FPInnovations
2665 East Mall
Vancouver, British Columbia V6T 1W5

A Comparative Life Cycle Assessment of Canadian Hardwood Flooring with Alternative Flooring Types

by

Lal Mahalle
Energy & Environment Group
Building Systems Department
Wood Products Division

Final report with external reviewer revisions issued April 29, 2011

Project No. 201002354

Lal Mahalle	Jennifer O'Connor	Erol Karacabeyli
Project Leader	Reviewer	Department Manager

Acknowledgements

This project is part of a research initiative designed to enhance the competitiveness of the hardwood industry in eastern Canada. Project funding was provided by Natural Resources Canada's Transformative Technologies Program and Québec's Ministère des Ressources naturelles et de la Faune industrial development strategy for high value-added products.

FPInnovations staff participating in this work include:

Lal Mahalle
Patrick Lavoie
Philippe Meek
Jean McDonald
Francis Fournier
Pierre Blanchet
Dany Normand
Jennifer O'Connor

FPInnovations appreciates the extensive technical guidance provided to our team by James Salazar and Jamie Meil of the ATHENA Institute for Sustainable Materials, Ottawa. FPInnovations also appreciates the participation of the Hardwood Bureau of the Canadian Lumberman's Association. Finally, we would like to thank the following external peer reviewers for their valuable comments on a draft of this report: Dr. Lindita Bushi, LCA Consultant, Toronto, Canada and Melissa Hamilton and Lise Laurin from EarthShift.

Executive Summary

This study presents a cradle-to-grave environmental profile for pre-finished hardwood flooring manufactured in eastern Canada and compares this to profiles for alternative flooring products such as carpets, ceramic tiles, vinyl, cork, and linoleum flooring. This is a life cycle assessment (LCA) study.

Study Goals

- Conduct a cradle-to-grave LCA for eastern Canadian hardwood flooring in a typical residential application;
- Create cradle-to-grave profiles for alternative flooring products for which existing LCA was available (carpets, ceramic tiles, vinyl, cork , and linoleum flooring) and their use in typical residential applications;
- Compare and contrast life cycle environmental impact of eastern Canadian hardwood flooring with alternative flooring types (carpets, ceramic tiles, vinyl, cork flooring, and linoleum) used in residential applications.

Methodology

The study was conducted in line with the methodology stated in the two standards set out by the International Organization for Standardization (ISO) for LCA: ISO 14040/44: 2006. The geographic boundary was initially set as North America to analyze hardwood flooring system and then extended to Europe in order to include the two European based flooring products (cork and linoleum) exported from there.

Firsthand data was gathered for resource harvesting from forests and for sawmilling. The data was combined with gate-to-gate pre-finished hardwood flooring life cycle inventory (LCI) data developed in another study conducted by the Athena Institute. Compared to other flooring types, hardwood flooring is a multi-product system with more valued main products (lumber and flooring) and less valued co-products (bark, wood waste etc.). The economic allocation principles were applied to partition environmental impacts between the main product and co-products (bark, wood waste, pulp chips etc.) produced during sawmilling and flooring manufacturing. Existing LCI and non-LCI data published in literature was used to create inventories for the use and end-of-life phases. LCI data available in the BEES manual and non-LCI data published in major flooring manufacturers' and consumer awareness websites was used to develop cradle-to-grave inventories for the alternative flooring types selected for the comparative assertion.

Application as a durable flooring surface in a living space was the primary function of floorings considered to define the functional unit (FU). The defined FU was 1000 square feet of installed floor covering with a 25 year default service life.

The study team followed ISO 21930 guidelines for building material environmental product declarations (EPDs) to select impact categories for this comparative assertion, and the selected impact categories are listed below:

- Climate change (greenhouse gases)
- Depletion of the stratospheric ozone layer
- Acidification of land and water sources
- Eutrophication
- Formation of tropospheric ozone (photochemical oxidants)

In addition to the five impact categories, non-renewable and renewable primary energy use was included in the assessment. The U.S. Environmental Protection Agency's TRACI (Tool for the Reduction and Assessment of Chemical and other environmental Impacts) life cycle impact assessment (LCIA) method was the impact assessment method used for the analysis. The method was modified by adding carbon dioxide from air as a negative emission to include carbon dioxide sequestration by forests. Also it was combined with a European based impact assessment method called "Cumulative Energy Demand" (CED) to calculate renewable and non-renewable primary energy consumption.

A series of sensitivity analyses were performed to test the validity of the study findings against service life (durability) variations, subfloor differences, different building site locations, alternative end-of-life practices, allocation method applied for hardwood flooring system, impact assessment method used, and floor cleaning (vacuuming) floor cleaning (vacuuming).

Key Study Findings

Environmental Performance of Pre-finished Hardwood Flooring

Flooring manufacturing is the dominant life cycle stage in terms of both energy and environmental flows as it consumes 72% of the total energy and emits 30-76% of environmental emissions in the chosen impact categories. This is the life cycle stage where attention could be efficiently focused on improvements in the environmental performance of hardwood flooring.

Another potential area for improvement is the end-of-life stage. Wood products in landfill can cause emission of methane, a potent greenhouse gas (GHG). Methane emissions can be avoided if post-consumer flooring waste is burnt for bioenergy, which in turn helps displace considerable amounts of fossil fuel as well.

From a cradle-to-grave perspective, environmental impact contributions from resource extraction and lumber manufacturing are comparatively small, however; some performance improvements could be made through more efficient resource use (i.e., more efficient logs to lumber conversion) and selling wood waste in alternative higher value markets. On economic basis of allocating impacts between the main product and co-products, selling co-products in higher value markets lowers the environmental burden of hardwood flooring by moving more of the environmental impacts to co-products.
Contributions from flooring transport from mill gate to consumer are minor regardless of the building site location in the US.

Comparative Flooring Life Cycle Analysis

A comparative life cycle analysis (LCA) was performed to compare and contrast the environmental performance of hardwood flooring with some alternative flooring types: carpet, ceramic floor tiles, vinyl flooring, cork, and linoleum. These alternative products were selected based on availability of existing LCA data. Note that the project scope did not allow for creation of new LCA data for products where such data is not readily available, for example, bamboo flooring. Application as a durable flooring surface in a living space was the primary function of flooring considered for the comparison. The conditions used for the baseline comparison are:

- The default building site chosen was New York City.
- A concrete subfloor was arbitrarily chosen as the subsurface to describe the LCA results.
- The base case service lives of hardwood, carpet (nylon broadloom carpet), ceramic tiles, vinyl (vinyl composition tiles), cork (floating floor type), and linoleum are 25, 11, 50, 40, 25, and 30 years respectively.

- Carpet is vacuum cleaned. Other floorings are swept with a broom to remove dust and grit.
- Floorings are disposed in a landfill at the end-of the life.

The base case comparative LCIA results over a 25 year service life span are presented in Figure A on a percent basis. Life cycle energy use and environmental impacts highly vary among the different flooring types. For instance, carpet is the most energy intensive flooring type and thus creates the greatest environmental burden due to its high reliance on fossil fuels. Energy intensive manufacturing and vacuum cleaning during the use phase are the reasons that carpet performs relatively poorly in terms of life cycle energy use. Vinyl is the least energy intensive flooring type in terms of both total energy and fossil energy consumption on a complete life cycle basis. Hardwood takes second place for total energy use, however the energy source for manufacturing is significantly composed of renewable and cleaner sources (wood fuel and hydro and nuclear powered electricity). While considering the fossil energy use, hardwood is on par with ceramic, cork, and linoleum. Compared to all other alternative floorings, hardwood shows the best performance in the global warming impact category and exhibits a net carbon credit of about 445 kg CO_2e. Cork also exhibits a net climate change benefit, but it is smaller compared to hardwood flooring (105 kg CO_2e).

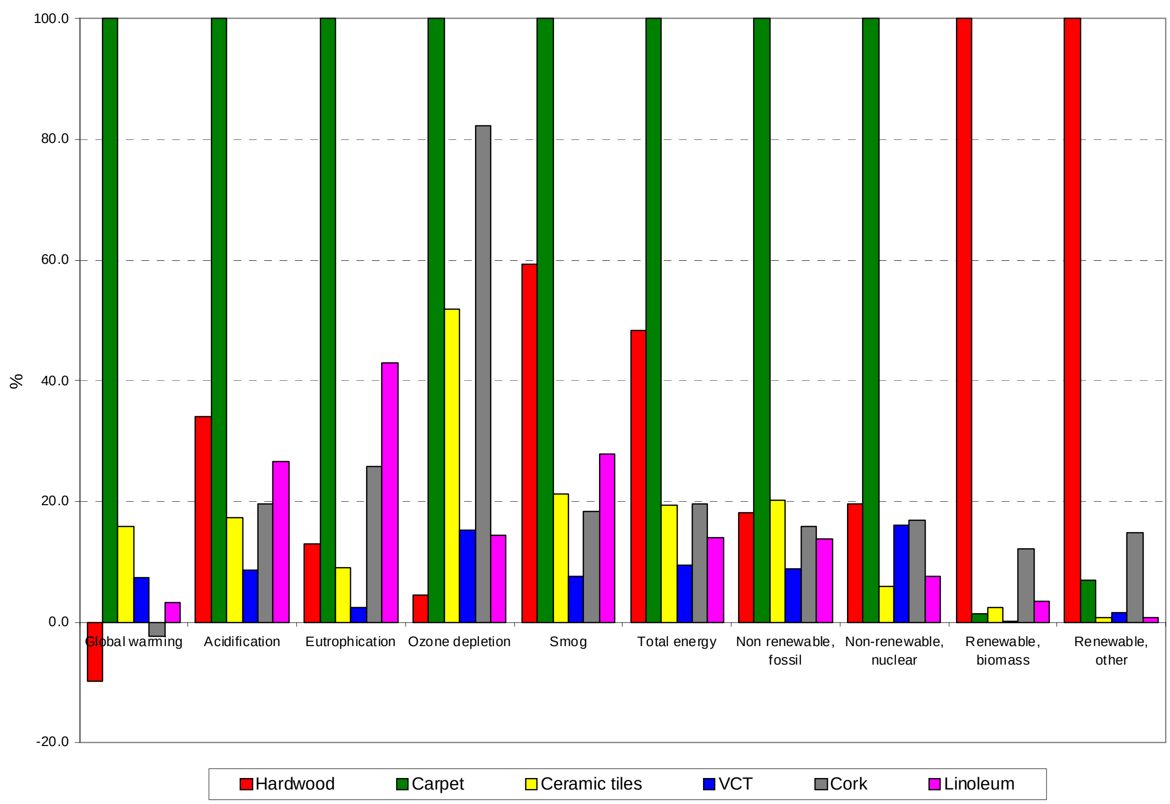

Figure A Comparative flooring LCIA results for the installation over concrete subfloor on a percent basis

This figure shows the performance of various flooring types relative to each other across ten different environmental impact measures. In each set of bars, the flooring with the highest impact in that category is the benchmark (100%) and the other products are shown as a percentage relative to the benchmark. The heights of the bars do not indicate the absolute value and do not indicate relative importance or impact of each measure. These graphs show the base case scenarios as described earlier.

Interpretation

A series of sensitivity analyses were performed to address the uncertainties associated with the above base case findings:

- Importance of underlayment differences when flooring is installed over a wood subfloor;
- Significant material and energy inputs and life cycle stages found within each of the flooring system. For example, electricity consumption for carpet vacuuming, mortar mixture used in ceramic tile installation, and landfilling organic-based floorings (i.e., hardwood, cork, linoleum) at the end of the flooring life were found significant during the flooring life cycles. Sensitivity scenarios developed for each of those significant cases were:
  - ✓ Carpets - frequency of vacuuming was reduced from once a week to once a month;
  - ✓ Ceramic tile installation was modeled with an alternative mortar mixture called “thinset mortar”;
  - ✓ Hardwood and cork were considered to be burnt for bioenergy at the end-of-life;
  - ✓ Linoleum was considered to behave like plastic in landfills;
  - ✓ Wood subfloor sensitivity of ceramic, VCT, cork, and linoleum were retested if the plywood underlayment is burnt for bioenergy at the end of flooring life.
- Ability to generalize baseline building location results to any other building site location in the US;
- The baseline service life assumptions made in line with the manufacturers’ and companies’ warranties. Uncertainties surrounding the baseline service lives were checked against flooring replacement for aesthetic or other reasons unrelated to warranties or manufacturers’ expectations. Sensitivity cases were developed using alternative flooring wear life data used by some of the U.S. counties for landlord tenant affairs (for example, Montgomery County in Maryland) and information available in consumer awareness websites and other LCA studies. The details are shown in Table A. Note that the study team adopted a conservative approach in selecting alternative service lives for sensitivity checks – a 50 year service life was used for hardwood flooring (despite many examples of much longer service lives) while selecting the upper limit of alternative wear lives for all other floorings.

Table A Flooring baseline and sensitivity service lives

Flooring type	Service life in years		
	Base case	**Alternative wear lives**	**Wear life chosen for sensitivity analysis**
Hardwood	25	25 - 100[+, 1]	50
Carpet	11	5 - 15[1,4,5]	15
Ceramic tiles	50	25 - 30[2]	30
VCT	40	15[1]	15
Cork	25	30 - 40[4]	40
Linoleum	30	20[3]	20

Sources: 1. Montgomery County Maryland, 2007, p. 13
2. Hubpages, 2010.
3. Gorree M. et.al., 2000, p.5
4. Minnesota Sustainable Housing Initiative, 2007-10.
5. Lippiatt, Barbara, 2007.

- Allocation method was changed from economic allocation to physical allocation;
- Consistency of findings against different impact assessment methods – used the impact assessment method “EPD 2008” published by the Swedish Environmental Management Council.
- Applied a 50/50 scenario for sweeping with broom vs vacuum cleaning for the rest of the product systems (hardwood, ceramic tiles, VCT, cork, and linoleum).
- Excluded data – Periodic floor cleaning and capital equipment were added to the hardwood flooring system to test the validity of base case findings against the excluded LCI flows.

Sensitivity analysis results indicate that the floorings generally exhibit similar results in the comparison between installations over a wood subfloor as they do when installed over a concrete subfloor. A similar trend in the comparative LCA results was also noted with the inclusion of excluded LCI flows (periodic floor cleaning and capital infrastructure) and change made to the allocation method, impact assessment method, and frequent floor cleaning. However, significant changes in the baseline results were noted in the flooring use phase, end of life, and service life sensitivity checks. For instance, in the service life sensitivity check, when the durability (service life) was doubled, hardwood flooring outperformed all the other flooring types in the areas of non-renewable fossil fuel consumption, acidification, eutrophication, and smog impact categories where in the base case hardwood performed relatively poorly in these categories. However, a longer service life for wood reduces the climate change benefits for wood flooring because this reduces by half the amount of carbon sequestered in the wood (the first floor was sequestering carbon in landfill, while the replacement floor put in service at year 25 was sequestering carbon as well). Similar results were noted in the use phase and end of life sensitivity check in the areas of fossil energy use and acidification impact categories, but a considerable increase in climate change benefits occur when hardwood flooring is burnt for bioenergy at the end of the service life. Burning for energy particularly avoids methane emissions from landfilling – a significant contributory factor due to the higher global warming potential of methane (21 times higher) than carbon dioxide. Among the above scenarios tested, the hardwood base case is found to be the worst case for the hardwood flooring system due to high methane emissions from landfilling and comparatively poor performance shown in acidification and non-renewable fossil fuel consumption impact categories. The performance greatly improves when flooring is burnt for energy at the end of life (the best case). The above improvements in the hardwood flooring system were noted against the best cases found in the sensitivity checks described under the second bullet point for other flooring types (i.e., performance of carpet, ceramic, cork, and linoleum greatly improved under those sensitivity checks). Figure B presents the final best case comparative LCA sensitivity results across all the flooring systems compared to the base case findings of the hardwood flooring system on a percent basis.

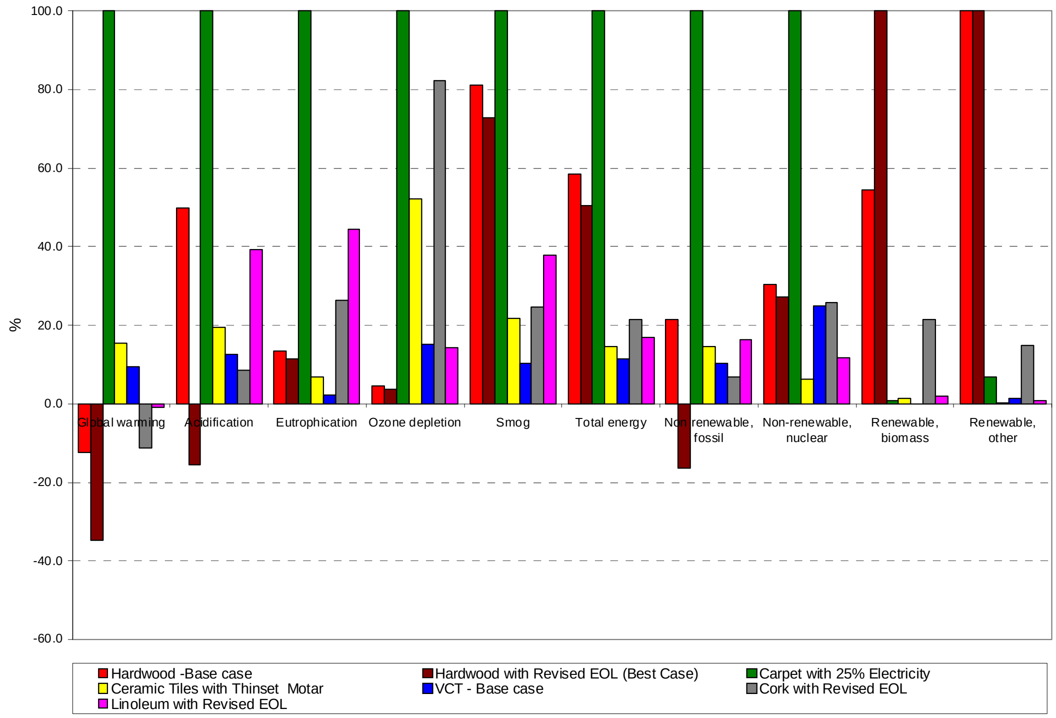

Figure B ***Hardwood base case and best case verses best cases (use phase and end of life sensitivities) of the other flooring systems – percent basis***

This figure shows the performance of various flooring types relative to each other across ten different environmental impact measures. In each set of bars, the flooring type with the highest impact in that category is the benchmark (100%) and the other floorings are shown as a percentage relative to the benchmark. The heights of the bars do not indicate the absolute value and do not indicate relative importance or impact of each measure.

Recommendations

Environmental performance of hardwood flooring could be improved by

- Using more wood waste generated during sawmilling and flooring milling to substitute for fossil fuel use in the mills;
- Find alternative higher value markets to sell wood waste from sawmilling and flooring milling;
- Improving logs to lumber conversion efficiency during sawmilling;
- Encouraging consumers to sweep the floors with a broom as much as possible rather than vacuuming to remove dust and grit;
- Encouraging consumers to recycle post-consumer flooring waste for energy at end-of-life rather than disposing in landfills;
- Extending the service life.

Table of Contents

List of Tables

List of Figures

1 Introduction

1.1 Background of the Study

Demand for credible and science-based information on product environmental performance is growing in the market place. Life cycle assessment (LCA) has received due recognition as a technique that is capable of expressing the environmental burden of a product or a service on a life cycle basis. LCA is useful for manufacturers to identify and reduce the life cycle burdens of products by considering the “hotspots” associated with the product’s upstream and downstream inputs and processes. The technique can also be used effectively to provide a comparative assertion of environmental burdens of products that perform similar functions. With the Quebec Ministry of Natural Resources funding support, FPInnovations undertook this LCA study to baseline the environmental performance of hardwood flooring relative to alternative flooring products and provide recommendations to its member companies to improve the product performance. This study develops a cradle-to-grave environmental profile for hardwood flooring manufactured in eastern Canada and performs a comparative assertion to alternative flooring products: carpets, ceramic tiles, vinyl, cork, and linoleum.

1.2 An Overview of Life Cycle Assessment

Life cycle assessment (LCA)[1] is an analytical tool designed for comprehensive quantification and interpretation of the environmental flows to and from the environment (including emissions to air, water and land, as well as the consumption of energy and other material resources), over the entire life cycle of a product (or process or service). LCA provides a comprehensive view of the environmental aspects of a product and a more accurate picture of the true environmental trade-offs in product selection throughout the product life cycle. The international standards in the ISO 14040-series[2] set out a four-phase methodology framework for completing an LCA, as shown in Figure ***1***: goal and scope definition, life cycle inventory, life cycle impact assessment, and interpretation.

[1] This introduction is based on international standards in the ISO-14040 series, *Environmental management – Life Cycle Assessment*.

[2] ISO 14040:2006, Environmental Management - Life Cycle Assessment - Principles and Framework and ISO 14044:2006, Environmental Management - Life Cycle Assessment – Requirements and Guidelines.

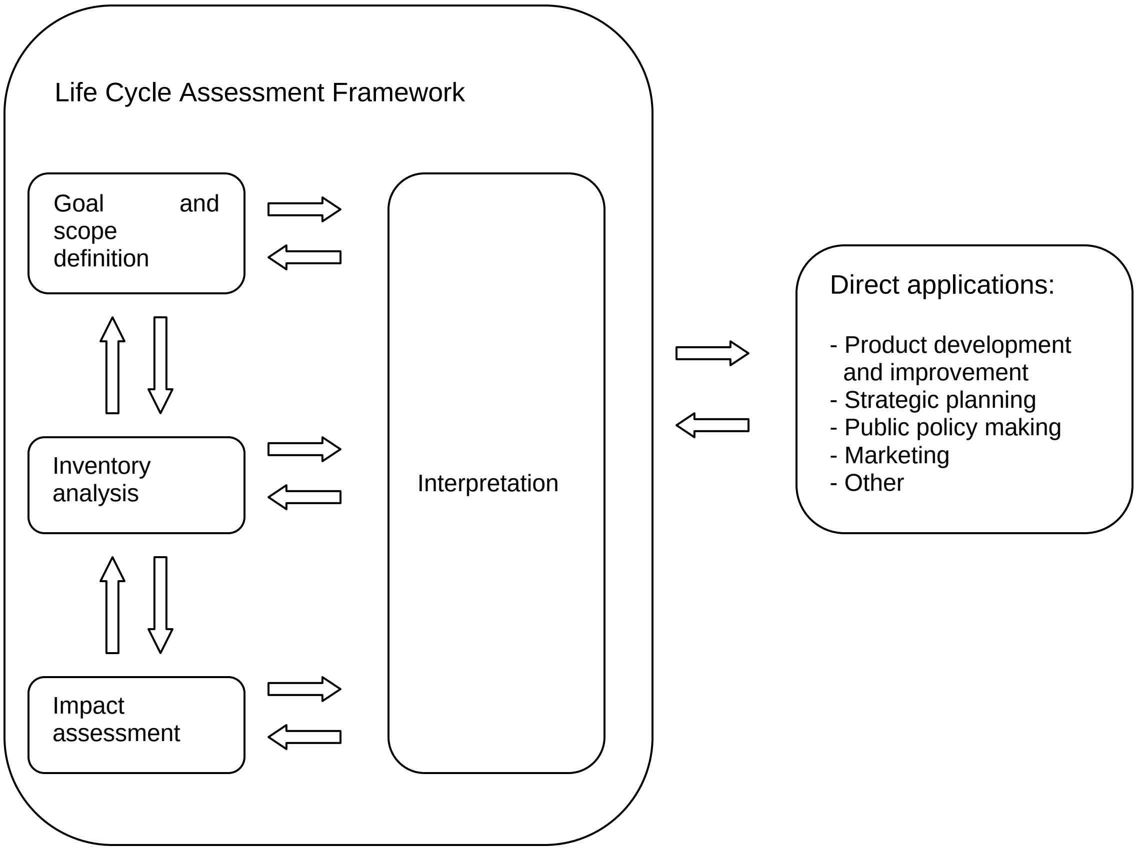

Figure 1 Life Cycle Assessment methodology: the ISO 14040 framework and applications

1.2.1 Goal and Scope Definition

A LCA starts with an explicit statement of the goal and scope of the study, the functional unit, the system boundaries, the assumptions and limitations and allocation methods used, and the impact categories chosen. The goal and scope includes a definition of the context of the study which explains to whom and how the results are to be communicated. The goal and scope of an LCA shall be clearly defined and shall be consistent with the intended application. The functional unit is quantitative and corresponds to a reference function to which all flows in the LCA are related. Allocation is the method used to partition the environmental load of a process when several products or functions share the same process.

