysis (displacing polyols)	Water (m3; Blue)	Net	-181.92	-207.20	-156.64
Glycolysis (displacing polyols)	Smog (kg O3 eq)	Incurred	177.88	177.88	177.88
Glycolysis (displacing polyols)	Smog (kg O3 eq)	Displaced	-386.75	-429.72	-343.78
Glycolysis (displacing polyols)	Smog (kg O3 eq)	Net	-208.87	-251.84	-165.90
Glycolysis (displacing polyols)	Energy (MJ)	Incurred	106,205.88	106,205.88	106,205.88
Glycolysis (displacing polyols)	Energy (MJ)	Displaced	-165,965.94	-184,406.60	-147,525.28
Glycolysis (displacing polyols)	Energy (MJ)	Net	-59,760.06	-78,200.72	-41,319.40
Glycolysis (displacing polyols)	Health, Cancer (Tox. Units)	Incurred	2.38E-04	2.38E-04	2.38E-04
Glycolysis (displacing polyols)	Health, Cancer (Tox. Units)	Displaced	-4.31E-04	-4.78E-04	-3.83E-04
Glycolysis (displacing polyols)	Health, Cancer (Tox. Units)	Net	-1.93E-04	-2.41E-04	-1.45E-04
Glycolysis (displacing polyols)	Health, NonCancer (Tox. Units)	Incurred	1.96E-04	1.96E-04	1.96E-04
Glycolysis (displacing polyols)	Health, NonCancer (Tox. Units)	Displaced	-3.75E-04	-4.17E-04	-3.33E-04
Glycolysis (displacing polyols)	Health, NonCancer (Tox. Units)	Net	-1.79E-04	-2.21E-04	-1.38E-04
Glycolysis (displacing polyols)	Ozone depl. (kg CFC-11 eq)	Incurred	8.22E-05	8.22E-05	8.22E-05

Glycolysis (displacing polyols)	Ozone depl. (kg CFC-11 eq)	Displaced	-7.02E-05	-7.80E-05	-6.24E-05
Glycolysis (displacing polyols)	Ozone depl. (kg CFC-11 eq)	Net	1.20E-05	4.22E-06	1.98E-05
Glycolysis (displacing polyols)	Eutroph. (kg N eq)	Incurred	0.37	0.37	0.37
Glycolysis (displacing polyols)	Eutroph. (kg N eq)	Displaced	-0.73	-0.81	-0.65
Glycolysis (displacing polyols)	Eutroph. (kg N eq)	Net	-0.36	-0.44	-0.28
Glycolysis (displacing polyols)	Acidification (kg SO2 eq)	Incurred	13.47	13.47	13.47
Glycolysis (displacing polyols)	Acidification (kg SO2 eq)	Displaced	-27.97	-31.08	-24.86
Glycolysis (displacing polyols)	Acidification (kg SO2 eq)	Net	-14.50	-17.61	-11.40
Glycolysis (displacing polyols)	Energy, Fossil (MJ)	Incurred	99,921.64	99,921.64	99,921.64
Glycolysis (displacing polyols)	Energy, Fossil (MJ)	Displaced	-146,935.43	-163,261.59	-130,609.27
Glycolysis (displacing polyols)	Energy, Fossil (MJ)	Net	-47,013.78	-63,339.94	-30,687.63
Scrap market (displacing freight)	GHG (kg CO2eq)	Incurred	17.80	17.80	17.80
Scrap market (displacing freight)	GHG (kg CO2eq)	Displaced	-132.17	-146.86	-117.49
Scrap market (displacing freight)	GHG (kg CO2eq)	Net	-114.38	-129.06	-99.69
Scrap market (displacing freight)	PM2.5 eq (kg)	Incurred	0.01	0.01	0.01
Scrap market (displacing freight)	PM2.5 eq (kg)	Displaced	-0.16	-0.17	-0.14
Scrap market (displacing freight)	PM2.5 eq (kg)	Net	-0.15	-0.16	-0.13