1.2.2 Inventory Analysis

In the life cycle inventory analysis (LCI), a flow model of the technical system is constructed using data on inputs and outputs. The flow model is often illustrated with a flow chart, which includes the activities that are going to be assessed and also gives a clear picture of the technical system boundary. The input and output data needed for the construction of the model are collected (such as resources, energy requirements, emissions to air and water and waste generation for all activities within the system boundaries). Then, the environmental loads of the system are calculated and related to the functional unit, and the flow model is finished.

1.2.3 Impact Assessment

Inventory analysis is followed by life cycle impact assessment (LCIA) - where the life cycle inventory (LCI) data are characterized in terms of their potential environmental impact (e.g., acidification, eutrophication, global warming potential effects etc.). The impact assessment phase of LCA is aimed at evaluating the significance of potential environmental impacts based on the LCI results. In the classification stage, the inventory parameters are sorted and assigned to specific impact categories.

The calculation of indicator results (called "characterization") involves the conversion of LCI results to common units and the aggregation of the converted results within the same impact category. This conversion uses characterization factors. The outcome of the calculation is a numerical indicator result typically stated on an equivalence basis. In many LCAs, characterization concludes the analysis; this is also the last compulsory stage according to ISO 14044:2006. However, some studies involve the further step of normalization against anything occurring within the region, which allows cross comparison of the total impacts from the study. During weighting, the different environmental impacts are weighted against each other to arrive at a single score for the total environmental impact.

1.2.4 Interpretation

The results from the inventory analysis and impact assessment are summarized during the interpretation phase. Conclusions and recommendations are the outcome of the interpretation phase of the study. According to ISO 14040:2006 the interpretation should include:

- Identification of significant issues for the environmental impact,
- Evaluation of the study considering completeness, sensitivity and consistency
- Conclusions and recommendations.

The working procedure of LCA is iterative as illustrated with the back-and-forth arrows in Figure 1. The iteration means that information gathered in a latter stage can cause effects in a former stage. When this occurs, the former stage and the following stages have to be reworked taking into account the new information. Therefore, it is common for a LCA practitioner to work at several stages at the same time.

2 Goal and Scope Definition

2.1 Goal and Intended Uses

The following goals were set for the study in order to fulfill the hardwood flooring member companies' (the primary audience of the report) intention to baseline and improve the environmental performance of hardwood flooring relative to alternative flooring types:

- Conduct a cradle-to-grave LCA for eastern Canadian hardwood flooring in a typical residential application;
- Create cradle-to-grave environmental profiles for alternative flooring products for which existing LCA was available (carpets, ceramic tiles, vinyl, cork , and linoleum flooring) and their use in typical residential applications;
- Compare and contrast life cycle environmental impact of eastern Canadian hardwood flooring with alternative flooring types (carpets, ceramic tiles, vinyl, cork flooring, and linoleum) used in residential applications.

The hardwood flooring members intend to use the results of this study for the following purposes:

- *Process Improvements* – The mills that participated in the survey can use the study findings to evaluate possible process improvements in manufacturing hardwood lumber and flooring.
- *Educational market support* –The results will be used to create environmental product declarations (EPDs) for hardwood flooring

In addition to the above intended uses, the results of this LCA may be used for the following purposes:

- *Market support* – Flooring Task Force members may use the study results to create type II environmental labels (self-declared environmental claims) to educate environmentally conscious customers.
- *ISO 14001* – The results of the study are useful as a benchmark in tracking significant aspects and environmental impacts in devising an ISO compliant environmental management program for the industry.
- *Sustainable Development Reporting and Indicators* – The plant LCI data may be used in part for sustainability reporting by the mills participated in the survey.

ISO 140044 guidelines state that, *comparative assertions* intended to be disclosed to the public shall be reviewed by a panel of interested parties in order to reduce potential confusions on external interested parties. This study deviated from this review process due to fiscal and time constraints. Instead, two independent external parties critically reviewed the final draft report to ensure that the study methods and conclusions were consistent with both the goal and scope of the study and ISO guidelines. See Annex VIII for the responses to the reviewers' comments and recommendations.

2.2 Scope

2.2.1 System Boundary

The system boundary of the study is depicted in Figure ***2***. The LCA considered life cycle environmental impacts from resource extraction, flooring manufacturing, installation and use, and end-of-life effects from a cradle-to-grave perspective for a 25 year service life. In addition to flooring, underlayment requirements for each of the flooring type and their differences were taken into account for the comparison. The geographical and technological coverage of the study was intentionally limited to N. America and Europe, representing average or typical technologies of flooring manufacturing in the two regions.

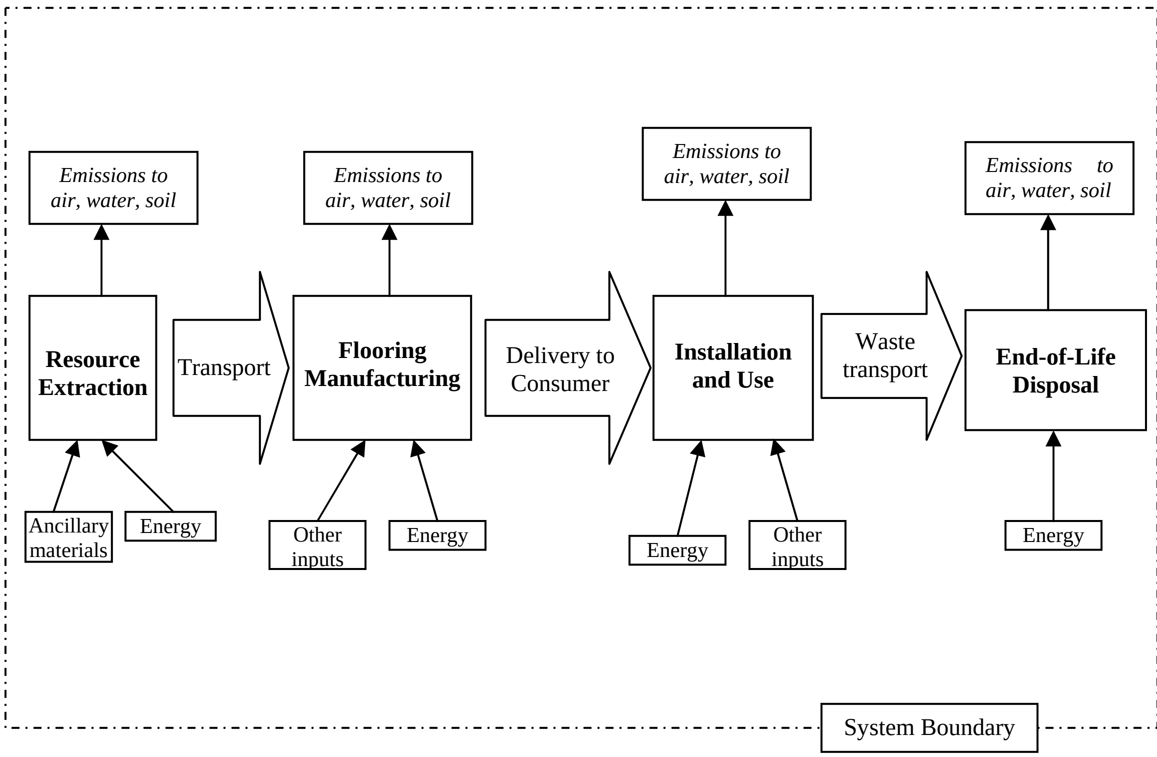

Figure 2 System boundary of the study

2.2.2 Functional Unit

Floorings installed in residential buildings perform different kinds of functions: *definition of space, durability, warmth, sound absorption, aesthetic functions, resistance to moisture etc.* The floorings differ in terms of these functions they perform in residential buildings. For example, vinyl, linoleum, and ceramic tiles are resistant to water, and hence, perform well (more durable) in wet/dirty places such as kitchens, bathrooms, laundry rooms compared to other floorings like hardwood and carpets. Carpets have better warmth and acoustic properties than the other flooring types.

In LCA, a **functional unit** (FU) is defined to quantify the performance characteristics (functions) of a product system. It allows comparison of products that perform a similar function. The study considered the living space and durability as the primary functions of floorings installed in a residential building in defining a FU. The FU was defined, considering the common measurements used to measure space and service life. The selected functional unit is 1000 sq. ft of floor covering installed in the areas free of dampness (e.g., main floor, living room, dining room, hallways etc.). It includes all the inputs (material and energy) and ancillary materials for different underlayment required for different flooring types and subfloors. Added functions like warmth, sound absorption, and aesthetic values were excluded from the comparison due to their complexity in nature. A 25-year default service life was chosen in line with the service life of hardwood flooring in order to address the hardwood flooring proponents' interests in baselining the environmental performance of hardwood flooring relative to alternative products.

Reference flows for each of the flooring system were calculated based on the selected FU (i.e., 1000 sq. ft. floor area with a default service life of 25 years). Some flooring types like carpets, ceramic tiles, vinyl, and linoleum have different service lives from the default service life chosen for the analysis, and reference flows for those flooring types were calculated on a proportionate basis to the default service life. For example, carpets have a service life of 11 years and hence, 2.3 (= 25/11) life cycles were used in calculating reference flows for this flooring system (see Appendix 1 for more details). This is called as a "linear approach". The concern is raised that a "linear approach" to this problem may misrepresent reality, i.e., it is not physically possible to produce 2.3 full life cycles of carpets.

An alternative to this approach is a non-linear approach where in the 1st year, the 1,000 sq ft finished carpets are produced, then the next 1000 sq.ft have to be manufactured again after 11 years of use in a residential building, and so on. Consequently, after 25 years, there have been three manufacturing/end of life cycles for the carpet flooring, and technosphere flows for the installation and use phase are normalized on a proportionate basis to fulfill the default service life (e.g., coefficient 2.3 cycles applied). Environmental impacts of the alternative floorings tend to be more if the reference flows are calculated this way. Therefore, in order to be conservative in undertaking this study, the author applied the linear approach to calculate the reference flows of the alternative flooring types.

2.2.3 Exclusion of LCI Flows

2.2.3.1 Human activity, capital equipment, and infrastructure

Human activity, capital equipment, and infrastructure were excluded from the system boundary due to the following reasons:

- The data collection that is required to properly quantify human activity (i.e., .labour involved in the production of raw materials and final flooring products) is particularly complicated, and allocating such flows to the hardwood harvesting and lumber production, as opposed to other societal activities, was not feasible for a study of this nature.
- The environmental effects of manufacturing and installing capital equipment and buildings have generally been shown to be minor relative to the throughput of materials and components over the useful lives of the buildings and equipment.
- Infrastructure was excluded from the system boundary due to the difficulties in allocation of environmental burden to long term investments like logging roads. For example, once roads are built, they last so long and there are other uses associated with them after harvesting (e.g. people start using the roads for other activities such as motorized recreation, fishing etc) and therefore, it becomes very difficult to allocate environmental burden of road construction among those alternative uses.
- The US LCI and ecoinvent databases contain some of the information on capital infrastructure (e.g., sawmilling in the hardwood flooring system, ancillary material production etc), but they lack information on the capital infrastructure used in all the flooring systems. As a result, a uniformity of the analysis across all the flooring systems could not be maintained with the inclusion of the limited available data.

In performing the analysis in SimaPro, the "include infrastructure" was turned off in order to prevent the infrastructure impacts coming into the modeling results.

2.2.3.2 Floor care during use

Floor cleaning requires both periodic and frequent cleaning. Usually, frequent cleaning includes regular remove of grit and sand either by sweeping the floor with a broom or vacuum cleaning while periodic cleaning activities require washing the floor with floor cleaners. The author conducted a web search for floor cleaners and their material safety data sheets (MSDS) posted on the manufacturers' websites and found that there is variety of floor cleaners available in the market for each flooring type and their compositions vary from manufacturer to manufacture. Also, manufacturers do not provide spread rates for their products because the selection and amount of cleaners use in residential buildings is usually dependant on personal cleaning habits of consumers. Also, there is no compiled data on the floor cleaner use in residential buildings in North America. From life cycle and service life perspective, the LCI flows related to periodic cleaning could be significant; however, those LCI flows were not included in the system boundary because there was no available data.

2.2.3.3 Insignificant LCI flows

In addition, the following cut-off criteria for input flows were set to exclude insignificant process LCI flows:

a) Mass – if a flow is less than **1%** of the cumulative mass of the model flows it may be excluded, providing its environmental relevance is minor.
b) Energy – if a flow is less than **1%** of the cumulative energy of the system model it may be excluded, providing its environmental relevance is minor.
c) Environmental relevance – if a flow meets the above two criteria, but is determined (via secondary data analysis) to contribute **1%** or more to a product life cycle impact category, it is included within the system boundary.

2.2.4 Multiple Outputs and Allocation of Environmental Burden

The alternative floorings considered for the comparative assertion are single products systems. In contrast, cradle-to-grave hardwood flooring is a multi-product system that produces more than one product. The survey respondents produce a significant amount of co-products (e.g., sawdust, planer shavings and pulp chips) and generate substantial revenue from those co-products other than lumber and flooring. Outcomes of LCA might differ depending on how we handle the co-products in the analysis; this is one of the most important and considered issues in LCA. There are two important emerging philosophies to resolve the issue: either partition the irrelevant co-products outside the system boundary (called "attributional LCA") or include the co-products within the system boundary by considering their functionality as environmental credits to the primary product (called "consequential LCA"). There are two accounting methodologies that could be used in this type of a situation: allocation (co-products are assigned a representative portion of the LCI) and "system expansion" (the primary product is credited the LCI of the co-products)[3].

According to ISO 14044:2006, allocation should be avoided wherever possible through dividing unit processes into two or more sub-processes or system expansion. If this is not possible, the first allocation procedure should be on the basis of the physical relationships of the system. This is often misinterpreted to mean that the product and co-product are no different in terms of causation of the LCI, and the flows are simply allocated based on the mass or volume of the product and co-product output. Usually lumber manufacturing results in less than 50% yield of the primary product (lumber). This means that a simple mass-based allocation that treats products and co-products equally would assign a greater environmental burden to the co-products than to the primary product. ISO 14044:2006 provides a second way to address the issue of causation by considering the revenue gained by each of the co-products and to base the allocation on the economic benefit gained by producing each. It was deemed that economic allocation of

[3] See Athena Sustainable Materials Institute, 2010. A Gate-to-Gate Life Cycle Assessment of Canadian Pre-finished Solid Strip Hardwood Flooring Drying, Milling and Finishing Unit Process Data and Assessment, Ottawa, Ontario.

environmental burden is more applicable than the physical allocation in the sense that there is no rationale to allocate environmental burden to co-products with minor values relative to the primary products.

2.2.5 Data Requirements and Initial Data Quality

The study requires data for all the energy, raw material, and ancillary materials inputs and environmental outputs (e.g. emissions to air, water, and soil) of all the considered flooring product systems. Data requirements were met by gathering primary data for the resource extraction from forests and lumber and flooring manufacturing in the hardwood flooring product system. Existing LCI data published in the BEES Manual and User Guide was used for all other floor covering product systems. Additional data requirements were met with data available from published literature.

A mass balance was conducted to ensure the validity of the primary data gathered for the hardwood flooring product system. Wherever secondary data was used, the study reviewed that data for consistency, precision, and reproducibility. The secondary LCI data sources were all determined to be complete (100%) and representative of North American practice in terms of the geographic coverage and average technologies and are all of a recent vintage, i.e. less than ten years old. Any deviations from these initial data quality requirements for secondary data are documented throughout the report. The author applied the study methodology uniformly across all the flooring systems to maintain its consistency. In addition, information on the study methodology and data values was adequately provided in the report in order to enable any independent LCA practitioner to reproduce the study results. Wherever relevant, uncertainty analyses were performed to address the validity of the data and models used and study assumptions.

2.2.6 Background Data Sources for Energy and Ancillary Material Inputs

The study relied mostly on two main LCI data sources to model the environmental impacts of the ancillary materials and energy sources used during harvesting and lumber manufacturing: the US LCI database (www.nrel.gov/lci) and the US-EI database (http://www.earthshift.com/US-EI%20library.pdf). Generally, the US LCI data is of a recent vintage (less than ten years old) and free and publicly available and thus offers a high degree of transparency. However, there are limitations with this particular LCI database as some processes are missing for some of the product systems. The US-EI database was created to address these issues.

In the US-EI database, 144 of the 178 “dummy” processes in the US LCI database have been replaced with ecoinvent data (version 2.01), a European database that contains 3,952 unit processes (http://www.ecoinvent.ch/). Those processes have been modified to suit to North American practice by replacing electricity grids with more representative US data. These US grids consist of very small amounts of wood waste used in electricity generation. The environmental burden from using this wood waste can be considered as minimal in the sense that very little quantities are added in the generation. Hence, theallocation procedure stated in Section 2.2.4 was not applied for the wood waste coming with this secondary LCI data on electricity. The study addresses this completeness issue wherever relevant in the report in drawing that data.

The study used another database called “Electricity Canada”, which was compiled by the Athena Institute, considering the grid make ups of various energy sources. Athena has used the US LCI electricity data to compile that database, and the database contains LCI data for electricity production in four provinces in Canada: British Columbia, Alberta, Ontario, and Quebec. The study drew on Ontario and Quebec electricity data whose grid mixes are shown in ***Table 1***.

Table 1 Grid mixes used for Ontario and Quebec electricity

Energy source	**Unit**	**Quantity used for 1 kWh after accounting for losses**	
		Ontario	**Quebec**
Bituminous coal	kWh	0.1878	-
Lignite coal	kWh	0.0056	-
Residual fuel oil	kWh	0.0076	0.0051
Natural gas	kWh	0.0961	0.0010
Nuclear	kWh	0.5464	0.0249
Hydro power	kWh	0.2463	1.0338

In addition to the above mentioned LCI data sources, the study used the Franklin LCI data to model fuel combustion (diesel, gasoline, wood fuel etc.) in industrial equipment, considering its more relevance to the specific processes than other data sources.

2.2.7 LCIA Methodology

2.2.7.1 Selected impact categories

The following impact categories were selected in accordance with the guidelines stated in ISO 21930[4] for building materials:

- Climate change (greenhouse gases)
- Depletion of the stratospheric ozone layer
- Acidification of land and water sources
- Eutrophication
- Formation of tropospheric ozone (photochemical oxidants)

All of the selected impact indicators are mid-point measures. Unlike end-point measures, the mid-point measures avoid the complications that uncertainty brings to the analysis. Thus, a description on the exceeding of thresholds, safety margins, or risks was not included in the LCIA results.

In addition to the five impact categories noted above, ISO 21930 also requires the accounting of non-renewable and renewable primary energy use, non-renewable and renewable material resource use, and fresh water consumption data that is derived from the LCI. Attention was given to those additional requirements when developing the LCIs.

2.2.7.2 Selected impact assessment methods

Because of the North American focus of this LCA study and the impact categories required by ISO 21930, the U.S. Environmental Protection Agency's TRACI[5] (Tool for the Reduction and Assessment of Chemical and other environmental Impacts) LCIA method was used with some modifications to characterize the LCI flows. The global warming category in TRACI was expanded to include carbon sequestration by the forests by adding carbon dioxide from air as a negative emission to conform to the

[4] ISO 21930:2007, Sustainability in Building Construction – Environmental Declaration of Building Products

[5] http://www.epa.gov/nrmrl/std/sab/traci/

IPCC 2007 impact assessment method (as described in Frischknecht and Jungbluth 2007[6]). Although the TRACI method supports fossil fuel depletion (on a global scale) it does not readily report primary energy use as an impact category. Therefore, TRACI was combined with a method called "Cumulative Energy Demand" (CED). CED is the sum of all energy resources drawn directly from the earth, such as natural gas, oil, coal, biomass, and hydro-based power. All substances that are characterized by these methods were included in the LCIA procedure.

2.2.7.3 Optional steps

The following three optional steps as stated in ISO 14044 were not undertaken as a part of the LCIA because such an analysis was not allowed in public studies:

a) Normalization – calculation of the magnitude of the category indicator results relative to some reference value (e.g., global warming potential of hardwood flooring production relative to the total per capita global warming potential of the US in a single year).
b) Grouping (by spatial effect) – assigning impact categories according to geographic effect (e.g., global, regional or local effects).
c) Weighting – a process for converting and aggregating individual indicator results across the entire impact indicator categories to arrive at a single score (e.g., combining global warming and eutrophication impacts).

2.2.7.4 Modeling software

SimaPro software v7.2.3 was used to generate LCIA results of this comparative assertion. Within SimaPro, all the process data including inputs (raw materials, energy and ancillary materials) and outputs (emissions and production volumes) were normalized to the FU and modeled to represent the unit processes of the product systems.

2.2.8 Assumptions

This study assumed a 25-year default service life in line with hardwood flooring, and landfilling was the common end of life disposal practice considered for the comparative assertion. The service lives of flooring products are highly variable within and among the flooring systems. For example, nylon carpets last 5-15 years while some flooring types have significantly higher service life of 30-50 years (e.g., cork, vinyl, and ceramic tiles) (Lippiatt C. Barbara, 2007, p. 158-205). The selected service lives used in the project were based on the information available in the BEES manual and warranty claims of manufacturers.

Although the end-of-life disposal of materials is changing due to new and emerging regulations, it is still quite common for construction and demolition debris to be landfilled. For instance, the US EPA estimates that 52% of all construction and demolition debris is discarded in landfills in 2003 (USEPA 2009a). Both these service life and end-of-life disposal assumptions concerning service life and end-of-life disposition received considerable attention in the study via sensitivity analysis to provide a basis for the conclusions (see Chapter 7.3.4).