Scrap market (displacing freight)	Water (m3; Blue)	Incurred	0.03	0.03	0.03
Scrap market (displacing freight)	Water (m3; Blue)	Displaced	-0.13	-0.15	-0.12
Scrap market (displacing freight)	Water (m3; Blue)	Net	-0.10	-0.12	-0.09
Scrap market (displacing freight)	Smog (kg O3 eq)	Incurred	0.81	0.81	0.81
Scrap market (displacing freight)	Smog (kg O3 eq)	Displaced	-45.27	-50.30	-40.24

Scrap market (displacing freight)	Smog (kg O3 eq)	Net	-44.46	-49.49	-39.43
Scrap market (displacing freight)	Energy (MJ)	Incurred	319.81	319.81	319.81
Scrap market (displacing freight)	Energy (MJ)	Displaced	-2,020.94	-2,245.49	-1,796.39
Scrap market (displacing freight)	Energy (MJ)	Net	-1,701.13	-1,925.68	-1,476.58
Scrap market (displacing freight)	Health, Cancer (Tox. Units)	Incurred	8.96E-07	8.96E-07	8.96E-07
Scrap market (displacing freight)	Health, Cancer (Tox. Units)	Displaced	-7.34E-06	-8.16E-06	-6.53E-06
Scrap market (displacing freight)	Health, Cancer (Tox. Units)	Net	-6.45E-06	-7.26E-06	-5.63E-06
Scrap market (displacing freight)	Health, NonCancer (Tox. Units)	Incurred	2.90E-06	2.90E-06	2.90E-06
Scrap market (displacing freight)	Health, NonCancer (Tox. Units)	Displaced	-1.00E-05	-1.12E-05	-8.92E-06
Scrap market (displacing freight)	Health, NonCancer (Tox. Units)	Net	-7.13E-06	-8.25E-06	-6.02E-06
Scrap market (displacing freight)	Ozone depl. (kg CFC-11 eq)	Incurred	4.46E-06	4.46E-06	4.46E-06
Scrap market (displacing freight)	Ozone depl. (kg CFC-11 eq)	Displaced	-2.97E-05	-3.30E-05	-2.64E-05
Scrap market (displacing freight)	Ozone depl. (kg CFC-11 eq)	Net	-2.53E-05	-2.86E-05	-2.20E-05
Scrap market (displacing freight)	Eutroph. (kg N eq)	Incurred	0.00	0.00	0.00
Scrap market (displacing freight)	Eutroph. (kg N eq)	Displaced	-0.09	-0.10	-0.08
Scrap market (displacing freight)	Eutroph. (kg N eq)	Net	-0.08	-0.09	-0.08
Scrap market (displacing freight)	Acidification (kg SO2 eq)	Incurred	0.05	0.05	0.05
Scrap market (displacing freight)	Acidification (kg SO2 eq)	Displaced	-2.47	-2.74	-2.19
Scrap market (displacing freight)	Acidification (kg SO2 eq)	Net	-2.42	-2.69	-2.14
Scrap market (displacing freight)	Energy, Fossil (MJ)	Incurred	313.79	313.79	313.79

Scrap market (displacing freight)	Energy, Fossil (MJ)	Displaced	-1,991.88	-2,213.20	-1,770.56
Scrap market (displacing freight)	Energy, Fossil (MJ)	Net	-1,678.09	-1,899.41	-1,456.77
Pyrolysis (displacing oil and carbon black)	GHG (kg CO2eq)	Incurred	283.52	283.52	283.52
Pyrolysis (displacing oil and carbon black)	GHG (kg CO2eq)	Displaced	-247.28	-274.76	-219.80
Pyrolysis (displacing oil and carbon black)	GHG (kg CO2eq)	Net	36.24	8.77	63.72
Pyrolysis (displacing oil and carbon black)	PM2.5 eq (kg)	Incurred	0.04	0.04	0.04
Pyrolysis (displacing oil and carbon black)	PM2.5 eq (kg)	Displaced	-0.26	-0.29	-0.23
Pyrolysis (displacing oil and carbon black)	PM2.5 eq (kg)	Net	-0.22	-0.24	-0.19
Pyrolysis (displacing oil and carbon black)	Water (m3; Blue)	Incurred	0.93	0.93	0.93
Pyrolysis (displacing oil and carbon black)	Water (m3; Blue)	Displaced	-0.23	-0.26	-0.21
Pyrolysis (displacing oil and carbon black)	Water (m3; Blue)	Net	0.70	0.68	0.73
Pyrolysis (displacing oil and carbon black)	Smog (kg O3 eq)	Incurred	5.27	5.27	5.27
Pyrolysis (displacing oil and carbon black)	Smog (kg O3 eq)	Displaced	-29.43	-32.70	-26.16
Pyrolysis (displacing oil and carbon black)	Smog (kg O3 eq)	Net	-24.16	-27.43	-20.89
Pyrolysis (displacing oil and carbon black)	Energy (MJ)	Incurred	1,561.66	1,561.66	1,561.66
Pyrolysis (displacing oil and carbon black)	Energy (MJ)	Displaced	-38,046.11	-42,273.45	-33,818.76
Pyrolysis (displacing oil and carbon black)	Energy (MJ)	Net	-36,484.44	-40,711.79	-32,257.10
Pyrolysis (displacing oil and carbon black)	Health, Cancer (Tox. Units)	Incurred	2.51E-06	2.51E-06	2.51E-06
Pyrolysis (displacing oil and carbon black)	Health, Cancer (Tox. Units)	Displaced	-1.61E-05	-1.79E-05	-1.43E-05
Pyrolysis (displacing oil and carbon black)	Health, Cancer (Tox. Units)	Net	-1.36E-05	-1.54E-05	-1.18E-05

Pyrolysis (displacing oil and carbon black)	Health, NonCancer (Tox. Units)	Incurred	1.88E-05	1.88E-05	1.88E-05
Pyrolysis (displacing oil and carbon black)	Health, NonCancer (Tox. Units)	Displaced	-1.85E-05	-2.05E-05	-1.64E-05
Pyrolysis (displacing oil and carbon black)	Health, NonCancer (Tox. Units)	Net	2.80E-07	-1.77E-06	2.33E-06
Pyrolysis (displacing oil and carbon black)	Ozone depl. (kg CFC-11 eq)	Incurred	1.07E-05	1.07E-05	1.07E-05
Pyrolysis (displacing oil and carbon black)	Ozone depl. (kg CFC-11 eq)	Displaced	-6.33E-04	-7.03E-04	-5.62E-04
Pyrolysis (displacing oil and carbon black)	Ozone depl. (kg CFC-11 eq)	Net	-6.22E-04	-6.92E-04	-5.52E-04
Pyrolysis (displacing oil and carbon black)	Eutroph. (kg N eq)	Incurred	0.01	0.01	0.01
Pyrolysis (displacing oil and carbon black)	Eutroph. (kg N eq)	Displaced	-0.14	-0.16	-0.12
Pyrolysis (displacing oil and carbon black)	Eutroph. (kg N eq)	Net	-0.13	-0.14	-0.11
Pyrolysis (displacing oil and carbon black)	Acidification (kg SO2 eq)	Incurred	0.31	0.31	0.31
Pyrolysis (displacing oil and carbon black)	Acidification (kg SO2 eq)	Displaced	-2.62	-2.91	-2.33
Pyrolysis (displacing oil and carbon black)	Acidification (kg SO2 eq)	Net	-2.31	-2.61	-2.02
Pyrolysis (displacing oil and carbon black)	Energy, Fossil (MJ)	Incurred	1,381.58	1,381.58	1,381.58