[6] Frischknecht R., Jungbluth N., (edt). (2007). Implementation of Life Cycle Impact Assessment Methods. ecoinvent report No. 3, Swiss Centre for LCI. Duebendorf, CH, http://www.ecoinvent.org/fileadmin/documents/en/03_LCIA-Implementation.pdf

2.2.9 Uncertainty and Limitations

Uncertainty occurs at the LCI stage due to cumulative effects of model imprecision, input uncertainty and data variability. The author addressed the uncertainty in the model by conducting sensitivity analysis and data verification/validation relative to cut-off criteria and study goals. While quality control was undertaken at each step in building the LCI and conducting the LCIA, uncertainty is still present in the results in non-quantifiable terms. For instance, the statistical distribution of both primary and secondary data was not provided and thus calculating confidence intervals around the inventory is impossible. This is the case with most LCAs, and reliance on LCA results in decision making must reflect this limitation.

3 Cradle-to-gate Life Cycle Inventories for Flooring Manufacturing

This chapter discusses how the cradle-to-gate life cycle inventories are created for the manufacturing of different flooring types selected for the comparative assertion. Raw material extraction, material transportation, and flooring manufacturing were taken into account for creating inventories for flooring products ready for shipment at the plant gate. The flooring products are studied on the basis of typical industry production reporting practices and then are related to the functional unit (1000 sq. ft of installed residential flooring).

At the beginning of each of the product inventory sections (3.1-3.6), an overview of production process is provided to familiarize the reader with the products and their manufacturing processes. The unit processes are then formally defined and the LCI flows for each unit process are presented at the end of the section. The use-phase and end-of-life processes are excluded from the cradle-to-gate subtotal. The use-phase and end-of-life LCI are grouped and described separately in Chapters 5 and 6.

3.1 Creation of an Inventory for Hardwood Flooring

The processes and unit processes associated with flooring manufacturing are depicted in Figure ***3***. Cradle-to-gate flooring manufacture starts with timber extraction from the forest and the delivery of harvested timber to a saw mill. At the saw mill, rough green lumber is manufactured which is used as an input into flooring manufacture.

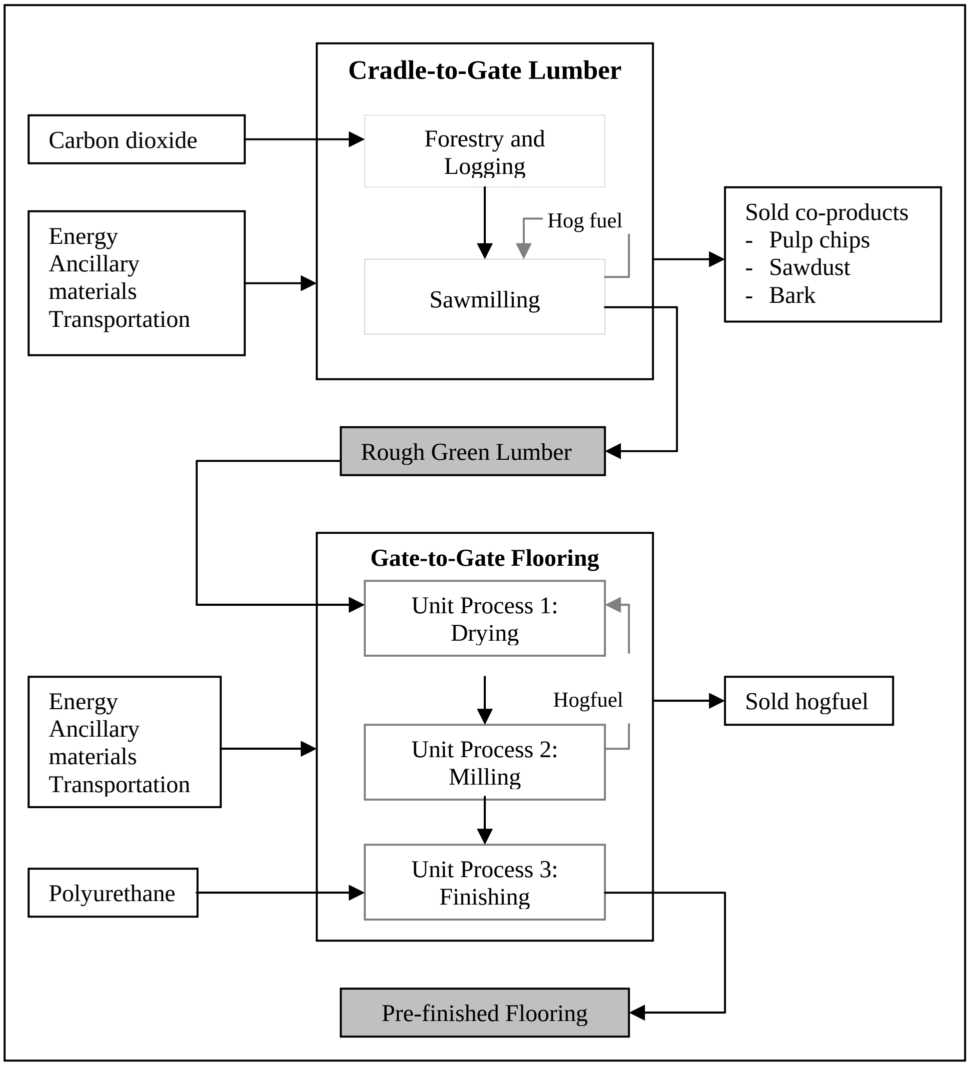

Figure 3 Cradle-to-gate unit processes

3.1.1 Cradle-to-gate Lumber Manufacturing

3.1.1.1 Process overview

Forest management and logging

Most hardwood harvesting in Eastern Canada is done according to the agreed management regimes that include leaving a certain percentage of trees (60%-70%) in order to allow for the development of the next crop. The rest of the volume comes from mixed wood clear-cut stands. Both semi-mechanized and fully mechanized systems are used for harvesting. In the semi-mechanized system, chainsaws are used to fell, delimb and top the trees to produce tree-length. Cable skidders complete the process by moving roundwood from the stump which is then stacked at the roadside. In the fully mechanized system, a feller-buncher is used to cut trees and stack the full trees at a roadside for further processing (i.e., delimbing and/or slashing) using a mechanized delimber and a slasher. Sometimes tree are delimbed and topped manually and a grapple skidder or cable skidder is used to move them to a roadside.

The main energy inputs to these processes are diesel and gasoline, while ancillary materials such as hydraulic fluid, lubricating fluid, motor oil, grease, and antifreeze are used for the machines during harvesting. In partial cutting systems, trees are marked with paint before logging. Gasoline is used to power chainsaws. Pick-up trucks are used to transport crews and material inputs from the mill town to the forest and also consume gasoline. The heavy machinery is usually diesel powered.

Tree lengths are further processed into sawlogs and other forms of roundwood useful to make flooring, pallets, and pulp chips. Trucks (semi-trailers) are used to deliver logs to mills. Residues from harvesting include both firewood and other bioenergy material but, for the most part, waste is left to decay in the forest.

Lumber manufacturing

Lumber manufacturing starts with transport of logs to a mill. Sawmilling mechanically converts logs received at the mill gate into lumber, co-products and by-products. Logs are first debarked and broken down into boards and cants, using a head saw (head rig or primary saw). A cant is further broken down in resawing into boards that undergo edging and trimming to produce rough green lumber. Lumber is then sorted by width, length, and grade. It can be sold as-is (rough green) or kiln dried. Mills mainly use electricity as the energy source for sawmilling, while other energy sources such as wood fuel and propane are used for facility heating and kiln-drying green lumber. Ancillary materials such as hydraulic fluids, motor oil, and greases are used for machinery used in the manufacturing process while energy sources such as diesel (for forklifts etc) is used to move logs and materials around within the mill. Sawmilling generates co-products (pulp chips) and by-product such as sawdust and bark (of lesser value).

3.1.1.2 Data gathering

The practice in LCA is to gather primary data for a reference year, usually the most recent one. The mills that were surveyed in this study ran under capacity in the previous year (2009) due to lack of demand caused by the recession. Therefore, the study deviated from this rationale by considering the potential misrepresentation of typical industry practice. For instance, in 2009, harvesting was mostly done at the sites with easiest access and terrain. At the same time, the mills were also running under-capacity. For these reasons, the reference years for harvesting and lumber manufacturing were chosen as 2008 and 2007 respectively.

3.1.1.3 Creation of an inventory for resource extraction

Survey Sample and Its Representativeness

Hardwood harvesting in eastern Canada occurs in three provinces: Quebec, Ontario, and New Brunswick[7]. A sample of three harvesting companies from those three provinces (one company from each of the three provinces) was chosen to collect data..

Table ***2*** shows the average annual sawlog production data for the three provinces and the quantity of sawlogs produced by the chosen logging companies in the three provinces in 2008. Sample production in both Quebec and Ontario is well above the 10% average annual industry production while the chosen respondent in New Brunswick has produced 85% of the average industry production. Overall the quantity of sawlogs harvested by the chosen respondents represents 20% of the annual industry production in 2008.

[7] See Quebec Ministry of Natural Resources and Wildlife, 2010. Resources and Forest Industries: Statistical Portrait February 2010. http://www.mrn.gouv.qc.ca/publications/forets/connaissances/stat_edition_complete/chap10.pdf

Table 2 Industry and sample sawlog production data

Province	Average annual industry production during 2004-2008 (000' m³)*	Sample production in 2008 (000' m³)	Sample proportion
Quebec	903	130	14%
Ontario	431	90	19%
New Brunswick	146	120	85%
Total	*1520*	*345*	*23%*

Source: * Annual averages were calculated from the information available in Quebec Ministry of Natural Resources and Wildlife (2010, 10).

The species that were harvested by the survey respondents are shown in Table ***3***. Maple sugar (hard), yellow birch, and beech are the main species that were harvested. In addition to those main species, the companies have also harvested aspen, maple (red), ash, oak, basswood etc. in smaller quantities.

Table 3 Species harvested by the sample logging companies

Species	Quantity of roundwood harvested (000'm³)		Portion of Total
	Traditional sawlogs	***Other roundwood***	
Maple, sugar (hard)	191	314	54%
Yellow birch	83	167	26%
Beech	33	42	8%
Other (e.g. aspen, red maple, ash, oak, basswood etc.)	38	72	12%
Total	345	595	100%

Resource Extraction LCI

In creating a LCI for resource extraction, the whole harvesting process was treated as a single unit process that included marking trees (only in partial cutting systems), felling trees, delimbing and topping trees to produce tree-lengths, making roundwood from tree-lengths, and skidding (transporting) logs and/or treelengths to a roadside.

Ancillary materials such as hydraulic fluid, lubricating oil, and motor oil are sent for recycling after use. Harvesting emits air emissions from the fossil fuel used to power machinery and create solid wastes from delimbing, slashing, and topping trees to produce roundwood. Those forest residues from harvesting were left to decay and were considered as an emission to the soil. The survey respondents have not tracked the amount of residues generated during the operations. Therefore, in-house estimates available for forest logging operations in eastern Canada for partial and clear cutting situations were used to quantify the forestry residues. The weighted average energy and ancillary material inputs used and forest residues generated per cubic meter of roundwood by the logging companies participated in the survey are shown in Table ***4***.

Table 4 Resource extraction LCI

Inputs	Unit	Amount per m^3 of roundwood*
Energy		
Diesel fuel	l	2.09
Gasoline	l	0.38
Ancillary materials		
Hydraulic fluid	l	1.45E-02
Lubricating fluid	l	5.39E-03
Motor oil	l	1.77E-02
Greases	kg	2.30E-03
Antifreeze	l	1.88E-04
Paint	kg	4.10E-03
Solid waste		
Forest residues	Tonnes (green)	1.12

Note: * Log rule: 1 m^3 = 200 bfm rough green lumber

3.1.1.4 Creation of a LCI for lumber manufacturing

Survey Sample and Its Representativeness
A sample of four lumber mills (three in Quebec and one in New Brunswick) was chosen to gather log and ancillary material input and environmental output data. Data was gathered using a structured questionnaire. The eastern hardwood lumber industry consists of two types of mills: sawmills purchasing low quality logs to produce more pulp chips and lumber; and mills that utilize high quality logs to produce quality lumber. Both types of mills were included in the sample to represent the industry.

According to the Quebec Forest Industry Council (2008, p2)[8], Canada has produced about 594 MMBfm of green lumber in 2007. The participated mills in the survey have produced about 61.4 MMBfm of green lumber in the same year, and thus represent approximately 10% of Canadian hardwood green lumber production in 2007.

The species utilized by the survey respondents are shown in Table ***5***. White birch, maple sugar (hard), yellow birch, and aspen are the main species utilized by the participated lumber mills in the survey. In addition to those main species, the companies have also utilized red maple, ash, and oak in smaller quantities in 2007.

[8] See Quebec Forest Industry, 2008. 2008 Statistics: Sawing softwood and hardwood pulp, paper, cardboard and panels. http://www.cifq.qc.ca/imports/_uploaded/file/Brochure-Stat-2008.pdf.

Table 5 Species utilized by the sample lumber mills

Species	Quantity (000'm^3)	Portion of Total
Birch, white	127569	34%
Maple, sugar (hard)	108109	29%
Birch, yellow	98763	27%
Aspen	25500	7%
Other (e.g. red maple, ash, oak etc.)	10681	3%
Total	*370622*	*100%*

Lumber Manufacturing Mass Balance

Figure ***4*** depicts the flow of harvested timber through lumber manufacturing system in producing one thousand board feet of rough green lumber. The weighted average green and oven dry densities of the species mix entering the lumber manufacturing are 942 and 546 kg/m^3 respectively. A mass balance was completed based on the oven dry mass of the roundwood inputs and the process outputs (i.e., rough green lumber and co-products). In addition, the flow of carbon sequestered and stored in roundwood was also calculated using the figures published by Lamlom and Savidge (2003, 383) for 41 North American species[9]. The weighted average carbon content was 48.08% based on the carbon content of the hardwood species utilized by the lumber mills in 2007. The mass ratio of CO_2 to C, 44/12, was used to convert from carbon content to carbon dioxide uptake from air. Note that the survey respondents did not track forest stand volumes and forest residues from timber extraction and hence, conducting a similar mass balance for timber harvesting from forests was impossible due to lack of data.

[9] Lamlom, S.H. and Savidge, R.A. (2003). A Reassessment of Carbon Content in Wood: Variation within and between 41 North American Species. Biomass and Bioenergy (25): 381-8.

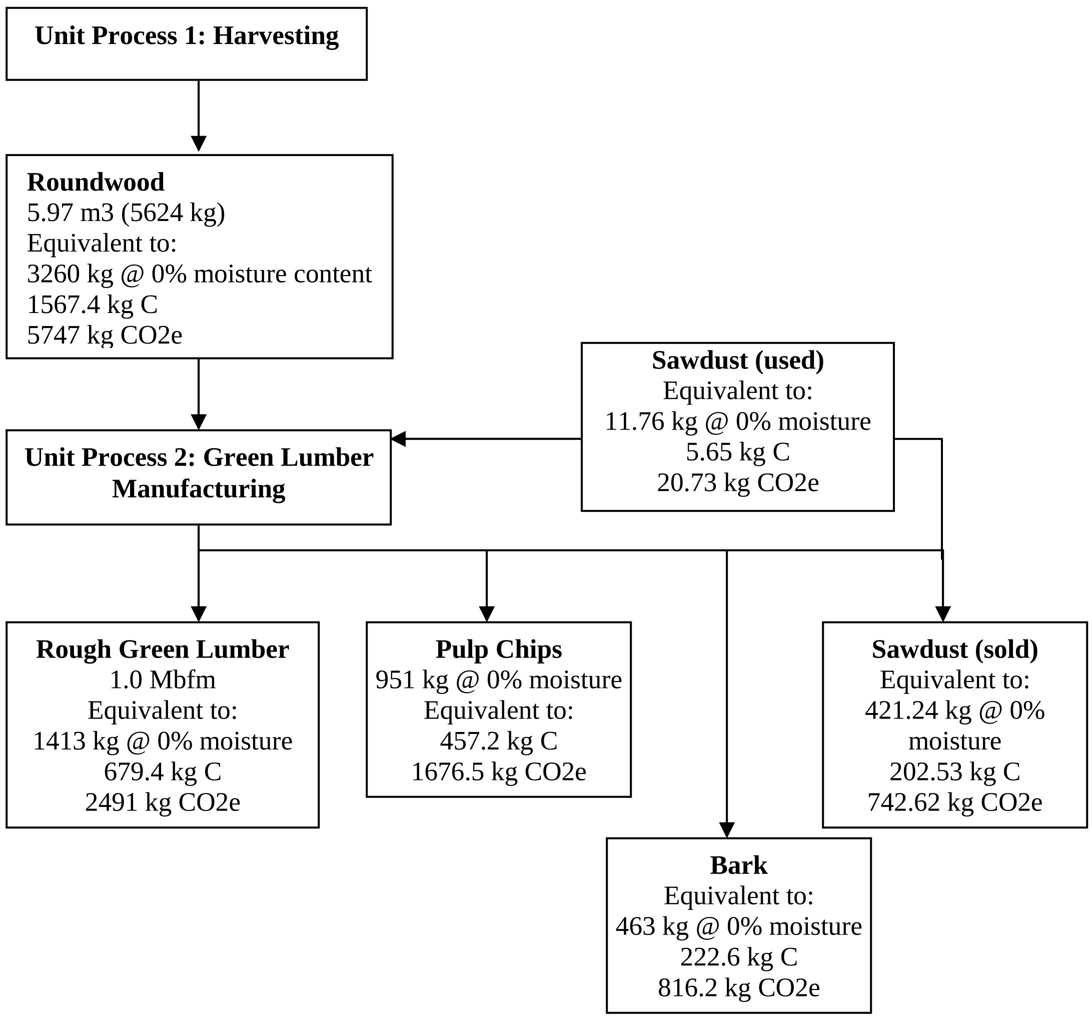

Figure 4 Rough green lumber manufacture mass balance

Lumber Manufacturing LCI

As stated earlier, lumber manufacturing was considered as a single unit process. The weighted average log, energy, and ancillary material inputs used and environmental emissions generated during lumber manufacturing are shown in Table ***6***. One of the mills that participated in the survey burned its own wood waste in an industrial boiler in order to generate heat for heating the facility.

Table 6 Lumber manufacturing LCI

Process inputs	Unit	Quantity per Mbfm green lumber	Quantity per oven dry tonne of green lumber
Timber inputs			
Logs	m^3	5.97	4.3
Energy			
Elec. Purchased	kWh	165.12	117.21
Diesel fuel	l	7.80	5.62
Gasoline	l	1.49E-2	9.87E-3
Wood fuel	kg	16.10	11.43
Propane	l	0.45	0.30
Ancillary materials			
Hydraulic fluid	l	0.61	0.43
Lubricating fluid	l	0.41	0.29
Motor oil	l	3.41E-2	2.32E-2
Greases	kg	8.61E-3	6.09E-3
Antifreeze	l	2.24E-2	1.49E-2
Steel strapping	kg	0.79	0.56
Packaging -foam)	kg	8.54E-3	6.24E-3
Packaging -polythene)	kg	6.04E-2	4.16E-2
Polyester wrap	kg	1.35E-2	1.01E-2
Water*	m^3	13.19	8.73
Emissions to air			
Particulates (PM10)	kg	2.91E-3	1.20E-3
Particulates (PM2.5)	kg	1.43E-3	5.89E-04
Particulates	kg	8.85E-3	3.91E-3
Nitrogen Oxides	kg	0.23	0.16
Hydrocarbons	kg	7.90E-3	1.79E-2
Sulfur Oxides	kg	0.14	0.10
Carbon Monoxide	kg	0.86	0.61
VOC	kg	4.76E-04	3.15E-04
CO2	kg	3.26E-05	2.32E-05
Emissions to soil			
Boiler ash	kg	0.19	8.47E-2
Used hydraulic fluid and lubricant etc.	l	0.39	0.17

Note: * Source – lake, river etc.

Combination diesel trucks and single diesel trucks were the common modes of road transportation used to transport logs and ancillary materials respectively. In addition, one mill that participated in the survey used single gasoline trucks to transport some of the ancillary materials. Transportation distances that were reported by the survey respondents are shown in Table ***7***. The sawmill in New Brunswick received ancillary materials from much further than the other mills (Western Quebec) and hence, its ancillary material transport distances were significantly higher than the rest of the sawmills.

Table 7 Log and ancillary material transportation distances

Transport	**Unit**	**Transportation distances**
Logs	km	80-274
Ancillary materials	km	15-1209

See Mahalle, L. (2010)[10] for more details on the resource extraction and lumber manufacturing LCA and the survey questionnaires used to gather data from the respondents.

3.1.2 Flooring Manufacturing

3.1.2.1 Process overview

CORRIM's recent LCA report on hardwood flooring manufacture in the eastern United States provides the following description to the hardwood flooring manufacturing process[11]. The manufacturing process involves three steps: drying, milling, and finishing.

Drying

Drying starts with rough green lumber received at the flooring manufacturing plant gate. This lumber is first stacked and stickered and then loaded into a kiln for drying, up to a final moisture content of 6-9% (oven dry basis). Optimal drying schedules depend on the hardwood species. The other activities involved in the drying process are handling of kiln emissions (steam and water), kiln maintenance, and transport of the newly dried lumber. Rough kiln-dried lumber, which is the output of the drying process become the input for flooring milling.

Milling

Manually or with the help of specialized machinery, the dried lumber come out from the drying process is first unstacked and destickered for milling. Milling involves planing, ripping, trimming, and moulding.

Planing. Planning adds uniform thickness and smooth surfaces to rough dried lumber that aid visual grading and sorting. Surfaced two sides (S2S) lumber is the main output of this unit process, which is ready for ripping and trimming. The process generates a useful byproduct, called "dry planer shavings".

Ripping. A rip saw (either straight-line or multi-rip) is used to add uniform widths along the lengths of planed dry lumber. Stock of uniform widths and byproducts such as dry sawdust and edge trimmings (edgings) are generated during the ripping process. Edgings may be used to produce

[10] Mahalle, L., 2010. A Cradle-to-Gate Life Cycle Assessment of Canadian Hardwood Lumber. FPInnovations, Quebec.

[11] CORRIM: Phase II Final Report Module F: Life-Cycle Inventory of Solid Strip Hardwood Flooring in the Eastern United States. Prepared by Steven S. Hubbard and Scott A. Bowe (www.corrim.org).

value added products such as moldings or parquet flooring. Some mills equipped with wood waste to energy conversion technologies utilize the byproducts of this process for energy generation.

Trimming. Planned and ripped lumber is trimmed using a chop saw to eliminate defects while crosscut the lumber into desired lengths. The process can be either manual or automated. Increased lumber yields and more uniformity are the advantages of the latter approach. Trimming produces stock of desired lengths and within defect tolerances required to manufacture final flooring product. Trim pieces produced during trimming are often recycled internally to produce energy.