Pyrolysis (displacing oil and carbon black)	Energy, Fossil (MJ)	Displaced	-37,899.13	-42,110.14	-33,688.11
Pyrolysis (displacing oil and carbon black)	Energy, Fossil (MJ)	Net	-36,517.55	-40,728.56	-32,306.54
Syn. cement (displacing Portland cement)	GHG (kg CO2eq)	Incurred	9,760.28	9,760.28	9,760.28
Syn. cement (displacing Portland cement)	GHG (kg CO2eq)	Displaced	-6,706.82	-8,942.42	-4,471.21
Syn. cement (displacing Portland cement)	GHG (kg CO2eq)	Net	3,053.46	817.85	5,289.07
Syn. cement (displacing Portland cement)	PM2.5 eq (kg)	Incurred	4.30	4.30	4.30
Syn. cement (displacing Portland cement)	PM2.5 eq (kg)	Displaced	-1.83	-2.44	-1.22

Syn. cement (displacing Portland cement)	PM2.5 eq (kg)	Net	2.47	1.86	3.08
Syn. cement (displacing Portland cement)	Water (m3; Blue)	Incurred	110.22	110.22	110.22
Syn. cement (displacing Portland cement)	Water (m3; Blue)	Displaced	-11.44	-15.25	-7.63
Syn. cement (displacing Portland cement)	Water (m3; Blue)	Net	98.78	94.96	102.59
Syn. cement (displacing Portland cement)	Smog (kg O3 eq)	Incurred	422.82	422.82	422.82
Syn. cement (displacing Portland cement)	Smog (kg O3 eq)	Displaced	-257.98	-343.97	-171.99
Syn. cement (displacing Portland cement)	Smog (kg O3 eq)	Net	164.84	78.85	250.84
Syn. cement (displacing Portland cement)	Energy (MJ)	Incurred	214,502.50	214,502.50	214,502.50
Syn. cement (displacing Portland cement)	Energy (MJ)	Displaced	-33,723.43	-44,964.57	-22,482.28
Syn. cement (displacing Portland cement)	Energy (MJ)	Net	180,779.07	169,537.93	192,020.21
Syn. cement (displacing Portland cement)	Health, Cancer (Tox. Units)	Incurred	3.68E-04	3.68E-04	3.68E-04
Syn. cement (displacing Portland cement)	Health, Cancer (Tox. Units)	Displaced	-1.44E-04	-1.93E-04	-9.63E-05
Syn. cement (displacing Portland cement)	Health, Cancer (Tox. Units)	Net	2.23E-04	1.75E-04	2.71E-04
Syn. cement (displacing Portland cement)	Health, NonCancer (Tox. Units)	Incurred	2.94E-04	2.94E-04	2.94E-04
Syn. cement (displacing Portland cement)	Health, NonCancer (Tox. Units)	Displaced	-3.49E-04	-4.66E-04	-2.33E-04
Syn. cement (displacing Portland cement)	Health, NonCancer (Tox. Units)	Net	-5.50E-05	-1.71E-04	6.15E-05
Syn. cement (displacing Portland cement)	Ozone depl. (kg CFC-11 eq)	Incurred	3.21E-04	3.21E-04	3.21E-04
Syn. cement (displacing Portland cement)	Ozone depl. (kg CFC-11 eq)	Displaced	-2.54E-04	-3.39E-04	-1.69E-04
Syn. cement (displacing Portland cement)	Ozone depl. (kg CFC-11 eq)	Net	6.66E-05	-1.82E-05	1.51E-04
Syn. cement (displacing Portland cement)	Eutroph. (kg N eq)	Incurred	0.88	0.88	0.88