Moulding. This is the most critical value-adding activity in secondary wood processing as the process changes the profile of the wood stock so drastically. Three things are done during moulding: create lengthwise a tongue and a grove on opposite sides, make an end matcher to be enable to join flooring strip ends, and put a lengthwise bevel along the top flooring face in order to make the flooring installation job easy. Moulding produces unfinished, solid strip or plank, tongue and groove flooring.

Finishing

Finishing adds value to the flooring through application of a stain or protective coating to the wood. There are two steps involved in finishing: finishing application and curing. There are several ways to add a finish to wood. Among those methods the following techniques are common:

Spray application in pressurized enclosed chambers: unfinished flooring is conveyed through a series of spray booths where high pressure air is utilized to distribute the coating over the wood. Excess coating material for reuse and solvent emissions can be better captured as spraying is taking place in enclosed chambers.

Use of large rollers similar to those used in residential or commercial painting: Flooring passes beneath the rollers, which spread the coating.

Vacuum coating: represents a third approach. This method applies the vacuum to remove excess coating so that coating thickness can be controlled precisely.

Finishing may be done in combinations of the above methods or their hybrid forms, depending on the size and complexity of a particular manufacturer's product mix. Sensors and scanning equipment is used today to apply precise amounts of desired coatings at equally precise start and stop times. Curing is done after application of a finish. Radiant heat, drying ovens, and exposure to ultraviolet (UV) light are the popular methods used in curing. Among those, UV has become a desirable method since it can cure stains and sealants in a matter of seconds. Nowadays, water-based coatings are gradually replacing traditional solvent-based finishes due to fewer burdens associated with water-based finish to the environment and human health.

3.1.2.2 Flooring manufacturing LCI

Flooring manufacturing LCI was created in a separate study conducted by the Athena Institute as a collaborative effort to develop a cradle-to-grave environmental profile for hardwood flooring[12]. The LCA study has defined three unit processes to develop a gate-to-gate LCI for flooring manufacturing. The unit processes and their reference flows are stated below.

[12] See Athena Sustainable Materials Institute, 2010. A Gate-to-Gate Life Cycle Assessment of Canadian Pre-finished Solid Strip Hardwood Flooring Drying, Milling and Finishing Unit Process Data and Assessment, Ottawa, Ontario.

- Unit Process 1 (Drying) Reference Flow: 1880 board feet dry lumber and 1000 square feet finished flooring
  Roughly 40% efficient and therefore, 1,880 board feet of lumber are dried.
- Unit Process 2 (Milling) Reference Flow: 1005 square feet unfinished flooring and 1000 square feet finished flooring
  Finishing phase is 99.5% efficient (0.5% lost as off-spec. waste) and 1005 square feet of flooring is milled.
- Unit Process 3 (Finishing) Reference Flow: 1000 square feet finished flooring

The LCIs created by that study for the three unit processes are shown in Table ***8***, ***9***, and ***10***.

Table 8 Drying LCI

Outputs to Technosphere	**Unit**	**Dry Lumber Basis (1 Mbfm)**	**Finished Flooring Basis (1000 sq. ft.)**
Primary product			
Rough sawn dried lumber	Mbfm	1.00	1.88
Waste to treatment	kg	15.68	29.47
Inputs from Technosphere			
Primary material input			
Rough sawn green lumber	Mbmf	1.00	1.88
Lumber trucking	Tkm (km)	788.17 (473.57)	1481.76 (473.57)
Energy inputs			
Quebec electricity	kwh	16.39	30.81
Ontario electricity	kwh	1.89	3.55
Natural gas	m3	1.47	2.76
Diesel fuel	l	1.88	3.54
Propane	l	0.05	0.09
Onsite biomass (Hogfuel-oven dry)	od kg	350.11	658.21

Table 9 Milling LCI

Outputs to Technosphere	Unit	Unfinished Flooring Basis (1000 sq. ft.)	Finished Flooring Basis (1000 sq. ft.)
Primary product			
Unfinished flooring	sq. ft	1000	1005
Co-products			
Biomass byproducts (combusted internally)	od kg	561.54	564.35
Wood byproducts (sold)	od kg	917.36	921.95
Waste to treatment			
Oil and grease	kg	0.37	0.37
Inputs from Technosphere			
Primary material input			
Rough sawn dried lumber	Mbfm	1.87	1.88
Energy inputs			
Quebec electricity	kWh	602.91	605.92
Ontario electricity	kWh	69.43	69.78
Natural gas	m3	0.58	0.58
Diesel fuel	l	1.19	1.20
Propane	l	259	2.60
Operating consumables			
Hydraulic fluid	l	0.40	0.40
Lubricating oil	l	1.13	1.14
Motor oil	l	0.24	0.24
Grease	kg	0.05	0.05
Antifreeze	l	0.02	0.02
Consumables trucking	tkm (km)	0.38(250)	0.38(250)

Table 10 Finishing LCI

Outputs to Technosphere	Unit	Pre-finished Flooring Basis (1000 sq. ft.)
Primary product		
Pre-finished flooring	sq. ft	1000
Waste to treatment		
Oil and grease	kg	0.16
Cleaning solvent	l	0.75
Polyurethane sealer	l	2.53
Stain	l	0.28
Trim ends	kg	5.66
Inputs from Technosphere		
Primary material input		
Unfinished flooring	sq. ft	1005
Polyurethane sealer	l	6.74
Stain	l	1.24
Energy inputs		
Quebec electricity	kWh	73.96
Ontario electricity	kWh	37.42
Natural gas	m3	4.27
Propane	l	1.16
Operating consumables		
Hydraulic fluid	l	0.01
Lubricating oil	l	0.004
Motor oil	l	0.0008
Grease	kg	0.002
Consumables trucking	tkm (km)	0.0033(250)
Packaging		
Shrink wrap	kg	1.46
Plastic strapping	kg	0.83
Steel strapping	kg	1.1
Paint	l	0.012
Corrugated cardboard	kg	24.68
Wood pallet	No.	1.92
Packaging trucking	tkm (km)	14.23 (250)

3.1.3 LCI Data Sources for Material and Energy Inputs

The secondary LCI data sources used to model the energy and material input consumption and truck transport during resource extraction from forests, lumber manufacturing, and flooring manufacturing are shown in Table ***11***. The study drew on the data modules available in US LCI, USEI, Athena, and Franklin databases. Data representativeness is the main criteria used in drawing LCI data from these data sources. Electricity data modules available in the Athena database were used to model environmental impacts from electricity consumption. The Franklin LCI data was used for diesel and gasoline combustion in industrial equipment and wood fuel combustion in industrial boilers because that data deemed to be more representative of the specific processes occurring in timber harvesting and lumber and flooring manufacturing than the other data sources. Franklin data is more than twelve years old, but the data representativeness of the specific processes is considered to be more important than the vintage in drawing that data. All other data requirements were met from US LCI and USEI databases. Note that the closest surrogates were chosen for hydraulic fluid, motor oil, grease, antifreeze, foam, polyurethane sealer, solvent, and stain in the absence of LCI data.

Table 11 LCI data sources for the raw materials and energy inputs used in harvesting, lumber manufacturing, and flooring manufacturing

Inputs/processes	Data source	Comment
Energy		
Diesel fuel	Franklin data	Process data – diesel use in industrial equipment
Gasoline	Franklin data	Process data – gasoline use in industrial equipment
Natural gas	US LCI	Process data – natural gas combusted in industrial boilers
Propane	US LCI	Process data – LPG combusted in industrial boilers
Electricity	Athena	Developed for Canadian circumstances based on US LCI data
Wood fuel	Franklin data	Source data for emissions from wood industrial boilers
Ancillary materials		
Hydraulic fluid	USEI	Surrogate process data – unit process for lubricating oil
Lubricating fluid	USEI	Ecoinvent unit process for lubricating oil
Motor oil	USEI	Surrogate process data – unit process for lubricating oil
Greases	USEI	Surrogate process data – unit process for lubricating oil
Antifreeze	USEI	Surrogate process data – unit process for ethylene glycol
Paint	USEI	Ecoinvent unit process for alkyd paint (solvent based)
Steel strapping	US LCI	Process data for cold rolled steel sheet
Packaging -foam	USEI	Surrogate process data – unit process for polyurethane flexible form
Packaging -polythene	US LCI	Process data for low density polyethylene resin
Polyester wrap	USEI	Ecoinvent unit process for polyester resin
Shrink wrap	US LCI	Process data for high density polyethylene
Corrugated cardboard	USEI	Ecoinvent unit process for corrugated cardboard
Other inputs		
Polyurethane sealer	USEI	Surrogate process data – unit process for polyurethane flexible form
Solvent	US LCI	Process data for white mineral oil production
Stain	USEI	Surrogate process data – unit process for acrylic paint
Transport		
Truck transport	US LCI	Combined diesel trucks for log transport and single diesel/gasoline trucks for ancillary materials
Wood pallet	USEI	Ecoinvent unit process for pallet production

3.2 Cradle-to-gate Life Cycle Inventory for Typical Carpets

This section describes how a representative cradle-to-gate life cycle inventory was developed for nylon broadloom carpet manufacturing in the US. 70% of carpets that are manufactured today are made from nylon (World Floor Covering Association, 2010). There are two types of nylon carpets: carpet tiles and broadloom carpets. Between the two types, broadloom carpet is the most widely used carpet type in both residential and commercial applications (US Department of the Army, 2003, p.A-2). While considering these reasons, nylon broadloom carpet was considered to be the typical carpet for the comparison. About 90% of the US carpet supply comes from the mills operating in Georgia (The Carpet and Rug Institute, 2008) and therefore, this state was chosen as the default carpet manufacturing facility location.

3.2.1 Manufacturing Overview

Three steps are involved in carpet manufacturing. The first step is called "tufting" where fiber is weaved into a primary backing material (a base cloth to hold the yarn in place). In the second step, dye is applied either before tufting (called yarn dyeing) or after tufting (called carpet dyeing). The 3rd step is the finishing process, where a latex coating is applied to tufted and dyed carpets' primary backing and then heat pressed to make the two parts hold together to preserve the shape (World Floor Covering Association, 2010). The cradle-to-gate typical carpet manufacturing processes is depicted in Figure **5Error! Reference source not found.**. The constituents of nylon broadloom carpets stated in the BEES manual are shown in the figure.

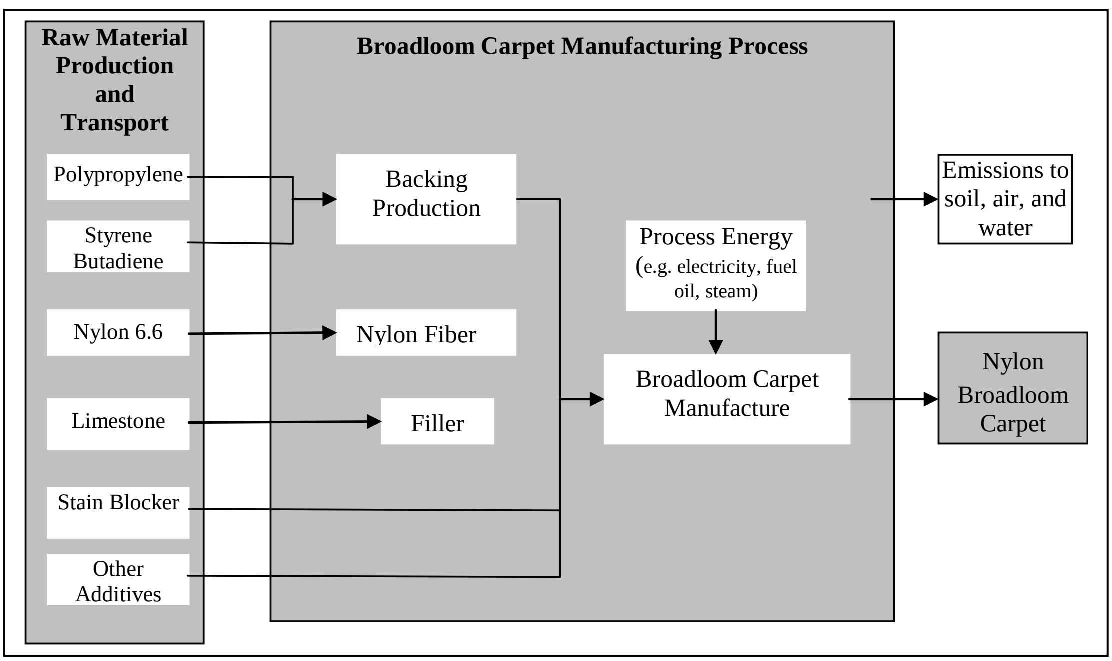

Figure 5 Cradle-to-gate system boundary for broadloom carpet manufacturing process

3.2.2 LCI Data Sources for Raw Material and Energy Inputs

Raw material LCI data sources used to build the model are shown in Table ***12***. The BEES manual does not specify the materials used for stainblocker and other additives. Email communication with NIST revealed that those materials have being ignored from BEES model due to the minor quantities used in the carpet manufacturing process. The information on those materials was not available for the study due to the proprietary nature and hence, stainblocker and other additives were excluded in building the model.

Table 12 LCI data sources for the raw materials used in nylon broadloom carpet manufacturing

Inputs	Data Source	Comments
Nylon 6,6	US EI	Ecoinvent unit processes with US electricity
Polypropylene	US EI	Ecoinvent unit processes with US electricity
Styrene butadiene latex	US EI	Ecoinvent unit processes with US electricity
Limestone ($CaCO_3$) filler	US EI	Ecoinvent unit processes with US electricity
Water	US EI	Ecoinvent unit processes with US electricity
Electricity	US LCI	Eastern US electricity
Fuel oil (#6)	US EI	Ecoinvent unit processes with US electricity
Heating steam	Industry data 2.0	For on-site steam production

3.2.3 Manufacturing LCIs

The inventory was created in line with the BEES data, considering the main industry locations of in the US. The technosphere flows are shown in Table ***13***. As noted, the default manufacturing facility location was considered to be Georgia. According to the calculations performed using BEES data, carpet manufacturing creates about 1% of solid waste from defective products. That waste was assumed to be recycled back into the manufacturing process.

Table 13 Manufacturing technosphere flows in manufacturing 1000 sq. ft of nylon broadloom carpet

	Inputs	Unit	Amount
Materials	Nylon 6,6	kg	95.60
	Polypropylene	kg	21.09
	Styrene butadiene latex	kg	24.43
	Limestone ($CaCO_3$) filler	kg	84.45
	Stain blocker	g	22.30
	Other additives	g	185.81
	Water	l	89.19
Energy	Electricity	kWh	10.22
	Fuel oil (#6)	MJ	325.16
	Heating steam	kg	66.89

3.2.4 Missing LCI Data

BEES data lacks information on ancillary materials and the amount of energy used during internal handling of materials (i.e. fuels used for forklifts etc.) during the manufacturing process and packing materials used to pack carpet ready for shipment.

3.3 Cradle-to-gate Life Cycle Inventories of Generic Ceramic Floor Tiles

This section describes the development of a cradle-to-gate LCI model for generic ceramic tile manufacturing in the US. Like other floor covering LCIs discussed above, the inventory was adapted from the BEES data for generic ceramic floor tile manufacturing in the US. The section concludes with a summary of the technosphere flows and LCI data sources for raw materials used in ceramic tile manufacturing.

3.3.1 Manufacturing Overview

Ceramic tile manufacturing process starts with transporting raw materials to a ceramic plant and mixing them together their appropriate weights. The predominantly used raw material is clay although various processed clays and other ceramic materials are also available to manufacture ceramic tiles. As a result, actual mixtures of tile manufacturing may contain one or several types of clay and other additives (Mishulovic, Alex and Evanco James, 2003). Ceramic tiles are manufactured by baking the ceramic mixture in kilns to a permanent hardness. Usually recycled windshield glass is added to the ceramic mix in order to improve its environmental performance (Lippiatt C. Barbara, 2007). A glaze is a glassy material designed to melt on the surface of tile body and adhere to tile body upon cooling. Glazing improves the surface durability and adds aesthetic values as well (Mishulovic, Alex and Evanco James, 2003). The cradle-to-gate tile manufacturing process is shown in Figure ***6***.

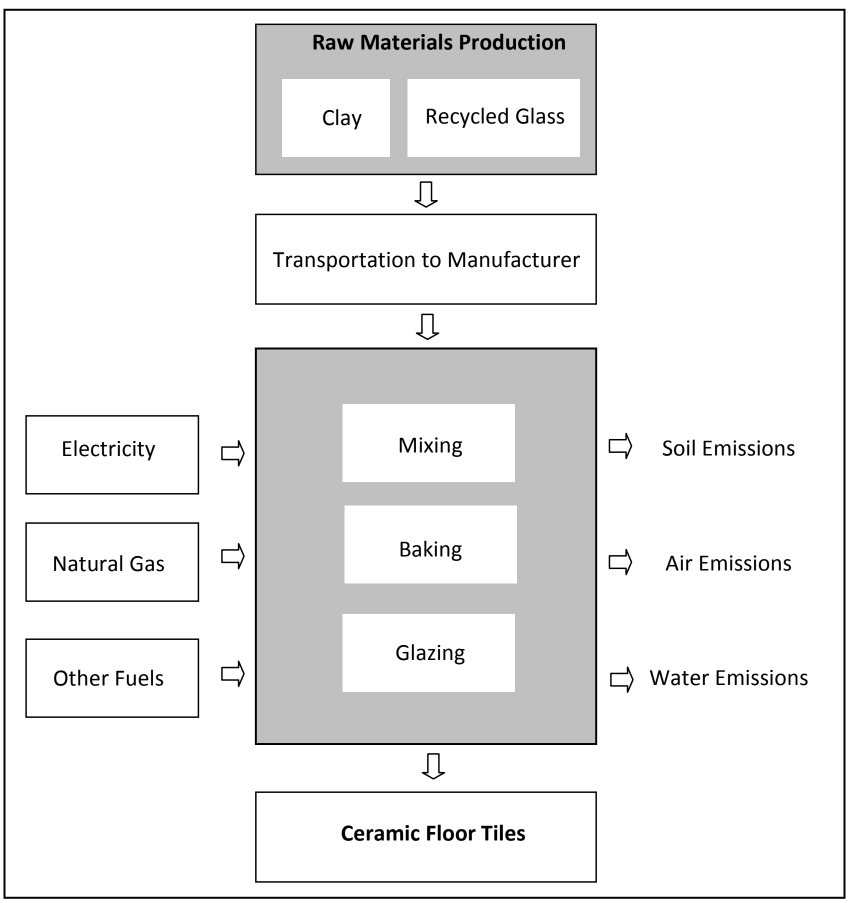

Figure 6 Cradle-to-gate system boundary for generic ceramic tile manufacturing process

3.3.2 LCI Data Sources for Raw Material and Energy Inputs

The LCI data sources used to model the environmental burden of the raw materials and energy sources consumed during the tile manufacturing are shown in Table ***14***. Note that US EI data was used for clay, recycled glass, and fuel oil in modeling their environmental impacts due of the lack of North American LCI data for those inputs.

Table 14 Input LCI data sources

Inputs		Data Source	Comments
Clay		US EI	Ecoinvent unit processes with US electricity
Recycled glass		US EI	Ecoinvent unit processes with US electricity
Energy	Coal	US LCI	Ecoinvent unit processes with US electricity
	Natural gas	US LCI	
	Fuel oil (#6)	US EI	Ecoinvent unit processes with US electricity
	Wood	US LCI	

3.3.3 Manufacturing LCI

It was assumed that the raw materials are refined or beneficiated prior to shipping to the ceramic plant. There is variety of ceramic floor tile sizes available in the market and the most common floor tile size is 12" x 12" (Home-Improvement-and-Financing.Com, 2004-2010). The technosphere flows shown in Table ***15*** were developed using the basic ceramic tile manufacturing input data published in the BEES manual.

Table 15 Technosphere flows in ceramic floor tile manufacturing

Inputs		Units	Amount
Materials	Clay*	kg/tile	0.6324
	Recycled glass	kg/tile	1.8972
	Water**	l/tile	0.92
Energy	Coal *	MJ/tile	0.5084
	Natural gas*	MJ/tile	3.8108
	Fuel oil (#6)*	MJ/tile	0.4136
	Wood*	MJ/tile	0.5666
	Electricity**	kWh/tile	0.16
Transport	Clay*	km	160
	Recycled glass*	km	804

Note: Ceramic tile size is 12”x12”x ½” and weighs 1264.8g
Sources: * Lippiatt C. Barbara, 2007, p. 159.
**Bobia D. Maria *et al.*, 2009, p. 37.

3.3.4 Missing LCI Data

Other than the technosphere flows mentioned in Table ***15***, ceramic tile manufacturing consumes energy (e.g. diesel for forklifts etc) and ancillary materials (motor oil, lubricant etc) to run machine equipment and packaging for the final product ready for shipment. The BEES manual lacks this data.

3.4 Cradle-to-gate Life Cycle Inventories for Generic Vinyl Composition Tile

This section describes the development of a cradle-to-gate LCI model for vinyl flooring manufactured in the eastern US where majority of vinyl is produced. There are two types of vinyl flooring: sheet flooring and tile. Both the types are divided into subcategories.

Sheet flooring is divided into three basic categories (homogeneous, inlaid and layered composite tile) while solid vinyl tiles and vinyl composition tiles (VCTs) are the two subcategories of vinyl tiles. The products differ in terms of both the manufacturing process and their raw material content (Vinyl Institute, 2010). The BEES manual contains data only for generic vinyl composition tile manufacturing and therefore, we focused only on VCTs due to lack of LCI data for other vinyl flooring types.

3.4.1 Manufacturing overview

VCTs are manufactured by mixing vinyl resin and additives. The formulations are proprietary and usually different from each other. The commonly used raw materials include polyvinyl chloride resins (vinyl chloride and vinyl acetate), fillers (limestone or clay), plasticizers (butyl benzyl phthalate and dissononyl phthalate), and pigments. The raw materials are mixed in a large industrial mixer to manufacture vinyl tile. The tiles can then be made either by melting the mixture at high temperatures and moulding into desired shapes or using the calendaring technique (i.e., feeding the mixture through a series of rollers in order to squeeze the material to the desired gauge) (Vinyl Institute, 2010). The manufacturing process is completed with the application of a 0.005mm finish coat of acrylic latex to the tile. Figure ***7*** illustrates the cradle-to-gate VCT manufacturing process.

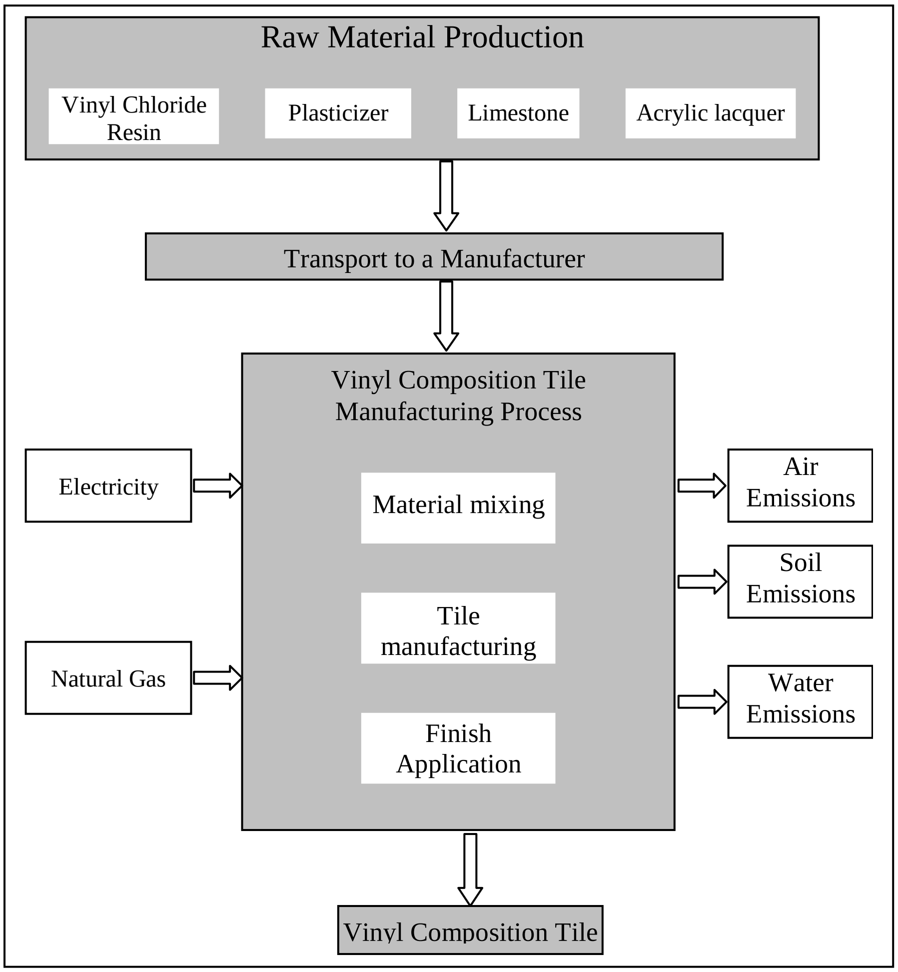

Figure 7 Vinyl composition tile manufacturing process

3.4.2 LCI Data Sources for Raw Material and Energy Inputs

The LCI data sources used to model the environmental impacts of the raw materials and energy inputs are shown in Table ***16***. LCI data for phthalic acid and benzyl alcohol was used as surrogates for butyl benzyl phthalate and dissononyl phthalate due to lack of LCI data for those inputs.

Table 16 Input LCI data sources

Inputs	Data Source	Comments
Limestone	US EI	Ecoinvent unit processes with US electricity
Vinyl resin (vinyl chloride and vinyl acetate)	US EI	Ecoinvent unit processes with US electricity
Plasticizer*	US EI	Ecoinvent unit processes with US electricity
Finish coat – acrylic latex	US EI	Ecoinvent unit processes with US electricity
Electricity	US LCI	Eastern US electricity data
Natural gas	US LCI	Represent N.America
Transport	US LCI	Combined truck

Note: * Phthalic acid and benzyl alcohol were used as surrogates

3.4.3 Manufacturing LCI

A generic vinyl composition tile manufacturing LCI was created in line with the raw material content stated in BEES for an average make up of vinyl composition tile in North America. Table ***17*** summarizes the technosphere flows for manufacturing generic vinyl composition tile.

Table 17 Technosphere flows for generic vinyl composition tile manufacturing

Inputs			Unit	Amount
Materials	Limestone		kg/sq.ft	0.515
	Vinyl resin	Vinyl chloride	kg/sq.ft	0.070
		Vinyl acetate	kg/sq.ft	0.004
	Plasticizer	Butyl benzyl phthalate	kg/sq.ft	0.015
		Diisononyl phthalate	kg/sq.ft	0.010
	Finish coat – acrylic latex		ml	0.200
Energy	Electricity		kWh/ sq.ft	0.228
	Natural gas		MJ/sq.ft	0.523
Transport	Raw materials		km	402

3.4.4 Missing LCI Data

The environmental profile provided in the BEES manual lacks data for ancillary materials (e.g., motor oil, lubricants etc) as well as the amount of energy used for internal handling of raw material inputs (i.e. fuels used for forklifts etc.) during the manufacturing process and packing materials used to pack the final product ready for shipment.

3.5 Cradle-to-gate Life Cycle Inventory for Generic Cork Flooring Manufacturing

This section discusses the cradle-to-gate LCI model developed for generic cork flooring manufacturing. Like other flooring types, this generic cork flooring manufacturing LCI was adapted from the BEES data.

Cork is a natural product made from the bark of cork oak trees. Current global production was taken into account in developing this cradle-to-gate inventory. Cork production primarily occurs in seven countries around the Western Mediterranean basin. Among those countries, about 50% of the world cork supply comes from Portugal (BuildingDirect, 2001-2010). In this study, it was assumed that cork flooring is manufactured in Portugal and shipped to North America for installation.

There are two cork flooring types: cork parquet floor tile and floating floor planks. Floating floor planks were considered to be the generic cork flooring because it is the most commonly used flooring type today (The Flooring Professor, 2007).

3.5.1 Floating Cork Flooring Manufacturing Overview

Cork flooring is manufactured using the remaining scraps of cork slabs after punching bottle stoppers. Scraps are ground into small granules, mixed with a resin binder (i.e. polyurethane), moulded into large blocks and baked in specialized ovens to produce flooring. The baking process increases durability of cork flooring. Baking and varying the granule size allows for the creation of light, medium and dark colors (BuildingDirect, 2001-2010). A High Density Fiberboard (HDF) is sandwiched between two cork layers and then cured to manufacture floating flooring (Lippiatt C. Barbara, 2007, p.207). Cradle-to-gate system boundary for cork flooring manufacturing is shown in Figure ***8***.

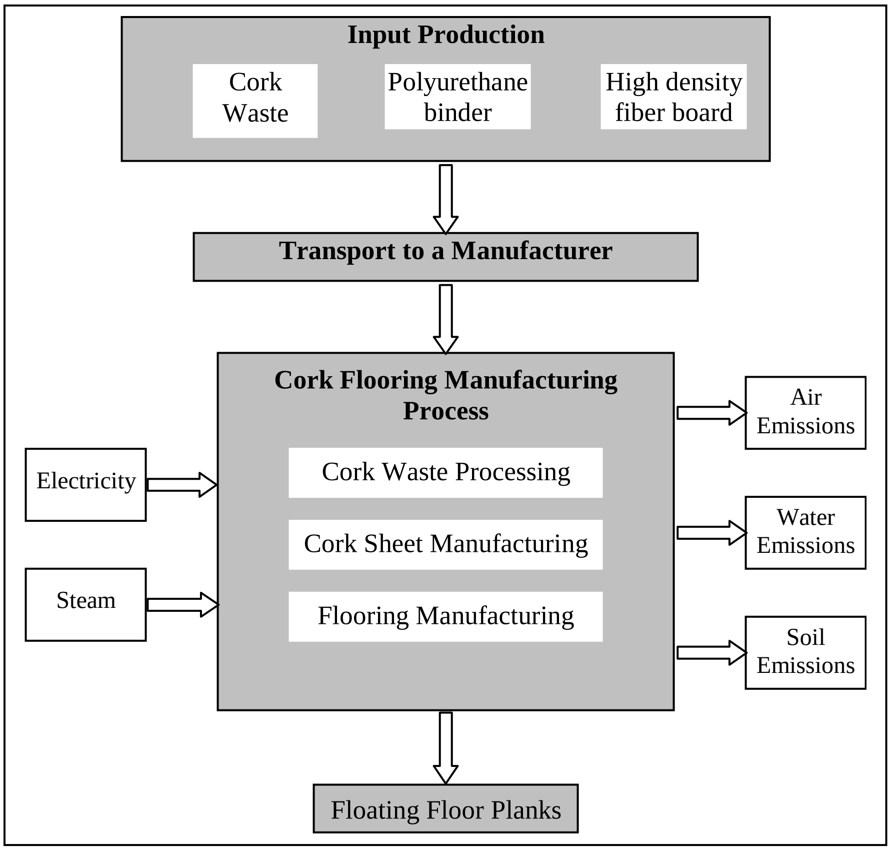

Figure 8 Cradle-to-gate system boundary for generic cork flooring manufacturing process

3.5.2 LCI Data Sources for Raw Material and Energy Inputs

Cork flooring manufacturing was assumed to take place in Europe (Portugal). As shown in Table ***18***, data sources available in the ecoinvent database were used to model the environmental impacts.

Table 18 Input LCI data sources

Inputs	Data Source	Comments
Binder (moisture cured urethane)	US EI database	Surrogate data from Ecoinvent unit processes for PUR adhesive
HDF	US EI database	Surrogate data from Ecoinvent unit processes for fiberboard, hard
Electricity	Econinvent database	Ecoinvent electricity data for Portugal
Steam (from waste cork)	US EI database	Surrogate data from Ecoinvent unit processes for heat generation from softwood chips

3.5.3 Manufacturing LCI

Cork flooring is manufactured using waste cork from wine-stopper manufacturing (BuildingDirect, 2001-2010a). During recycling, the cork waste undergoes changes in the inherent properties as the scraps are ground into small granules, mixed with a resin binder, moulded into large blocks, and baked in specialized ovens.

Allocation of the environmental burden of cork production created for bottling was done according to the allocation principles stated in Sections 4.3.4.2 and 4.3.4.3 of ISO 14044:2006. Flooring manufacturing was considered as an open loop process that starts with wastes that would otherwise be disposed of. As per the ISO allocation principles, the environmental impacts of a product system are not allocated to waste. Therefore, the study did not allocate the initial environmental burden associated with harvesting planks/slabs of cork bark and their subsequent processing for wine-stopper manufacturing to the flooring product system. The technosphere flows for manufacturing unfinished floating cork flooring leaving the mill gate are shown in Table ***19***.

Table 19 Technosphere flows for generic floating cork flooring manufacturing

Inputs		Unit	Amount
Raw materials	Recycled cork waste	kg/m^2	4.32
	Binder (moisture cured urethane)	kg/m^2	0.22
	HDF	kg/m^2	2.9
Energy	Electricity	kWh/m^2	3.04
	Steam (from waste cork)	MJ/m^2	9.69

3.5.4 Missing LCI Data

The raw material transportation distances were not available for this study as that information was not provided in the BEES manual. The cork flooring environmental profile also lacks information on the ancillary materials (e.g., motor oil, lubricants etc) used during flooring manufacturing, energy consumed during internal handling of raw material inputs (i.e. fuels used for forklifts etc.), and packing materials used for the final product ready for shipment.

3.6 Cradle-to-gate Life Cycle Inventories for Generic Linoleum

This section provides an overview to the manufacturing process, manufacturing LCI, and background data sources for the material inputs. Linoleum is a floor covering made from renewable materials such as solidified (oxidized) linseed oil (called linoxyn), tall oil, pine rosin, wood flour, powdered cork, and mineral fillers like limestone (Lippiatt C. Barbara, 2007 p. 160-2 and Extonet Ltd., 2010). This cradle-to-gate LCI was developed using the existing LCI data available in the BEES manual for generic linoleum sheet flooring. As stated in BEES, linoleum is exported from Europe to the US, and hence, the manufacturing facility location was considered as Europe in creating the inventory.

3.6.1 Manufacturing overview

The manufacturing process involves boiling oil, mixing with melted resins, and combining with other raw materials such as wood floor, powdered cork, resins etc. The mixture is then formed into a backing (e.g. jute) by applying heat and pressure to produce continuous long sheets. The sheets are then dried by hanging them in drying rooms or in ovens. Once the required flexibility and resilience is reached, sheets are then cut into rolls to produce the final flooring product ready for shipment (Lippiatt C., Barbara, 2007 p. 183 and Extonet Ltd., 2010). Figure ***9*** illustrates the cradle-to-gate processes included in the system boundary.

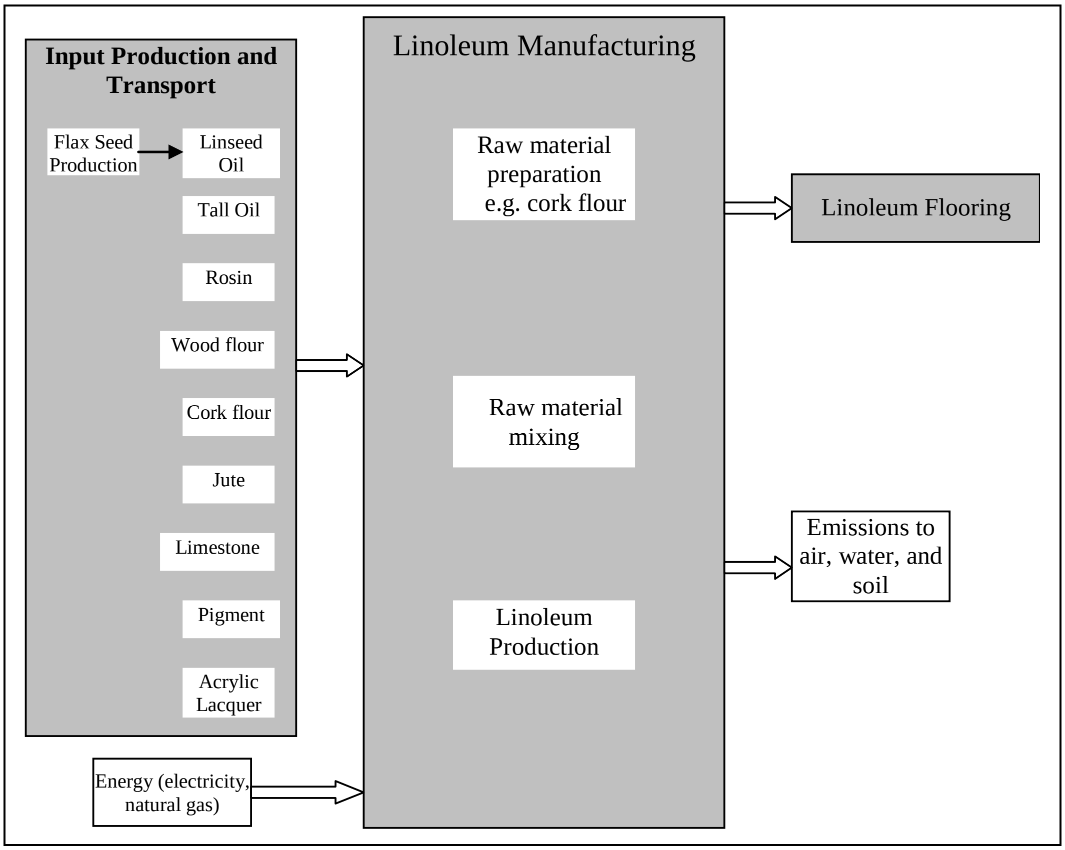

Figure 9 Cradle-to-gate linoleum manufacturing system boundary

3.6.2 Data Sources for Raw Materials

3.6.2.1 Linseed oil production

LCI data available in the IDEMAT 2001 database[13] was used to fulfill most of the data requirements to develop an inventory for the production of linseed oil. Linseed oil production requires cultivation and harvesting of linseed and extraction of oil from seeds. Table ***20*** and***Table*** 21 show the inputs used during seed production and oil extraction. Diesel tractors are used during land preparation and harvesting while fertilizer is added during plant growth. Since IDEMAT 2001 database does not provide the energy consumption data for oil extraction from flax seeds, the ecoinvent data on fuel oil consumption in crude coconut oil extraction was used as a surrogate. BEES has allocated environmental burden of linseed oil production on an economic basis to linseed oil (87%) and linseed cake (13%). The same allocation factors were used in creating the model.

[13] See http://www.idemat.nl/

Table 20 Inputs used in flax seed production

Inputs	Unit	Amount per kg of linseed
Fertilizer	kg	0.14
Diesel	l	0.25

Source: IDEMAT 2001

Table 21 Inputs used in linseed oil production

Inputs	Unit	Amount per kg of linseed oil
Linseed*	kg	2.78
Fuel oil**	MJ	0.297

Source: * IDEMAT 2001
** Ecoinvent data

3.6.2.2 Other raw materials

The LCI data sources used to model the other material inputs to linoleum production are shown in Table ***22***. Tall oil is a co-product of the Kraft process of wood pulp manufacturing. The value of the tall oil produced in that process is one percent of the total value of all the products and co-products (Gorree M. et.a al., 2000. p. 20), and the tall oil yield during wood pulp manufacturing amounts to 30-50 kg per tonne of pulp produced (Stenius Per (ed), 2000, p.74). LCI data available in the ecoinvent database was used with that allocation factor to model tall oil consumption in linoleum manufacturing. As stated in the BEES manual, pine rosin harvesting is a manual process and hence, assumed no environmental burden is caused during the production of this raw material (Lippiatt C. Barbara, 2007 p. 185).

Table 22 LCI Data sources for other inputs

Raw material	Data source
Tall oil	Franklin data for Kraft paper
Limestone	US LCI data
Wood flour	US LCI data
Cork flour	US EI data
Pigment	US EI data
Jute (backing)	US EI data
Acrylic lacquer	US EI data

3.6.3 Manufacturing LCI

Raw material and energy inputs stated in Lippiatt C. Barbara (2007: p. 162-3) were used to model the environmental burden of manufacturing linoleum. Raw material and energy usage, as well as emissions, caused by manufacturing 1000 sq ft. of linoleum flooring are shown in Table ***23***. Raw material transportation distances are provided in Table ***24***.

Table 23 Inputs and environmental emissions for manufacturing 1000 sq.ft of linoleum flooring

Inputs	Unit	Amount
Raw materials		
Linseed oil	kg	62.25
Tall oil	kg	17.47
Pine rosin	kg	3.34
Limestone	kg	47.29
Wood flour	kg	81.48
Cork flour	kg	13.38
Pigment (TiO_2)	kg	11.80
Jute (backing)	kg	29.08
Acrylic lacquer	kg	0.93
Energy		
Electricity	kWh	158.26
Natural gas	MJ	2749.64
Air emissions		
Volatile organic compounds (VOC)	g	4.60
Solvents	g	2.70
Particulates (unspecified)	g	0.66

Source: Lippiatt C. Barbara, 2007 p. 162-3, 184

Table 24 Raw material transport modes and distances

Raw material	Distance (km)	Mode
Linseed oil	4350	Ocean freighter
	1500	Train
Tall oil	2000	Ocean freighter
Pine rosin	2000	Ocean freighter
Limestone	800	Train
Wood flour	600	Train
Cork flour	2000	Ocean freighter
Pigment (TiO_2)	500	Diesel truck
Jute (backing)	10000	Ocean freighter
Acrylic lacquer	500	Diesel truck

Source: Lippiatt C. Barbara, 2007 p. 164

3.6.4 Missing LCI data

The existing LCI data sources lacks information on ancillary materials and the amount of energy used for internal handling of materials (i.e. fuels used for forklifts etc.) during the manufacturing process and packing materials used to pack final flooring product ready for shipment. In addition, BEES does not provide trucking distances for the transportation of raw materials to the flooring manufacturing facility.

4 Use Phase Life Cycle Inventories

Processes involved during flooring installation, use, and maintenance during the service life are discussed in this section. As shown in Figure ***10***, the use phase inventories take into account all the inputs and outputs associated with the transport of pre-finished flooring from the plant gate to a default building site in addition to their installation, use, and maintenance. Different underlayment requirements for both concrete and wood subsurfaces are included in the analysis in creating gate-to-gate use phase LCIs.

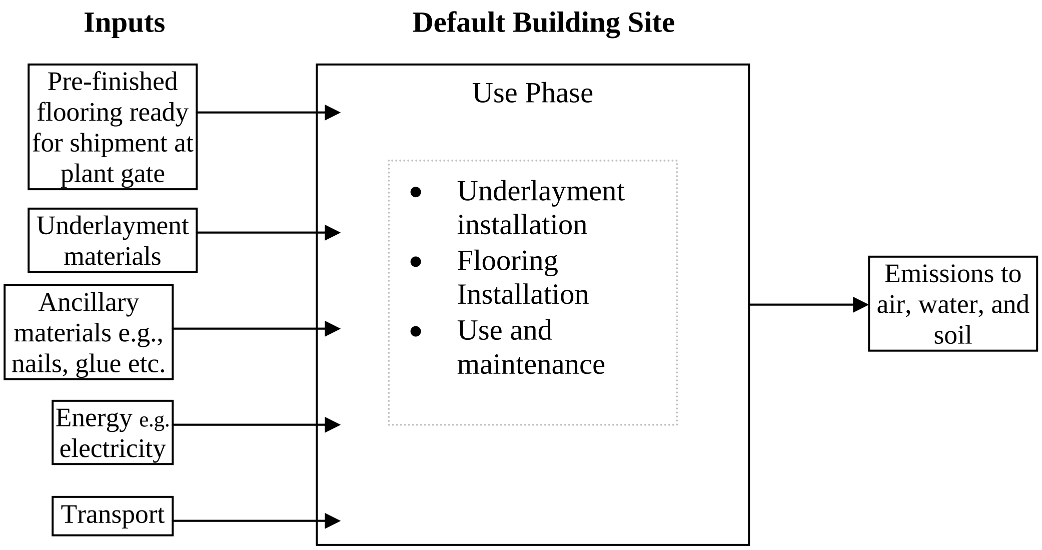

Figure 10 Gate-to-gate system boundary of the use phase

4.1 Selection of a Default Building Site Location

A default building site was chosen by considering the recent hardwood flooring shipments data. According to the average shipment values calculated using in-house data, 96% of hardwood flooring was shipped to the US during 2000-2009. Among the four US regions (Northeast, Midwest, South, and West) designated by Census Bureau, the highest percentage of shipments (32%) was shipped to the Northeast region, and within that region about 32% went to New York State. Therefore, New York was chosen as the default building site location to model the flooring use phase.

4.2 Transportation to Building Site

4.2.1 Flooring Transport Distances and Modes

It was assumed that flooring manufactured in North America was transported directly from the flooring manufacturing facilities to the default building site in New York, using diesel combination trucks. Hardwood flooring mills located in both Quebec and Ontario have more or less the same distance to New York City and hence, an average transport distance was used for modeling. Other flooring types manufactured in the U.S. were assumed to be transported from the closest facility to the default building site. As stated in the BEES manual, the two flooring products received from Europe (i.e., cork and linoleum) were assumed to be first shipped to a distribution facility in the U.S. before being delivered to the default building site. Flooring transport distances and modes are shown in Table ***25***.

Table 25 Flooring transportation distances and modes

Flooring type	Delivery distance (km)	Mode
Hardwood	800	Combined diesel truck
Carpet	1328	Combined diesel truck
Ceramic tiles	323	Combined diesel truck
Vinyl composition tiles	261	Combined diesel truck
Cork	6437*	Ocean tanker (fuel oil)*
	1292	Combined diesel truck
Linoleum	6022*	Ocean freighter
	324	Combined diesel truck

Source: *Lippiatt C. Barbara, 2007

4.2.2 Other Input Transportation

It is assumed that ancillary materials such as nails, glue, etc. were transported from within a 50 km radius and delivered using single gasoline trucks.