Syn. cement (displacing Portland cement)	Eutroph. (kg N eq)	Displaced	-0.54	-0.72	-0.36
Syn. cement (displacing Portland cement)	Eutroph. (kg N eq)	Net	0.34	0.16	0.52
Syn. cement (displacing Portland cement)	Acidification (kg SO2 eq)	Incurred	35.44	35.44	35.44
Syn. cement (displacing Portland cement)	Acidification (kg SO2 eq)	Displaced	-12.99	-17.32	-8.66
Syn. cement (displacing Portland cement)	Acidification (kg SO2 eq)	Net	22.46	18.13	26.79
Syn. cement (displacing Portland cement)	Energy, Fossil (MJ)	Incurred	200,698.50	200,698.50	200,698.50
Syn. cement (displacing Portland cement)	Energy, Fossil (MJ)	Displaced	-30,499.88	-40,666.51	-20,333.26
Syn. cement (displacing Portland cement)	Energy, Fossil (MJ)	Net	170,198.61	160,031.99	180,365.24

Data for Figure 4.7: Wood routes, processing one tonne of recovered wood (not including collection or primary recycling)

Scenario	Impact Type	Incurred/Displaced	result	result_lo	result_hi
Mulch	GHG (kg CO2eq)	Incurred	12.62	12.62	12.62
Mulch	GHG (kg CO2eq)	Displaced	-125.61	-139.57	-111.66
Mulch	GHG (kg CO2eq)	Net	-112.99	-126.95	-99.03
Mulch	PM2.5 eq (kg)	Incurred	0.03	0.03	0.03
Mulch	PM2.5 eq (kg)	Displaced	-0.07	-0.08	-0.06
Mulch	PM2.5 eq (kg)	Net	-0.04	-0.05	-0.03
Mulch	Water (m3; Blue)	Incurred	0.09	0.09	0.09
Mulch	Water (m3; Blue)	Displaced	-0.25	-0.28	-0.22
Mulch	Water (m3; Blue)	Net	-0.15	-0.18	-0.13
Mulch	Smog (kg O3 eq)	Incurred	0.44	0.44	0.44
Mulch	Smog (kg O3 eq)	Displaced	-9.29	-10.32	-8.26
Mulch	Smog (kg O3 eq)	Net	-8.85	-9.88	-7.82
Mulch	Energy (MJ)	Incurred	267.21	267.21	267.21
Mulch	Energy (MJ)	Displaced	-34,627.82	-38,475.35	-30,780.28

Mulch	Energy (MJ)	Net	-34,360.60	-38,208.14	-30,513.07
Mulch	Health, Cancer (Tox. Units)	Incurred	1.56E-06	1.56E-06	1.56E-06
Mulch	Health, Cancer (Tox. Units)	Displaced	-8.10E-06	-9.00E-06	-7.20E-06
Mulch	Health, Cancer (Tox. Units)	Net	-6.54E-06	-7.44E-06	-5.64E-06
Mulch	Health, NonCancer (Tox. Units)	Incurred	8.10E-07	8.10E-07	8.10E-07
Mulch	Health, NonCancer (Tox. Units)	Displaced	-1.63E-05	-1.81E-05	-1.45E-05
Mulch	Health, NonCancer (Tox. Units)	Net	-1.55E-05	-1.73E-05	-1.37E-05
Mulch	Ozone depl. (kg CFC-11 eq)	Incurred	1.01E-06	1.01E-06	1.01E-06
Mulch	Ozone depl. (kg CFC-11 eq)	Displaced	-3.01E-05	-3.34E-05	-2.67E-05
Mulch	Ozone depl. (kg CFC-11 eq)	Net	-2.91E-05	-3.24E-05	-2.57E-05
Mulch	Eutroph. (kg N eq)	Incurred	0.00	0.00	0.00
Mulch	Eutroph. (kg N eq)	Displaced	-0.02	-0.02	-0.02
Mulch	Eutroph. (kg N eq)	Net	-0.02	-0.02	-0.02
Mulch	Acidification (kg SO2 eq)	Incurred	0.03	0.03	0.03
Mulch	Acidification (kg SO2 eq)	Displaced	-0.45	-0.50	-0.40
Mulch	Acidification (kg SO2 eq)	Net	-0.42	-0.47	-0.37
Mulch	Energy, Fossil (MJ)	Incurred	203.62	203.62	203.62