4.2.3 LCI Data Sources for Flooring Transport

The LCI data sources that were used to model flooring transport to the default building site are shown in Table ***26***. Cork and linoleum are assumed to be transported from Europe, and hence ecoinvent LCI data was used to model the ocean transport of those two flooring products.

Table 26 LCI data sources for material transport

Mode	LCI data source
Combined diesel truck	US LCI
Single diesel truck	US LCI
Ocean tanker (fuel oil)*	ecoinvent
Ocean freighter	ecoinvent

4.3 Flooring Installation and Use LCI Flows

The study assumed that the flooring installation and subsequent maintenance would be done in accordance with the guidelines of the major flooring manufacturers and associations. In developing the LCI flows, it was assumed that the subfloor met the necessary conditions required to install flooring:

- Flat and dry (i.e., humidity is less than 12%)
- Clean (free from any debris , such as cleats, nail heads, dried glue or any other material)
- Free of movements (in case of a wooden floor)

Flooring installation in residential buildings is usually a manual process and may require some electricity for tools such as power guns and drills. It was assumed that electricity consumption during installation was negligible and was not modeled. Flooring installation waste was assumed to be disposed in a landfill.

Floorings require both periodic and frequent cleaning, and as stated in goal and scoping, periodic cleaning was excluded from the system boundary due to lack of data. Frequent cleaning involves removing dust and grit. In frequent cleaning, carpets differ from the other floorings; carpets should be vacuumed (vacuuming consumes electricity) to remove dust and grit[14] while the other floorings in residential applications can be cleaned by sweeping with a broom in residential applications. From an environmental perspective, frequent cleaning of other floorings with a broom is a manual process, and hence, does not create environmental impacts. However, electricity use for carpet vacuuming does create environmental burden during use, and this difference was taken into account in creating use phase inventories. The other flooring types could be cleaned with a vacuum cleaner as well, and this difference was addressed under the uncertainty analysis.

4.3.1 Hardwood Flooring

Depending on the type of subfloor (i.e., concrete, wood, radiant flooring) there are variety of methods available for hardwood flooring installation. Among those methods, the "condo method", is the most commonly used installation method that installers use to install hardwood flooring. This method can be applied over any type of subfloors (concrete, wood, and radiant subfloors), and hence was chosen as the default method for the analysis. The method requires laying down plywood (preferred material due to its nail retaining properties) over the subfloor and then installing an approved vapour barrier paper over it. (Jobin Jerome, 2010) Inputs used during the installation on top of concrete and wood subfloors are summarized in Tables ***28*** and ***29*** at the end of the chapter. Note that no board replacement during the service life was assumed as hardwood flooring comes with a 25 year finish warranty. Flooring is assumed to be maintained according to the manufacturers' guidelines.

4.3.2 Typical Carpet

Use phase inputs for carpet installation and use on top of concrete and wood subfloors are shown in Tables ***28*** and ***29*** provided at the end of the chapter. The installation input flows were developed in line with BEES data. BEES assumes a service life of 11 years for nylon broadloom carpets, and therefore, it requires three installations during a 25 year floor use. Flat rubber is the widely used underlayment type for carpets (West Sarah, 2008) and was assumed in developing the inventory. As recommended by the Carpet and Rug Institute (2009), low emitting floor covering adhesive was assumed in developing the inventory. No glue is assumed to be wasted. Note that the quantities of installation inputs mentioned in the table are an estimate for a single installation over a 1000 sq.ft floor. In developing a model, the technosphere flows for 11 year service life were normalized on a proportionate basis to the default service life to calculate per FU flows. The Institute, recommends vacuuming at least once a week to keep carpet clean from dust and grit[15]. The study team used the power consumption estimates of European Council for Energy Efficient Economy (ECEEE, 2010) for weekly carpet vacuuming to create a use phase inventory.

4.3.3 Ceramic Floor Tiles

A summary of the LCI flows for the installation and use of ceramic tiles over concrete and wood subfloors are shown in Table ***28*** and ***29*** at the end of the chapter. The constituents of the latex/mortar blend used to install tiles are shown in Table ***27***. As stated in the BEES manual, ceramic tiles have a 50 year service life (Lippiatt C. Barbara, 2007, p. 158). In developing a model for ceramic tiles, the installation technosphere flows (shown in the tables 26 and 27) for a single installation were halved to

[14] See http://www.carpet-rug.org/residential-customers/cleaning-and-maintenance/basic-cleaning/vacuuming.cfm

[15] See http://www.carpet-rug.org/residential-customers/cleaning-and-maintenance/basic-cleaning/vacuuming.cfm

normalize the flows to the FU. According to the Tile Council of America Inc. (2001, p. 16), ceramic tiles do not require the installation of a water proof membrane over concrete subfloors when installed with latex-Portland cement mortar.

Table 27 Latex/motar blend constituents

Constituent		Mass %
Mortar	Portland cement	69.6
	Sand	17.0
Styrene-butadiene latex		3.4

Source: Lippiatt C. Barbara, 2007, p. 159

4.3.4 Vinyl Composition Tiles

A summary of the installation and use phase inputs for vinyl composition tiles over concrete and wood subfloors are shown in Table ***28*** and ***29*** at the end of the chapter. Data available in the BEES manual and the installation guidelines of the major VCT manufacturers were used to develop the use phase LCI. VCTs last 40years based on historic observations (Lippiatt C. Barbara, 2007, p. 168) and hence a 40-year service was assumed in modeling the use phase. In developing a model for VCT, the installation technosphere flows (shown in the tables 28 and 29) for a 40 year service life were normalized on a proportionate basis to the default service life to calculate per FU flows.

4.3.5 Cork Floating Floor Tiles

A summary of the installation and use phase inputs for cork floating floor tiles over concrete and wood subfloors are provided in Table ***28*** and ***29*** at the end of the chapter. Note that the mass of flooring boards was estimated using the cork flooring density information available in the BEES manual. BEES assumed a 50 year service life. But, the structural warranty given by US flooring companies varies from 5 to 25 years[16]. Therefore, the service life was assumed to be 25 years. Finishing application was assumed to be done once in every five years during use, considering the finish warranty given by North American flooring companies.

4.3.6 Linoleum Flooring

A summary of the installation and use phase inputs for linoleum over concrete and wood subfloors are provided in Table ***28*** and ***29*** at the end of the chapter. Linoleum flooring has a useful life of 30 years (Lippiatt C. Barbara, 2007, p.164), and therefore, no replacement was assumed during the 25-year use. In developing a model for linoleum, the installation technosphere flows (shown in the tables 26 and 27) for a 30 years service life were normalized on a proportionate basis to the default service life to calculate per FU flows. The use phase LCI was developed using data from the BEES manual and consumer awareness websites.

[16] See HomeStyleChoices.com. Cork Flooring Durability, Comfort & Unique Style: Warranty Varies Per Manufacturer. http://www.home-style-choices.com/cork-flooring.html.

Table 28 Flooring installation/use phase inventory – concrete subfloor

Technosphere flows		Unit	Quantity					
			Hardwood	Carpet	Ceramic tiles	VCT	Cork	Linoleum
For a single installation								
Flooring		Sq.ft.	1050[10] (1¼” wide, ¾” thick boards)	1057[9]	1100[2,*]	1050	1050 (639.35 kg)	1050 (279.5 kg)
Vapour barrier paper (polyethylene)		Sq.ft.	1020[10] (6 mil gauge)	-	-	1020[1] (0.2 mm gauge)	1020 (0.2 mm gauge)[6]	1020 (0.5 mm gauge)[3]
Underlay	Plywood	Sq.ft.	1060[10] (16mm thick)	-	-	-	-	-
	Rubber	kg.	-	58[8]	-	-	-	-
Nails		No.	300[10] (2” long, 18 gauge)	-	-	-	-	-
Adhesive		kg	6.35[10] (Carpenters’ glue)	60[9] (Styrene butadiene)	-	13.3[9, **] (Styrene butadiene)		27[9] (Acrylic polymer)
Latex mortar blend		kg	-	-	568.18[9]	-	-	-
Grout			-	-	57[5]	-	-	-
Stain and finish		l				-	14.0[7]	-
Sealant – water based polyurathane		l				-	8[7]	-
Installation waste		%	5[11]	5.7[9]	5[9]	5[9]	5[9]	5[3]
Flows for 25 years of use								
Electricity		kWh	-	1562.5[4]	-	-	-	-
Stain and finish		l			-	-	7.0[7]	-
VOC emissions		g	-	50.63[9]	1.72[9]	4.97[9]	-	5.57[9]

Notes : * Quantity includes tile replaced during the 50 year service life ** No waste assumed for adhesive

Sources:
1. Amitico International, 2010
2. Easy2.Com.,Inc., 2010
3. FindAnyFloor.com, 2008
4. ECEEE, 2010
5. Floortransformed.com, 2010
6. Globas Cork, 2010.
7. Natural Interiors 2010
8. Tootoo, 2008.
9. Lippiatt C. Barbara, 2007, p.158-208
10. PG Model Inc., Jobin Jerome, 2010
11. PG Model Inc., published year not known, p.3

Table 29 Flooring installation/use phase inventory – wood subfloor

Technosphere flows		**Unit**	**Quantity**					
			Hardwood	**Carpet**	**Ceramic tiles**	**VCT**	**Cork**	**Linoleum**
Flor a single installation								
Flooring		Sq.ft.	1050[10] (1¼” wide, ¾” thick boards)	1057	1100[3,*]	1050	1050 (639.35 kg)[11]	1070 (279.5 kg)[11]
Vapour barrier paper (polyethylene)		Sq.ft.	1020[10] (6 mil gauge)	-	1020[12] (1/8” gauge)	1020 (0.2 mm gauge)[1]	1020[7] (0.2 mm gauge)	1020 (0.5 mm gauge)[5]
Underlay	Plywood	Sq.ft.	1060[10] (16mm thick)	-	1060 (exterior grade – 1,1/8” thick)[2]	1060 (3/4” thick)[1]	1060 (1/4” thick)[7]	1060 (1/4” thick)[5]
	Rubber	kg.	-	58[13]	-	-	-	-
Nails		No.	300[10] (2” long, 18 gauge)	-	300 (2½”)	300 (1¼”)	300 (1¾”)	300 (1¼ ”, 3d)[5]
Adhesive		kg	6.35[12] (Carpenters’ glue)	60[8] (Styrene butadiene)	-	13.3[11, **] (Styrene butadiene)	-	27[11] (Acrylic polymer)
Latex mortar blend		kg	-	-	568.18[11]	-		
Grout			-	-	57[5]	-		
Stain and finish		l	-	-	-	-	14.0[9]	
Sealant – water based polyurathane		l	-	-	-	-	8[9]	
Installation waste		%	5[11]	5.7[8]	5[8]	5[8]	5[8]	7[5]
Flows for 25 years of use								
Electricity		kWh	-	1562.5[4]	-	-		
Stain and finish		l	-	-	-	-	7.0[9]	
VOC emissions		g	-	50.63[8]	1.72[8]	4.97[8]		5.57[8]

Notes: * Quantity includes tile replaced during the 50 year service life ** No waste assumed for adhesive

Sources:

1. Amitico International, 2010.
2. Ceramic tile floor information, 2010.
3. Easy2.Com.,Inc., 2010
4. ECEEE, 2010
5. FindAnyFloor.com, 2008
6. Floortransformed.com, 2010
7. Globas Cork, 2010
8. Lippiatt C. Barbara, 2007, p.158-208
9. Natural Interiors 2010
10. PG Model Inc., Jobin Jerome, 2010
11. PG Model Inc., published year not known, p.3
12. Time4 Media Inc., 2006.
13. Tootoo, 2008

5 End of Life

This section describes the end of life scenarios chosen to model the disposing of floor covering at the end of the service life. A default end of life scenario was chosen based on the widely used construction and demolition (C&D) waste disposal and management practice in the US. Attention was paid to the common C&D waste disposal practice specifically occurring in the default building site city in developing the end-of-life scenario. Alternative end-of-life disposal scenarios are addressed in sensitivity analysis.

5.1 Current Status of C&D Waste Management

According to the USEPA estimates, in 2003 about 52% of C&D waste was discarded in landfills while approximately 48% was recovered for reuse, recycle, or use in energy recovery applications. A major portion of C&D waste ends up in specifically designated landfills with the remainder is disposed with municipal solid waste (MSW) and disposed in MSW landfills or combusted in incinerators (USEPA 2009a).

In studies of material fate in landfills, it has been found that organic materials do not completely decompose (Ham and Bookter, 1982) as landfills do not provide a perfect environment for anaerobic micro-bacteria. Estimates for the decomposition of solid-wood have been estimated by the US Forest Service and vary from as little as 3% (Micales and Skog, 1997) to a more recent estimate of 23% (Skog, 2008). Decomposition emits landfill gases, mainly CH_4 and CO_2 (50:50) into the atmosphere (USEPA, 2006, p. 81).

About 59% of modern landfills in the US are equipped with some sort of landfill gas collection system (USEPA, 2006, p.87), which operate at an average well density of 1 well/ 4000 m^2 (Themelis and Ulloa, 2007). Average well density results in the capture of 75% of emitted LFG, while 25% enters the atmosphere (USEPA, 1995). After capture, landfill gas is either openly flared or combusted with energy recovery to avoid the combustion of fossil fuels by providing heat for direct use or electricity generation. As per the calculations based on the information provided in USEPA (2009b, p.8-3), about 53% of landfill gas (LFG) was burned for energy recovery while the remaining 47% was flared in 2007.

5.2 Default End-of-Life Disposal Scenario

The USEPA report on C&D waste management in 2003 states that 48% recovery rate may be an overestimate because of the inclusion of materials coming from non-building sources; and. not represents the entire country since the sample states represent only about 21% of the US population (USEPA 2009a). The report also did not specify the fate of C&D waste materials on an individual basis. While the recovery rates of each of the flooring type considered for the analysis were not known, flooring products like carpet, ceramic tiles, and linoleum might have mostly ended up in landfills. As such, in order to maintain the uniformity of analysis across all the flooring product systems, landfilling was considered to be the default end-of-life disposal scenario. This in turn, helps the hardwood flooring proponent to fully understand the impacts of landfilling hardwood flooring at its end of the service life.

As a routine practice, underlayment is removed along with the floor covering before installing new flooring (Black and Decker, 2009). The end-of-life processes are depicted in Figure ***11***. The disposal process starts with the hauling of dismantled flooring to the landfill. New York City recently ran out all its own landfill space and started exporting all its waste to neighboring landfills (Cohen Steve, 2008). A hauling distance was chosen to represent the waste disposal practice of the City.

The current status of LFG recovery in the U.S. was taken into account in modeling of the landfilling of flooring. The captured gas is comprised of equal parts carbon dioxide and methane by mass and has a heating value of 0.54 MJ/m^3 (Themelis and Ulloa, 2007). The LFG is burned in energy recovery systems, and is assumed to substitute for coal and natural gas in electricity generation (i.e., system expansion was used to calculate the avoided flows).

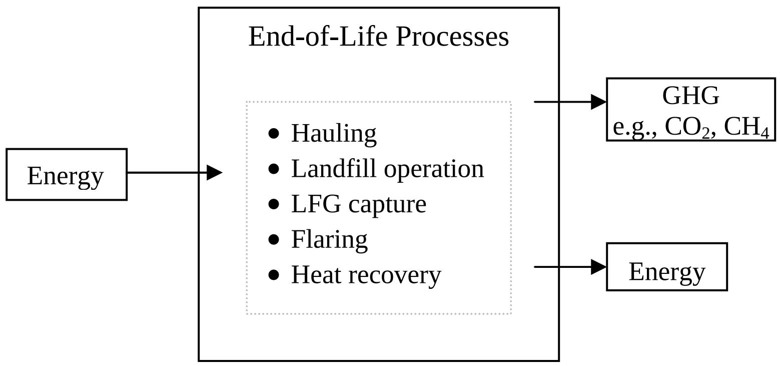

Figure 11 End-of-life processes

Table ***30*** summarizes the assumptions used to model the production, capture, and avoidance of fuels caused by the landfilling of wood-based materials at the end of their service lives. The estimated GHG emissions resulted from flooring and their plywood underlayment disposal in landfills are shown in ***Table 31***. Manufacturers claim that both cork and linoleum flooring materials are biodegradable. Therefore, GHG emissions from disposal of those two flooring types in landfills were estimated based on the assumption that they decompose in a similar manner as solid wood. The other flooring types (i.e., ceramic, vinyl, and nylon carpet) are generally resistant to degradation and were considered to be inert materials in landfills. US EI data for building waste disposal and inert material landfill was used to model the flooring disposal in landfills.

Table 30 Hauling and landfill gas management modeling assumptions

Process	Assumed value
Hauling distance	165 km
Wood decomposition	23%
Capture equipment in place	59%
Average capture efficiency	75%
Energy recovery	53%
Energy value for fuel offset	0.54 MJ/m^3

Table 31 Landfill gas management net greenhouse gas emissions per installation

Landfill	Emissions	Amount
Hardwood flooring: 1129.79 kg	CO_2	407.50
	CH_4	18.78
Cork flooring: 691.92 kg	CO_2	271.91
	CH_4	12.53
Linoleum flooring*: 272.93 kg	CO_2	103.34
	CH_4	4.76
Plywood: (per 1kg)	CO_2	0.37
	CH_4	0.02

Note: Estimated carbon content in linoleum is 50.6%.

5.3 LCI Data Sources

Table ***32*** presents the LCI data sources used to model the environmental impacts from landfilling of flooring and other materials at the EOL. These data sources were modified with the hauling distance and net GHG emission numbers mentioned in Tables 30 and 31 respectively to make that data more representative to circumstances in the US. Note that linoleum is mentioned under both wood based materials and polyethylene because linoleum was considered to be behaving like both wood (in the base case) and plastic (in the sensitivity analysis) in landfills.

Table 32 LCI data sources used to model landfilling of materials at the EOL

Material	Data Source	Comments
Wood based materials (e.g., hardwood, cork, plywood, linoleum etc.)	US EI database	Disposal of building wood waste (untreated)
Polyethylene, nylon (carpet), vinyl (VCT), and linoleum	US EI database	Disposal of inert waste in inert material landfill
Nails	US EI database	Disposal, steel, 0% water, to inert material landfill
Polyurethane	US EI database	Disposal, polyurethane, 0.2% water, to inert material landfill
Ceramic tiles	US EI database	Disposal, glass, 0% water, to inert material landfill
Cement mortar and grout	US EI database	Disposal, cement, hydrated, 0% water, to residual material landfill
Sealant and finish including acrylic binder	US EI database	Disposal, paint, 0% water, to inert material landfill/

6 Life Cycle Impact Assessment Results

This chapter discusses the LCIA results of the flooring systems. First, the chapter provides a discussion on the results of the contribution analyses performed for each of the flooring systems and states where the significant environmental impacts occur within each. The robustness of findings was addressed by considering installation over a wood subfloor in the sensitivity analysis. A comparative assessment is then provided to compare and contrast the life cycle environmental burdens of the six flooring types.

6.1 Contribution Analysis

6.1.1 Cradle-to-grave Hardwood Flooring Product System

LCIA results of the contribution analysis performed for the hardwood flooring product system are shown in Tables ***33*** and ***34*** on an absolute and percent basis respectively. The cradle-to-grave flooring system uses approximately 44.6 GJ of energy in total, and about 72% of the total energy is consumed during flooring manufacturing. Also about 33% of non-renewable fossil fuel consumption occurs during the manufacturing phase. In addition to energy use, other impacts also occur during flooring manufacturing and hence, it is the most dominant life cycle stage in the hardwood flooring system in terms of environmental impacts. Therefore, more attention should be given to the flooring manufacturing phase to reduce the overall impacts of the complete flooring system.

The end-of-life disposal is another potential area for improvement as a considerable amount of GHG emissions occur from landfilling flooring at the end of life, particularly caused by methane emissions. Other life cycle stages are either comparatively small or minor depending on their contributions to the totals. For instance, contributions from sawmilling and the flooring use phase are comparatively small. These phases account for approximately 7-12% of the total energy that is consumed while other impacts range from 2-28%. Impacts from logging are minor and account for less than 3% of energy consumption. However, logging creates 22% of the life cycle smog due to incomplete combustion by mobile sources like trucks and heavy machinery.

There are climate change benefits of using hardwood flooring when taking into account the carbon sequestered in flooring boards. For example, atmospheric CO_2 sequestered in flooring boards during forest growth is more than enough to offset the life cycle CO_2 emissions.

Table 33 Hardwood flooring LCIA summary by life cycle stage - absolute values

Impact category	Unit	Total	Forest C	Logging	Sawmilling	Flooring manufacturing	Transportation to Consumer	Installation and Use	End-of-life
Global warming	kg CO2 eq.	-444.72	-1877.75	136.45	123.47	304.67	88.70	-872.26	1651.99
Acidification	H+ moles eq.	455.88	0.00	76.98	76.05	136.26	29.34	123.39	13.87
Eutrophication	kg N eq.	0.49	0.00	0.07	0.07	0.21	0.03	0.09	0.02
Ozone depletion	kg CFC-11 eq.	4.34E-06	0.00	1.42E-07	7.68E-08	3.31E-06	3.33E-09	1.27E-07	6.8E-07
Smog	kg NOx eq.	7.87	0.00	1.70	1.52	2.34	0.61	1.32	0.40
Total energy	MJ eq.	44630.41	0.00	1879.80	3364.54	32355.30	1213.31	5284.99	532.47
Non renewable, fossil	MJ eq.	14909.01	0.00	1867.91	1743.75	4909.56	1203.04	4656.83	527.93
Non-renewable, nuclear	MJ eq	1788.46	0.00	11.53	83.34	1073.93	10.27	604.94	4.46
Renewable, biomass	MJ eq.	24208.43	0.00	0.31	601.81	23588.60	0.00	17.69	0.02
Other renewables, eg. Hydro, solar, wind	MJ eq.	3724.50	0.00	0.06	935.64	2783.21	0.00	5.53	0.06

Table 34 Hardwood flooring LCIA summary by life cycle stage – percent basis

Impact category	Unit	Total	Logging	Sawmilling	Flooring manufacturing	Transportation to Consumer	Installation and Use	End-of-life
Global warming	%	-100	-391.55%	27.76	68.51	19.95	-196.14%	371.47
Acidification	%	100	16.89	16.68	29.89	6.44	27.07	3.04
Eutrophication	%	100	15.09	13.77	43.55	5.70	18.72	3.16
Ozone depletion	%	100	3.27	1.77	76.27	0.08	2.94	15.67
Smog	%	100	21.59	19.25	29.70	7.72	16.70	5.04
Total energy	%	100	4.21	7.54	72.50	2.72	11.84	1.19
Non renewable, fossil	%	100	12.53	11.70	32.93	8.07	31.23	3.54
Non-renewable, nuclear	%	100	0.64	4.66	60.05	0.57	33.82	0.25
Renewable, biomass	%	100	0.00	2.49	97.44	0.00	0.07	0.00
Other renewables, eg. Hydro, solar, wind	%	100	0.00	25.12	74.73	0.00	0.15	0.00

The results of the contribution analysis performed for each of the life cycle stage to identify the hotspots within the stages are discussed below.

6.1.1.1 Contribution analysis of cradle-to-gate hardwood lumber production

LCIA results for cradle-to-gate hardwood lumber manufacturing are presented in Table ***35*** on an absolute basis. Figure ***12*** depicts the same results expressed on a percent basis. Between the two processes, resource extraction from forests (i.e., logging) contributes more towards the chosen environmental impact indicators than sawmilling due to its greater reliance on non-renewable fossil fuel than sawmilling. For example, although sawmilling consumes 55% more total energy than harvesting, about half of its total energy requirement is met from non-fossil fuel sources, mainly electricity and wood waste biofuel. Quebec electricity is mostly hydro and nuclear (97% and 2% respectively). Both wood fuel and electricity generated from hydro and nuclear sources create significantly less environmental burden in terms of the selected impact indicators compared to fossil energy sources. On the other hand, timber harvesting is a fossil energy-intensive process that completely relies on diesel use for heavy machinery and gasoline for chainsawing and crew transport.

The contributions from other process inputs such as ancillary materials (e.g. hydraulic fluid, lubricating oil, motor oil, grease etc.) and packaging material used during lumber manufacturing are minor. While logging is a fossil energy intensive process, sawmilling offers opportunities for reducing the overall environmental stress of the two processes through improving the logs to lumber conversion efficiency (i.e., more efficient resource utilization and internal recycling of wood waste for biofuel to supplement fossil energy).

Table 35 LCIA results for manufacturing one thousand board feet of green lumber – absolute basis

Impact category	Unit	Total	Sawmilling	Logging
Global warming	kg CO2 eq	122.17	53.05	69.12
Acidification	H+ moles eq	77.52	38.53	39.00
Eutrophication	kg N eq	0.072	0.034	0.038
Ozone depletion	kg CFC-11 eq	1.11E-07	3.89E-08	7.19E-08
Smog	kg NOx eq	1.63	0.77	0.86
Total energy	MJ eq	2656.71	1704.43	952.28
Non renewable, fossil	*MJ eq*	1829.61	883.36	946.26
Non-renewable, nuclear	*MJ eq*	48.06	42.22	5.84
Renewable, biomass	*MJ eq*	305.02	304.87	0.16
Renewable, other	*MJ eq*	474.01	473.98	0.03

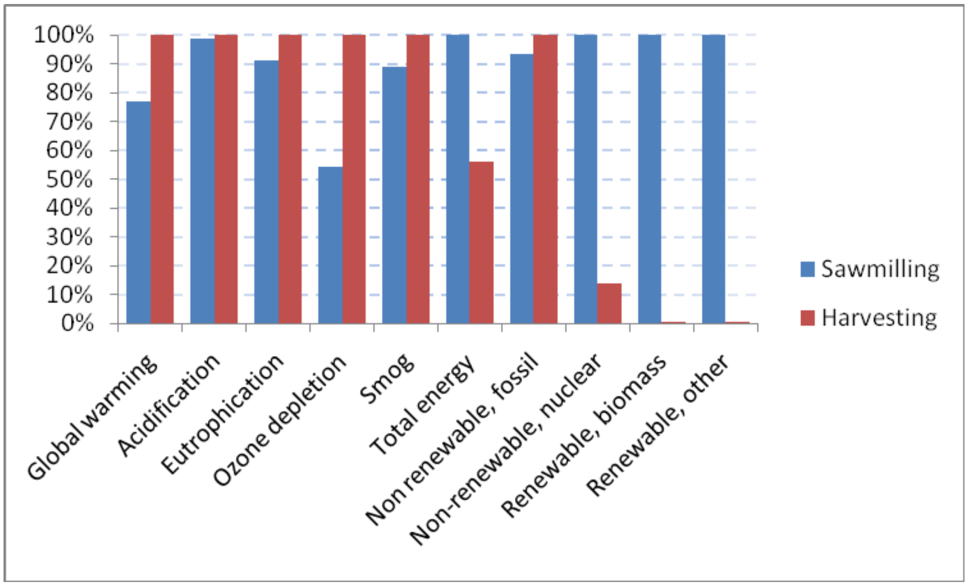

Figure 12 LCIA results for manufacturing one thousand board feet of green lumber – percent basis

6.1.1.2 Gate-to-gate flooring manufacturing contribution analysis

The LCIA results of the gate-to-gate flooring manufacture are presented in Table ***36*** and Figure ***13*** on an absolute value and percent basis respectively. Hardwood flooring manufacturing requires around 31 GJ of energy on a 1000 sq. ft. of pre-finished hardwood flooring basis, and about 73% of this total energy is met from renewable bioenergy sources. Among the three unit processes in flooring manufacturing, the drying process is the most energy intensive process that accounts for approximately 75% of total energy consumption on a gate-to-gate basis. Over 83% of that energy is derived from renewable fuels.

Despite the reliance on biomass fuel, the drying unit process is responsible for most of the GHG emissions. In addition, the drying process also contributes significantly towards all other impact categories relative to the other two unit processes. On the other hand, milling, finishing, and packaging unit processes consume 11% and 14% of total energy respectively and their impacts are significantly less than the drying process. This is due to the fact that milling and finishing are primarily powered by electricity supplied from the regional grids (Ontario and Quebec), which mainly rely on hydro and nuclear sources (97% and 2% respectively). The contribution analysis results suggest that attention should be given to the drying process to reduce the environmental impacts from flooring manufacturing.

Table 36 LCIA results for manufacturing one thousand board feet of pre-finished hardwood flooring – absolute basis

Impact category	Unit	Total	Milling	Drying	Finishing
Global warming	kg CO2 eq	290.17	34.43	145.16	110.57
Acidification	H+ moles eq	129.77	12.69	84.27	32.81
Eutrophication	kg N eq	0.20	0.00	0.08	0.12
Ozone depletion	kg CFC-11 eq	3.15E-06	4.31E-08	5.7E-09	3.1E-06
Smog	kg NOx eq	2.23	0.08	1.88	0.26
Total energy	MJ eq	30814.57	3359.30	23092.26	4363.01
Non renewable, fossil	*MJ eq*	4675.77	581.83	2185.98	1907.96
Non-renewable, nuclear	*MJ eq*	1022.79	565.23	47.90	409.66
Renewable, biomass	*MJ eq*	22465.33	0.06	20739.98	1725.29
Renewable, other	*MJ eq*	2650.68	2212.18	118.40	320.10

Note: Carbon sequestered in hog fuel was credited in calculating global warming impacts

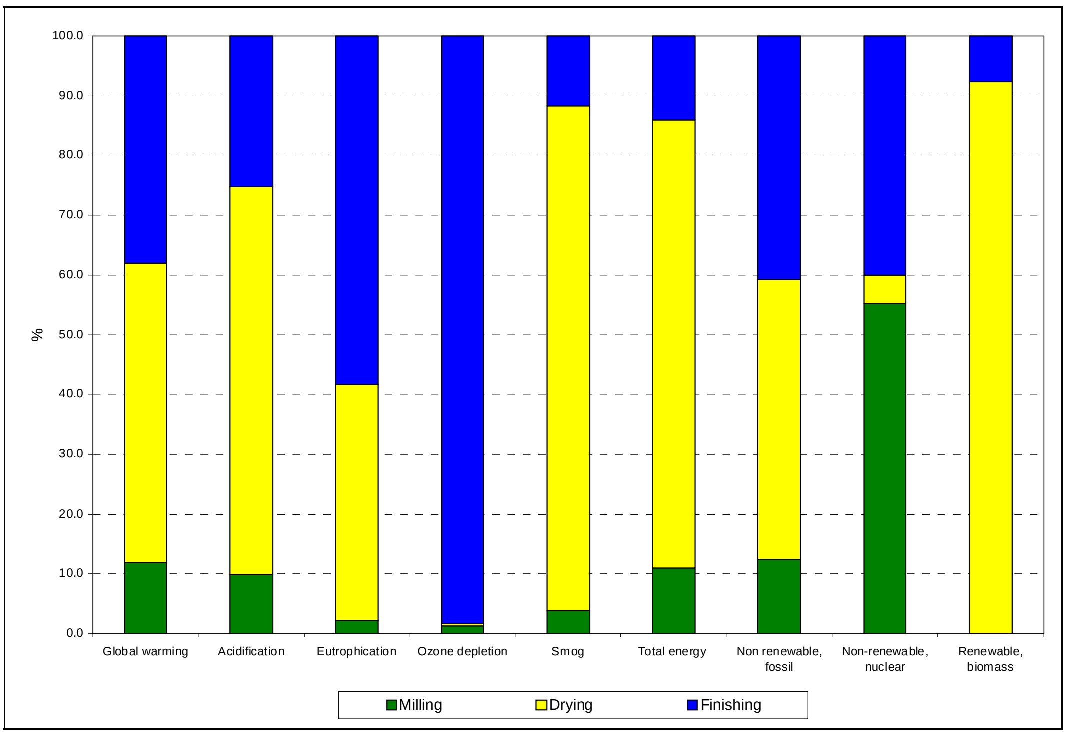

Figure 13 LCIA results for manufacturing one thousand board feet of pre-finished hardwood flooring – percent basis

6.1.2 Cradle-to-grave Typical Carpet Flooring System

The results of the LCIA by life cycle stage are summarized in Tables ***37*** and ***38*** on an absolute and percent basis respectively. Among the four life cycle stages, both carpet manufacturing and installation and use phases are the most dominant phases in terms of both energy use and environmental impacts. The both life cycle stages consume more or less the same amount of energy (49% each) and are responsible for more than 95% of the total emissions in all the impact categories. The highest eutrophication effects (about 83%) occurr during the carpet manufacturing phase. Electricity consumption for vacuuming is the primary driver of the impacts caused during the use phase. Impacts from carpet transport to the consumer and the end-of-life are minor, accounting for less than 3% of total impacts.

Table 37 Typical carpet LCIA summary by life cycle stage - absolute values

Impact category	Unit	Total	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	kg CO2 eq	4513.99	2435.19	70.97	1993.88	13.95
Acidification	H+ moles eq	1340.62	537.47	23.48	774.65	5.03
Eutrophication	kg N eq	3.78	3.32	0.02	0.43	0.01
Ozone depletion	kg CFC-11 eq	9.71E-05	1.48E-05	2.66E-09	8.2E-05	2.47E-07
Smog	kg NOx eq	13.28	5.76	0.49	6.92	0.11
Total energy	MJ eq	92400.48	45506.94	970.82	45729.63	193.09
Non-renewable, fossil	MJ eq	82689.48	41457.13	962.60	40078.30	191.44
Non-renewable, nuclear	MJ eq	9142.44	3704.38	8.22	5428.22	1.62
Renewable, biomass	MJ eq	312.05	194.98	0.00	117.06	0.01
Renewable, other	MJ eq	256.52	150.45	0.00	106.04	0.02

Table 38 Typical carpet LCIA summary by life cycle stage – percentage basis

Impact category	Unit	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	%	53.95	1.57	44.17	0.31
Acidification	%	40.09	1.75	57.78	0.38
Eutrophication	%	87.80	0.59	11.45	0.15
Ozone depletion	%	15.29	0.00	84.46	0.25
Smog	%	43.41	3.67	52.13	0.79
Total energy	%	49.25	1.05	49.49	0.21
Non-renewable, fossil	%	50.14	1.16	48.47	0.23
Non-renewable, nuclear	%	40.52	0.09	59.37	0.02
Renewable, biomass	%	62.48	0.00	37.51	0.00
Renewable, other	%	58.65	0.00	41.34	0.01

6.1.3 Cradle-to-grave Ceramic Tile Flooring System

A summary of the LCIA results for ceramic tile installed on a concrete subfloor is shown in Tables ***39*** and ***40*** on an absolute and percent basis respectively. The cradle-to-grave flooring system uses a total of about 18 GJ of total energy. Approximately 50% and 44% of this total energy is consumed and 51% and 39% of GHG emissions occur during the resource extraction/manufacturing and use phases respectively. The raw material extraction/tile manufacturing and use phases are the dominant phases in the ceramic tile flooring system. The cement mortar mixture used during installation is a significant contributor towards the environmental impacts. The contributions from tile transportation to consumer and waste treatment are minor in terms of energy use and environmental impacts.

Table 39 Ceramic tile LCIA summary by life cycle stage for installation over concrete subfloor - absolute values

Impact category	Unit	Total	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	kg CO2 eq	716.07	363.85	46.09	276.82	29.31
Acidification	H+ moles eq	230.73	120.52	15.25	84.43	10.54
Eutrophication	kg N eq	0.34	0.09	0.01	0.11	0.13
Ozone depletion	kg CFC-11 eq	5.05E-05	4.96E-05	1.73E-09	3.36E-07	5.35E-07
Smog	kg NOx eq	2.82	1.27	0.32	1.01	0.22
Total energy	MJ eq	17908.02	8975.56	630.40	7896.06	406.00
Non-renewable, fossil	MJ eq	16763.40	8072.15	625.07	7663.71	402.47
Non-renewable, nuclear	MJ eq	535.06	319.98	5.34	206.28	3.46
Renewable, biomass	MJ eq	579.52	571.43	0.00	8.07	0.02
Renewable, other	MJ eq	30.05	12.00	0.00	18.00	0.05

Table 40 Ceramic tile LCIA summary by life cycle stage for installation over concrete subfloor – percentage basis

Impact category	Unit	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	%	50.81	6.44	38.66	4.09
Acidification	%	52.23	6.61	36.59	4.57
Eutrophication	%	25.96	4.26	31.70	38.09
Ozone depletion	%	98.27	0.00	0.67	1.06
Smog	%	45.02	11.22	35.95	7.81
Total energy	%	50.12	3.52	44.09	0.76
Non-renewable, fossil	%	48.15	3.73	45.72	2.40
Non-renewable, nuclear	%	59.80	1.00	38.55	0.65
Renewable, biomass	%	98.60	0.00	1.39	0.00
Renewable, other	%	39.93	0.00	59.90	0.17

6.1.4 Cradle-to-grave Vinyl Composition Tile Flooring System

Table ***41*** summarizes the results of the contribution analysis performed for the cradle-to-grave VCT flooring installed over a concrete subfloor on an absolute basis. The contributions of the life cycle stages are shown in Table ***42*** on a percentage basis. The VCT flooring system uses a total of 8,775 MJ of energy in its life cycle, and approximately 79% of that total energy is consumed during raw material extraction and manufacturing. This phase also accounts for nearly 75% of non-renewable fossil fuel on a complete life cycle basis. About 73-99% of the environmental impacts also occur during this phase and hence, raw material extraction and manufacturing is the most dominant life cycle stage in the VCT flooring system. The environmental burden of VCT installation and use is small as it has accounts for 7% of the total energy use and 1-25% of the environmental impacts. The contributions from the transportation to the consumer and end-of-life disposal stages are minor and account for less than 1% of the total energy and 1-7% of the environmental impacts.

Table 41 VCT LCIA summary by life cycle stage for installation over concrete subfloor – absolute values

Impact category	Unit	Total	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	kg CO2 eq	335.22	281.12	10.26	36.68	7.16
Acidification	H+ moles eq	114.52	83.82	3.39	24.72	2.58
Eutrophication	kg N eq	0.087	0.069	0.003	0.013	0.003
Ozone depletion	kg CFC-11 eq	1.48E-05	1.47E-05	3.85E-10	9.48E-09	1.27E-07
Smog	kg NOx eq	1.01	0.76	0.07	0.13	0.05
Total energy	MJ eq	8770.17	6921.91	140.36	1608.75	99.14
Non-renewable, fossil	MJ eq	7230.49	5414.75	139.18	1578.27	98.29
Non-renewable, nuclear	MJ eq	1476.55	1446.17	1.19	28.36	0.83
Renewable, biomass	MJ eq	5.24	4.80	0.00	0.44	0.00
Renewable, other	MJ eq	57.89	56.20	0.00	1.68	0.01

Table 42 VCT LCIA summary by life cycle stage for installation over concrete subfloor – percentage basis

Impact category	Unit	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	%	83.86	3.06	10.94	2.14
Acidification	%	73.20	2.96	21.58	2.25
Eutrophication	%	78.52	3.72	14.45	3.32
Ozone depletion	%	99.08	0.00	0.06	0.85
Smog	%	75.25	6.97	12.43	5.34
Total energy	%	78.93	1.60	18.34	1.13
Non-renewable, fossil	%	74.89	1.92	21.83	1.36
Non-renewable, nuclear	%	97.94	0.08	1.92	0.06
Renewable, biomass	%	91.54	0.00	8.38	0.08
Renewable, other	%	97.09	0.00	2.89	0.02

6.1.5 Cradle-to-grave Cork Flooring System

LCIA results for cork flooring installed over a concrete subfloor are depicted in Tables ***43*** and ***44*** on an absolute value and percentage basis respectively. The flooring system uses approximately 18,099 MJ of total energy on a complete life cycle basis. Raw material extraction and product manufacturing is the most dominant life cycle stage and accounts for 65% of total energy use and 40-62% of environmental impacts. About 72% of the total energy demand is met through non-renewable fossil fuel, and about 56% of that fossil fuel consumption occurs in the raw material extraction and manufacturing phase.

The amount of carbon sequestered in cork flooring system exceeds the total CO_2 emissions and hence, use of this flooring has a net climate change benefit of approximately 105 kg CO_2e per 1000 sq.ft. of installed flooring. The contributions from cork flooring installation and use are also significant and account for more than 25% of total energy and more than 15% of environmental impacts. Energy consumption during flooring delivery to consumer is small (about 8% of the total energy); however, its contributions to the impact categories like global warming, acidification, eutrophication, and smog are substantial (over 18%). A considerable amount of GHG emissions occur at the end-of-life from landfilling, although this phase is minor in terms of all other impact categories.

Table 43 Cork LCIA summary by life cycle stage for installation over concrete subfloor – absolute values

Impact category	Unit	Total	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	kg CO2 eq	-105.10	-944.75	108.84	156.91	573.90
Acidification	H+ moles eq	262.73	137.48	58.57	61.71	4.97
Eutrophication	kg N eq	0.98	0.60	0.18	0.19	0.01
Ozone depletion	kg CFC-11 eq	8E-05	3.17E-05	2.72E-06	4.54E-05	2.44E-07
Smog	kg NOx eq	2.44	1.17	0.76	0.37	0.14
Total energy	MJ eq	18095.95	11856.90	1514.69	4533.36	191.00
Non renewable, fossil	MJ eq	13051.33	7343.18	1502.34	4016.44	189.38
Non-renewable, nuclear	MJ eq	1546.18	1180.60	12.10	351.88	1.60
Renewable, biomass	MJ eq	2944.31	2894.14	0.07	50.09	0.01
Renewable, other	MJ eq	554.12	438.97	0.18	114.95	0.02

Table 44 Cork LCIA summary by life cycle stage for installation over concrete subfloor – percentage basis

Impact category	Unit	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	%	-898.93	103.56	149.30	546.06
Acidification	%	52.33	22.29	23.49	1.89
Eutrophication	%	61.66	18.21	19.56	0.57
Ozone depletion	%	39.55	3.40	56.75	0.30
Smog	%	47.87	31.33	15.01	5.79
Total energy	%	65.52	8.37	25.05	1.06
Non renewable, fossil	%	56.26	11.51	30.77	1.45
Non-renewable, nuclear	%	76.36	0.78	22.76	0.10
Renewable, biomass	%	98.30	0.00	1.70	0.00
Renewable, other	%	56.26	11.51	30.77	1.45

6.1.6 Cradle-to-grave Linoleum Flooring System

The LCIA results for linoleum installed over a concrete subfloor are presented in Table ***45*** on an absolute value basis. A summary of the results calculated on a percent basis are shown in Table ***46***. The flooring system consumes about 12,914 MJ of total energy during its life cycle, and nearly 88% of the total energy is met using fossil fuel. Among the cradle-to-grave life cycle stages, about 68% of the total energy is consumed during raw material extraction and manufacturing while 64-98% of environmental impacts occur during this phase. Note that the greenhouse gas emissions of the extraction and manufacturing phase is a net credit when the carbon sequestration in the organic ingredients (linseed oil, tall oil, cork and wood flour, and jute) is considered.

The installation and use phase is also significant and accounts for around 29% of the total energy consumption. More than one half of global warming and some amounts of acidification, ozone depletion effects occur in this phase. Energy consumption during the other stages (flooring delivery to consumer and end-of-life) are minor (less than 1%). Significant GHG emissions occur from landfilling linoleum at the end of the service life due to the methane emissions that are not captured for energy recovery.

Table 45 Linoleum LCIA summary by life cycle stage for installation over concrete subfloor – absolute values

Impact category	Unit	Total	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	kg CO2 eq	146.65	-132.91	20.39	80.48	178.70
Acidification	H+ moles eq	357.08	268.15	20.49	66.59	1.85
Eutrophication	kg N eq	1.62	1.58	0.017	0.023	0.002
Ozone depletion	kg CFC-11 eq	1.39E-05	9.83E-06	1.65E-06	2.37E-06	9.07E-08
Smog	kg NOx eq	3.69	3.19	0.26	0.20	0.05
Total energy	MJ eq	12914.05	8764.24	292.94	3785.81	71.06
Non renewable, fossil	MJ eq	11341.29	7300.21	290.29	3680.34	70.45
Non-renewable, nuclear	MJ eq	690.65	591.12	2.40	96.54	0.60
Renewable, biomass	MJ eq	853.15	850.38	0.048	2.73	0.003
Renewable, other	MJ eq	28.96	22.54	0.202	6.21	0.008

Table 46 Linoleum LCIA summary by life cycle stage for installation over concrete subfloor – percentage basis

Impact category	Unit	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	%	-90.63%	13.90%	54.88%	121.85%
Acidification	%	75.10	5.74	18.65	0.52
Eutrophication	%	97.43	1.05	1.39	0.13
Ozone depletion	%	70.50	11.82	17.03	0.65
Smog	%	86.33	6.95	5.36	1.36
Total energy	%	67.87	2.27	29.32	0.55
Non renewable, fossil	%	64.37	2.56	32.45	0.62
Non-renewable, nuclear	%	85.59	0.35	13.98	0.09
Renewable, biomass	%	99.67	0.01	0.32	0.00
Renewable, other	%	77.84	0.70	21.43	0.03

6.2 Comparative Flooring LCIA Results

The comparative LCIA results of the alternative flooring systems over a 25 year life cycle on an absolute value basis are summarized in Table ***47***. Figure ***14*** depicts the results on a percent basis, normalizing to the flooring system exhibiting the highest value for each impact indicator.

Energy Use:

While considering the total life cycle energy consumption, there is significant variation among the six flooring types considered for the comparison. Carpet is the most energy intensive flooring system, consuming around three times more energy than hardwood and 2-7 times more energy than the other four flooring products. Hardwood flooring is the second most energy intensive product, with total energy consumption 2.5-5 times higher than the other four flooring products. VCT is the least energy intensive of the six flooring types.