Mulch	Energy, Fossil (MJ)	Displaced	-2,129.26	-2,365.84	-1,892.67
Mulch	Energy, Fossil (MJ)	Net	-1,925.64	-2,162.23	-1,689.06
Reuse	GHG (kg CO2eq)	Incurred	7.03	7.03	7.03
Reuse	GHG (kg CO2eq)	Displaced	-153.30	-204.40	-102.20
Reuse	GHG (kg CO2eq)	Net	-146.27	-197.37	-95.17
Reuse	PM2.5 eq (kg)	Incurred	0.00	0.00	0.00
Reuse	PM2.5 eq (kg)	Displaced	-0.27	-0.36	-0.18
Reuse	PM2.5 eq (kg)	Net	-0.27	-0.36	-0.18
Reuse	Water (m3; Blue)	Incurred	0.01	0.01	0.01
Reuse	Water (m3; Blue)	Displaced	-0.52	-0.69	-0.35
Reuse	Water (m3; Blue)	Net	-0.51	-0.68	-0.33

Reuse	Smog (kg O3 eq)	Incurred	0.32	0.32	0.32
Reuse	Smog (kg O3 eq)	Displaced	-15.91	-21.22	-10.61
Reuse	Smog (kg O3 eq)	Net	-15.59	-20.90	-10.29
Reuse	Energy (MJ)	Incurred	126.33	126.33	126.33
Reuse	Energy (MJ)	Displaced	-45,064.61	-60,086.14	-30,043.07
Reuse	Energy (MJ)	Net	-44,938.28	-59,959.82	-29,916.75
Reuse	Health, Cancer (Tox. Units)	Incurred	3.54E-07	3.54E-07	3.54E-07
Reuse	Health, Cancer (Tox. Units)	Displaced	-1.50E-05	-2.00E-05	-1.00E-05
Reuse	Health, Cancer (Tox. Units)	Net	-1.46E-05	-1.96E-05	-9.65E-06
Reuse	Health, NonCancer (Tox. Units)	Incurred	1.15E-06	1.15E-06	1.15E-06
Reuse	Health, NonCancer (Tox. Units)	Displaced	-3.08E-05	-4.11E-05	-2.05E-05
Reuse	Health, NonCancer (Tox. Units)	Net	-2.96E-05	-3.99E-05	-1.94E-05
Reuse	Ozone depl. (kg CFC-11 eq)	Incurred	1.76E-06	1.76E-06	1.76E-06
Reuse	Ozone depl. (kg CFC-11 eq)	Displaced	-2.57E-05	-3.43E-05	-1.71E-05
Reuse	Ozone depl. (kg CFC-11 eq)	Net	-2.40E-05	-3.25E-05	-1.54E-05
Reuse	Eutroph. (kg N eq)	Incurred	8.81E-04	8.81E-04	8.81E-04
Reuse	Eutroph. (kg N eq)	Displaced	-0.03	-0.04	-0.02
Reuse	Eutroph. (kg N eq)	Net	-0.03	-0.04	-0.02
Reuse	Acidification (kg SO2 eq)	Incurred	0.02	0.02	0.02
Reuse	Acidification (kg SO2 eq)	Displaced	-0.75	-1.00	-0.50
Reuse	Acidification (kg SO2 eq)	Net	-0.73	-0.98	-0.48
Reuse	Energy, Fossil (MJ)	Incurred	123.95	123.95	123.95
Reuse	Energy, Fossil (MJ)	Displaced	-2,442.61	-3,256.81	-1,628.41
Reuse	Energy, Fossil (MJ)	Net	-2,318.66	-3,132.86	-1,504.46
BioEnergy	GHG (kg CO2eq)	Incurred	78.85	78.85	78.85
BioEnergy	GHG (kg CO2eq)	Displaced	-651.84	-724.26	-579.41
BioEnergy	GHG (kg CO2eq)	Net	-572.99	-645.42	-500.56
BioEnergy	PM2.5 eq (kg)	Incurred	0.61	0.61	0.61

BioEnergy	PM2.5 eq (kg)	Displaced	-0.05	-0.06	-0.05
BioEnergy	PM2.5 eq (kg)	Net	0.56	0.56	0.57
BioEnergy	Water (m3; Blue)	Incurred	0.51	0.51	0.51
BioEnergy	Water (m3; Blue)	Displaced	-0.13	-0.15	-0.12
BioEnergy	Water (m3; Blue)	Net	0.37	0.36	0.39
BioEnergy	Smog (kg O3 eq)	Incurred	63.51	63.51	63.51
BioEnergy	Smog (kg O3 eq)	Displaced	-8.17	-9.07	-7.26
BioEnergy	Smog (kg O3 eq)	Net	55.35	54.44	56.25
BioEnergy	Energy (MJ)	Incurred	1,140.94	1,140.94	1,140.94
BioEnergy	Energy (MJ)	Displaced	-12,176.83	-13,529.81	-10,823.85
BioEnergy	Energy (MJ)	Net	-11,035.89	-12,388.87	-9,682.91
BioEnergy	Health, Cancer (Tox. Units)	Incurred	1.11E-05	1.11E-05	1.11E-05
BioEnergy	Health, Cancer (Tox. Units)	Displaced	-5.53E-06	-6.14E-06	-4.91E-06
BioEnergy	Health, Cancer (Tox. Units)	Net	5.61E-06	5.00E-06	6.23E-06
BioEnergy	Health, NonCancer (Tox. Units)	Incurred	3.89E-04	3.89E-04	3.89E-04
BioEnergy	Health, NonCancer (Tox. Units)	Displaced	-7.61E-06	-8.46E-06	-6.77E-06
BioEnergy	Health, NonCancer (Tox. Units)	Net	3.81E-04	3.80E-04	3.82E-04
BioEnergy	Ozone depl. (kg CFC-11 eq)	Incurred	2.57E-06	2.57E-06	2.57E-06
BioEnergy	Ozone depl. (kg CFC-11 eq)	Displaced	-7.09E-05	-7.88E-05	-6.31E-05
BioEnergy	Ozone depl. (kg CFC-11 eq)	Net	-6.84E-05	-7.63E-05	-6.05E-05
BioEnergy	Eutroph. (kg N eq)	Incurred	0.12	0.12	0.12
BioEnergy	Eutroph. (kg N eq)	Displaced	-0.03	-0.03	-0.02
BioEnergy	Eutroph. (kg N eq)	Net	0.10	0.09	0.10
BioEnergy	Acidification (kg SO2 eq)	Incurred	2.09	2.09	2.09
BioEnergy	Acidification (kg SO2 eq)	Displaced	-0.61	-0.67	-0.54
BioEnergy	Acidification (kg SO2 eq)	Net	1.48	1.41	1.55
BioEnergy	Energy, Fossil (MJ)	Incurred	939.75	939.75	939.75
BioEnergy	Energy, Fossil (MJ)	Displaced	-12,128.93	-13,476.59	-10,781.27

BioEnergy	Energy, Fossil (MJ)	Net	-11,189.17	-12,536.83	-9,841.51
Landfill	GHG (kg CO2eq)	Incurred	53.23	53.23	53.23
Landfill	GHG (kg CO2eq)	Net	53.23	53.23	53.23
Landfill	PM2.5 eq (kg)	Incurred	0.01	0.01	0.01
Landfill	PM2.5 eq (kg)	Net	0.01	0.01	0.01
Landfill	Water (m3; Blue)	Incurred	0.26	0.26	0.26
Landfill	Water (m3; Blue)	Net	0.26	0.26	0.26
Landfill	Smog (kg O3 eq)	Incurred	2.07	2.07	2.07
Landfill	Smog (kg O3 eq)	Net	2.07	2.07	2.07
Landfill	Energy (MJ)	Incurred	317.79	317.79	317.79
Landfill	Energy (MJ)	Net	317.79	317.79	317.79
Landfill	Health, Cancer (Tox. Units)	Incurred	1.29E-06	1.29E-06	1.29E-06
Landfill	Health, Cancer (Tox. Units)	Net	1.29E-06	1.29E-06	1.29E-06
Landfill	Health, NonCancer (Tox. Units)	Incurred	9.00E-06	9.00E-06	9.00E-06
Landfill	Health, NonCancer (Tox. Units)	Net	9.00E-06	9.00E-06	9.00E-06
Landfill	Ozone depl. (kg CFC-11 eq)	Incurred	3.94E-06	3.94E-06	3.94E-06
Landfill	Ozone depl. (kg CFC-11 eq)	Net	3.94E-06	3.94E-06	3.94E-06
Landfill	Eutroph. (kg N eq)	Incurred	0.004	0.004	0.004
Landfill	Eutroph. (kg N eq)	Net	0.004	0.004	0.004
Landfill	Acidification (kg SO2 eq)	Incurred	0.09	0.09	0.09
Landfill	Acidification (kg SO2 eq)	Net	0.09	0.09	0.09
Landfill	Energy, Fossil (MJ)	Incurred	308.16	308.16	308.16
Landfill	Energy, Fossil (MJ)	Net	308.16	308.16	308.16