Hardwood flooring uses significant renewable energy sources (biofuel and hydro and nuclear powered electricity). Despite being the second highest total energy consumer, this material is on par with ceramic, cork, and linoleum floorings in terms of fossil energy consumption.

Environmental Impacts:

Carpet also causes the greatest environmental impacts for all the categories due to its heavy use of fossil fuels. No single product outperformed all others in the various impact categories that were considered. For instance, VCT flooring had the lowest impacts in the categories of acidification, eutrophication, and smog while hardwood flooring demonstrated the best performance in terms of global warming and ozone depletion. The carbon sequestration benefits of the hardwood flooring caused this material to exhibit a net credit of carbon emissions of approximately 445 kg CO_2e. Cork flooring also exhibited a smaller net climate change benefit (105 kg CO_2e).

Table 47 Comparative flooring LCIA results for the installation over concrete subfloors

Impact category	Unit	Hardwood	Carpet	Ceramic tiles	VCT	Cork	Linoleum
Global warming	kg CO2 eq	-444.72	4513.99	716.07	335.22	-105.10	146.65
Acidification	H+ moles eq	455.88	1340.62	230.73	114.52	262.73	357.08
Eutrophication	kg N eq	0.49	3.78	0.34	0.09	0.98	1.62
Ozone depletion	kg CFC-11 eq	4.34E-06	9.71E-05	5.05E-05	1.48E-05	8E-05	1.39E-05
Smog	kg NOx eq	7.87	13.28	2.82	1.01	2.44	3.69
Total energy	MJ eq	44630.41	92400.48	17908.02	8770.17	18095.95	12914.05
Non renewable, fossil	MJ eq	14909.01	82689.48	16763.40	7230.49	13051.33	11341.29
Non-renewable, nuclear	MJ eq	1788.46	9142.44	535.06	1476.55	1546.18	690.65
Renewable, biomass	MJ eq	24208.43	312.05	579.52	5.24	2944.31	853.15
Renewable, other	MJ eq	3724.50	256.52	30.05	57.89	554.12	28.96

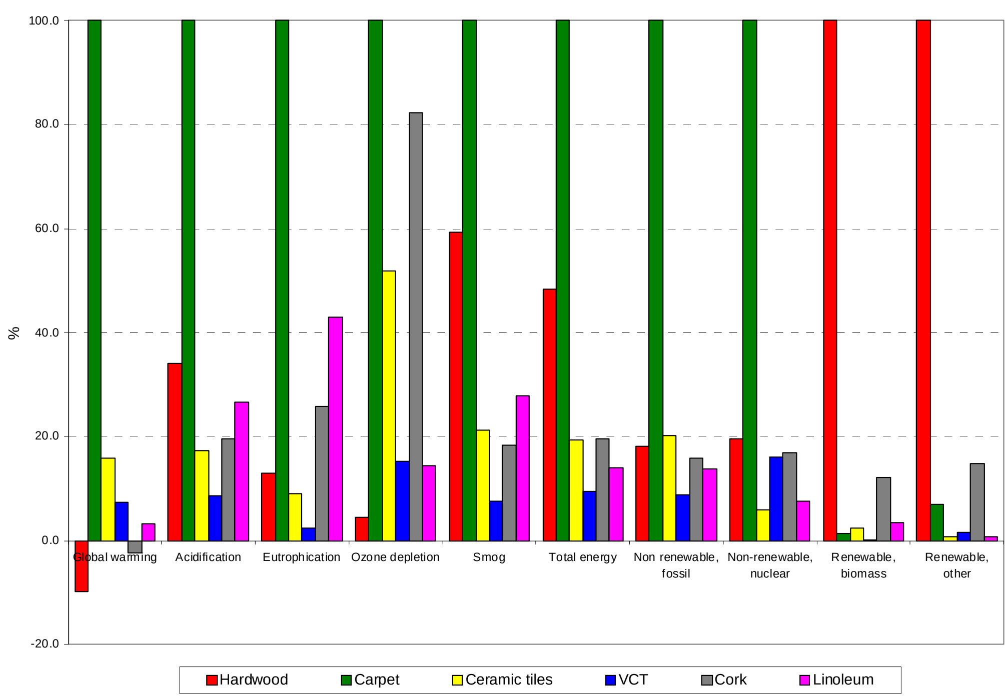

Figure 14 Comparative flooring LCIA results for the installation over concrete subfloor on a percent basis

7 Interpretation

In this chapter, sources of uncertainty are identified by revisiting the assumptions that were made in developing the life cycle models as well as the results of the contribution analysis and comparative LCIA to address the significant issues. The sources of uncertainties in the findings of the LCIA are discussed and evaluated to provide context to the conclusions and recommendations.

7.1 Sources of Uncertainty

The author maintained the equivalency of the flooring types selected for the comparative assertion throughout the study by treating all the flooring types in a similar manner. For instance, the study defined a same FU based on a selected set of performance characteristics across all the flooring types and applied this FU to normalize process inputs and environmental output flows for each of the flooring system. In addition, the equivalency was maintained through the application of the same methodology across all the flooring types; applied the same system boundaries, decision rules including cut off criteria to evaluate inputs and environmental outputs, and impact assessment. Despite all these efforts, uncertainty still prevails in the baseline findings in the areas mentioned below.

7.1.1 Goal and scope definition

Cleaning

In defining the study goals and scope, periodic cleaning of the selected floorings for the comparison was excluded from the system boundary because there was no available data. This element was excluded because of difficulty in modeling the variety of cleaning products available in the market and the average application of them. In the absence of data, it is difficult to comment how this omission affects the final results of the comparative assertion but it is presumed to be of little overall consequence.

Subfloor differences

A concrete subfloor was chosen as the baseline to perform LCIA for a default building site. The materials may have potentially significant different results if flooring is installed over wood subfloors that require different underlayment.

Building locations

Significant discrepancies could occur in the results when flooring is installed in a building site that is far from the manufacturing site. This is particularly the case with the more dense flooring materials.

Allocation principles

In the hardwood flooring product system, economic allocation principles were used to partition environmental impacts between main products and co-products. As a result, most of the environmental burden was allocated to flooring and lumber, which are more valued products than their less valued co-products. Environmental burden of flooring would be lower if the physical allocation is applied or co-products are used for higher value purposes.

Impact assessment method used

TRACI was used to calculate LCIA results due to the N.American focus of the study, but the baseline findings, may differ with the other impact assessment methods focused on the similar impact categories.

7.1.2 Inventory analysis

Data quality and missing data:

In creating inventories for the cradle-to-gate systems, the study team gathered firsthand data for the hardwood flooring manufacturing. This data represents the actual hardwood flooring industry situation in eastern Canada. The data was verified through mass balances for precision and accuracy. The data published in the BEES manual was used for the other five flooring types. BEES has compiled that data mostly from secondary data sources and to some extent from the information received from industry contacts, and therefore, the author could not comment on the representativeness and reproducibility of that data. Some insight into data completeness and data quality is presented in Table ***48***. No data was available for power consumption during installation for any of the flooring types, but flooring installation is a generally a manual process that consumes small amount of electricity.

Table 48 Flooring manufacturing missing data and data quality summary

Flooring type	Data sources	Data quality	Comments
Hardwood flooring	Primary survey	High	Missing data on power consumption during flooring installation
Carpet	Secondary data (BEES)	Low - medium	Missing data: • internal energy and ancillary material consumption data for material handling, facility heating, and packaging and packing material consumption • power consumption during flooring installation
Ceramic tiles	Secondary data (BEES and other sources)	Low - medium	Missing data: • internal energy and ancillary material consumption data for material handling, facility heating, and packaging and packing material consumption • power consumption during flooring installation
VCT	Secondary data (BEES)	Low - medium	Missing data: • internal energy and ancillary material consumption data for material handling, facility heating, and packaging and packing material consumption • power consumption during flooring installation
Cork	Secondary data (BEES)	Low - medium	Missing data: • internal energy and ancillary material consumption data for material handling, facility heating, and packaging and packing material consumption • power consumption during flooring installation
Linoleum	Secondary data (BEES)	Low - medium	Missing data: • internal energy and ancillary material consumption data for material handling, facility heating, and packaging and packing material consumption • power consumption during flooring installation

Assumptions on the flooring service lives:

The service lives of the flooring products were based on the information available in BEES and warranties given by major flooring manufacturers. While there are warranty variations within some of the flooring types, the actual life spans of floorings also vary. We know that individual practice may differ from this somewhat, with some changing flooring products before the warranty expires for aesthetic or other reasons. People tend to replace flooring when a home is renovated or a new owner moves into a home, and in either case. Changing the replacement frequency would significantly vary the results directly related to the length of the service life.

Assumptions on the frequent floor cleaning

Among all the flooring types, only carpet was assumed to be vacuum cleaned. However, consumers may vacuum clean other floorings as well in order to remove dust and grit.

Assumptions on the end of life phase:

The technosphere flows for the end of life stage were developed based on a default landfilling scenario. However, according to the most recent construction and demolition waste disposal data in the US, 52% of waste ends up in landfills with 48% recycled for other uses.

7.2 Evaluation of Uncertainty – Sensitivity Checks

Due to the lack of statistical distribution data for USLCI datasets, author performed a sensitivity analysis to test the validity of the baseline modeling results calculated for the installations. Sensitivity scenarios were developed by considering the potential subfloor differences, the assumptions made for each flooring product service lives, and for other elements found to be significant drivers of impacts in the contribution analysis.

7.2.1 Significance of Subfloor Differences – Wood Subfloor

Four of the flooring types require specific underlayment that is different when a wood subfloor is used; these are ceramic, cork, linoleum, and VCT. Therefore, a sensitivity analysis was performed for ceramic, cork, linoleum, and VCT to highlight the differences due to variation in underlayment requirements.

7.2.1.1 Subfloor sensitivities within the flooring systems

Ceramic Tiles

The LCIA results for the ceramic tiles installed over a wood subfloor are summarized in Table ***49***. In terms of global warming potential, the installation impacts change from positive to negative when a carbon credit is given to the plywood in the wood subfloor system. The carbon sequestered in the plywood significantly decreases the overall GHG emissions (82 kg less). In addition, the total energy consumption increases by 5,683 MJ while some increase in smog is noted. The increases can be attributed to the extra materials, mainly plywood and polyethylene added to underlayment used for wood subfloor.

Table 49 Ceramic tile LCIA summary by life cycle stage for installation over wood subfloor – absolute values

Impact category	Unit	Total	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	kg CO2 eq	634.80	363.85	46.09	-511.25	736.12
Acidification	H+ moles eq	367.25	120.52	15.25	215.42	16.06
Eutrophication	kg N eq	0.286	0.089	0.015	0.165	0.018
Ozone depletion	kg CFC-11 eq	5.07E-05	4.96E-05	1.73E-09	3.76E-07	7.1E-07
Smog	kg NOx eq	4.15	1.27	0.32	2.18	0.38
Total energy	MJ eq	23581.91	8975.56	630.40	13354.38	621.57
Non-renewable, fossil	MJ eq	21956.96	8072.15	625.07	12643.48	616.27
Non-renewable, nuclear	MJ eq	1015.36	319.98	5.34	684.83	5.21
Renewable, biomass	MJ eq	579.52	571.43	0.00	8.07	0.02
Renewable, other	MJ eq	30.06	12.00	0.00	18.00	0.06

VCT

Table ***50*** presents a summary of the LCIA results for VCT flooring installed over a wood subfloor on an absolute value basis. The results are generally similar to VCT installed over a concrete subfloor but increase in total energy consumption by 1,015 MJ and decrease in GHG emissions by about 31 kg CO_2 eq. on a 1000 sq.ft basis. The reasons for those changes are the additional energy use and environmental impacts associated with the extra underlayment materials required for installations over a wood subfloor. For instance, increase in total energy use occurs from the energy used to manufacture and transport of those additional materials while carbon sequestered in plywood causes decrease in GHG emissions.

Table 50 VCT LCIA summary by life cycle stage for installation over wood subfloor – absolute values

Impact category	Unit	Total	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	kg CO2 eq	304.82	281.12	10.26	-192.16	205.60
Acidification	H+ moles eq	140.28	83.82	3.39	48.17	4.89
Eutrophication	kg N eq	0.10	0.07	0.00	0.02	0.01
Ozone depletion	kg CFC-11 eq	1.57E-05	1.47E-05	3.85E-10	1.63E-08	9.75E-07
Smog	kg NOx eq	1.37	0.76	0.07	0.42	0.11
Total energy	MJ eq	9785.55	6921.91	140.36	2493.68	229.59
Non-renewable, fossil	MJ eq	8115.95	5414.75	139.18	2337.23	224.80
Non-renewable, nuclear	MJ eq	1605.75	1446.17	1.19	154.26	4.14
Renewable, biomass	MJ eq	5.34	4.80	0.00	0.44	0.10
Renewable, other	MJ eq	58.51	56.20	0.00	1.75	0.55

Cork

Table ***51*** summarizes the LCIA results for cork flooring installed over a wood subfloor on an absolute value basis. When cork is installed over a wood subfloor, significant changes occur in the areas of total energy consumption and global warming; both the total energy consumption and climate change benefits go up approximately by 1,531 MJ and 51 kg CO_2e on a per 1000 sq.ft of installed flooring basis respectively. This increase in total energy consumption and global warming benefits can be attributed to the added energy brought into the model by the additional underlayment materials and carbon sequestered in plywood respectively.

Table 51 Cork LCIA summary by life cycle stage for installation over wood subfloor – absolute values

Impact category	Unit	Total	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	kg CO2 eq	-155.68	-944.75	108.84	-208.15	888.37
Acidification	H+ moles eq	303.18	137.48	58.57	99.56	7.57
Eutrophication	kg N eq	1.00	0.60	0.18	0.21	0.01
Ozone depletion	kg CFC-11 eq	8.02E-05	3.17E-05	2.72E-06	4.54E-05	4.03E-07
Smog	kg NOx eq	2.99	1.17	0.76	0.85	0.22
Total energy	MJ eq	19626.97	11856.90	1514.69	5962.85	292.54
Non renewable, fossil	MJ eq	14379.44	7343.18	1502.34	5244.00	289.92
Non-renewable, nuclear	MJ eq	1748.89	1180.60	12.10	553.64	2.55
Renewable, biomass	MJ eq	2944.32	2894.14	0.07	50.09	0.02
Renewable, other	MJ eq	554.32	438.97	0.18	115.11	0.05

Linoleum

A summary of the LCIA results for linoleum flooring installed over a wood subfloor is provided in Table ***52*** an absolute value basis. Compared to the baseline results, significant changes occur in total energy consumption and global warming impact categories when linoleum is installed over a wood subfloor. For instance, the total energy consumption goes up by 1,267 MJ while global warming impacts go down by 39 kg CO_2e on a per 1000 sq.ft of installed flooring basis. Causes for those changes can be attributed to the energy consumption for extra underlayment material manufacturing and transportation added into the systems, and credit given to carbon sequestered in plywood.

Table 52 Linoleum LCIA summary by life cycle stage for installation over wood subfloor – absolute values

Impact category	Unit	Total	Extraction and Manufacturing	Transport to Consumer	Installation and Use	End-of-life
Global warming	kg CO2 eq	107.44	-132.91	20.39	-224.68	444.65
Acidification	H+ moles eq	390.53	268.15	20.49	97.83	4.05
Eutrophication	kg N eq	1.642	1.583	0.017	0.037	0.005
Ozone depletion	kg CFC-11 eq	1.41E-05	9.83E-06	1.65E-06	2.38E-06	2.64E-07
Smog	kg NOx eq	4.15	3.19	0.26	0.60	0.11
Total energy	MJ eq	14181.55	8764.24	292.94	4965.08	159.28
Non-renewable, fossil	MJ eq	12439.82	7300.21	290.29	4691.65	157.67
Non-renewable, nuclear	MJ eq	859.45	591.12	2.40	264.40	1.53
Renewable, biomass	MJ eq	853.17	850.38	0.05	2.73	0.01
Renewable, other	MJ eq	14.56	11.27	0.10	3.15	0.03

7.2.1.2 Subfloor sensitivity across the flooring systems

A summary of the comparative LCIA results for flooring installation over a wood subfloor is presented in Table ***53*** and Figure ***15*** on an absolute value and percent basis respectively. Although there are significant increases in energy consumption and improvements in global warming due to underlayment differences, the floorings installed over a wood subfloor generally exhibit similar results in the comparison as the scenarios in which they are laid over a concrete subfloor.

Table 53 Comparative flooring LCIA results for the installation over wood subfloors

Impact category	Unit	Hardwood	Carpet	Ceramic tiles	VCT	Cork	Linoleum
Global warming	kg CO2 eq	-444.72	4513.99	634.80	304.82	-155.68	107.44
Acidification	H+ moles eq	455.88	1340.62	367.25	140.28	303.18	390.53
Eutrophication	kg N eq	0.49	3.78	0.29	0.10	1.00	1.64
Ozone depletion	kg CFC-11 eq	4.34E-06	9.71E-05	5.07E-05	1.57E-05	8.02E-05	1.41E-05
Smog	kg NOx eq	7.87	13.28	4.15	1.37	2.99	4.15
Total energy	MJ eq	44630.41	92400.48	23581.91	9785.55	19626.97	14181.55
Non renewable, fossil	MJ eq	14909.01	82689.48	21956.96	8115.95	14379.44	12439.82
Non-renewable, nuclear	MJ eq	1788.46	9142.44	1015.36	1605.75	1748.89	859.45
Renewable, biomass	MJ eq	24208.43	312.05	579.52	5.34	2944.32	853.17
Renewable, other	MJ eq	3724.50	256.52	30.06	58.51	554.32	29.11

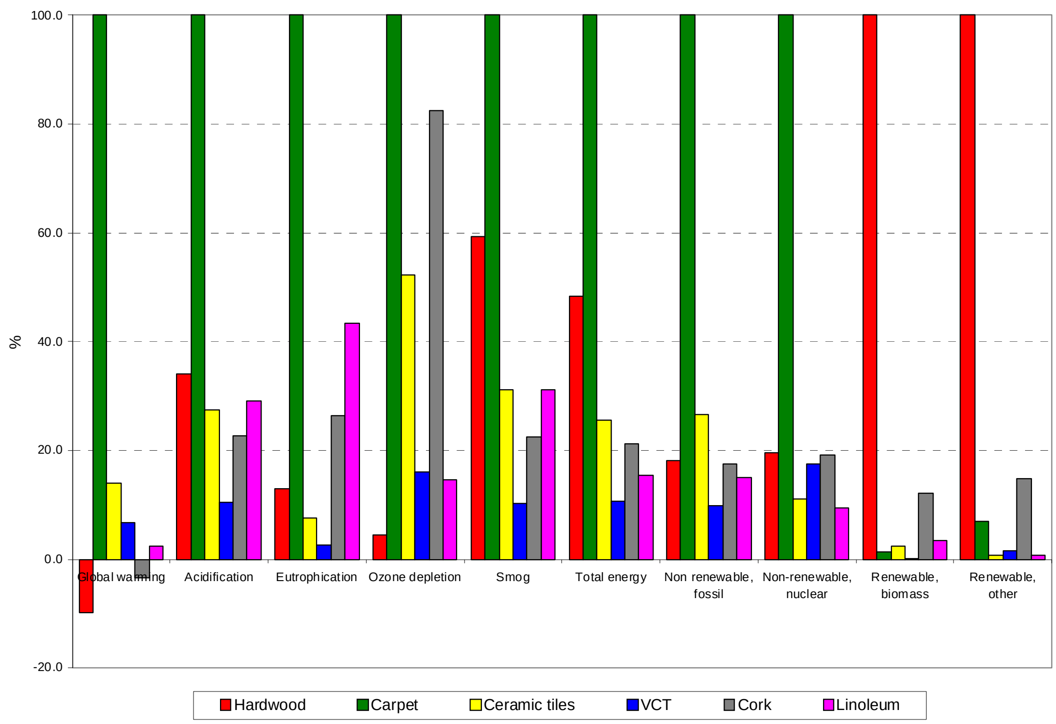

Figure 15 Comparative flooring LCIA results for the installations over wood subfloors

7.2.2 Significant Life Cycle Stages and Inputs

7.2.2.1 Sensitivity within the flooring systems

Hardwood Flooring System

The contribution analysis revealed that the default end-of-life processes significantly contribute to global warming due to the methane emissions from decaying woody materials. Currently, mandatory recycling regulations in North America are emerging in order to avoid the disposal of construction and demolition materials in landfills due to rapidly dwindling landfill space and other environmental concerns (HQ Air Force Centre for Environmental Excellence 2001, 3). While considering this trend, an alternative end of life scenario was developed based on the assumption that flooring boards, together with plywood underlayment, could be recovered for bioenergy at the end of the service life.

Summary LCIA results of the base case and cradle-to-grave flooring system with the energy recovery end of life scenario are shown in Table ***54***. Sensitivity results indicate that considerable improvements to the hardwood flooring environmental profile can be achieved if the flooring and plywood are burned for energy at the end of life.

Recovering wood waste for fuel substitutes for 26,293 MJ of fossil fuel that would have otherwise been consumed makes a big difference to the environmental performance of hardwood flooring. Note that non-renewable fossil fuel becomes a negative number because the amount of fossil fuel displaced exceeds the life cycle fossil fuel consumption. Also, on a per 1000 sq.ft of installed flooring basis, the net global warming credit increases by 792 kg CO_2e. Additionally, acidification effects go down by about 598 H^+ moles eq. due to the avoidance of coal combustion which is a significant cause of acidification.

Table 54 Summary results for the base case verses sensitivity analysis of the hardwood flooring system (absolute basis)

Impact category	Unit	Hardwood flooring - Base case	Hardwood Flooring - Revised EOL
Global warming	kg CO2 eq	-444.72	-1237.20
Acidification	H+ moles eq	455.88	-142.61
Eutrophication	kg N eq	0.49	0.42
Ozone depletion	kg CFC-11 eq	4.34E-06	3.66E-06
Smog	kg NOx eq	7.87	7.05
Total energy	MJ eq	44630.41	38416.77
Non renewable, fossil	MJ eq	14909.01	-11383.97
Non-renewable, nuclear	MJ eq	1788.46	1597.45
Renewable, biomass	MJ eq	24208.43	44478.84
Renewable, other	MJ eq	3724.50	3724.45

Carpet Flooring System

In the contribution analysis it was found that electricity consumption for vacuuming during carpet use is the largest contributor towards the life cycle energy use (49.5%) and environmental impacts (i.e., 11-85% of the emissions in the selected impact categories). The base case was created considering electricity consumption for vacuuming once a week. It was changed to once a month vacuuming by reducing electricity consumption to 25%, and the results were assessed against the baseline to check the sensitivity of electricity consumption towards the total impacts. The results of this revision are presented in Table ***55***. Significant improvements in total energy and fossil energy use, global warming, acidification impact categories occur with the reduced electricity use for vacuuming.

Table 55 Summary results for the base case verses sensitivity analysis of the carpet flooring system (absolute basis)

Impact category	Unit	Carpet - Base case	Carpet - Revised use
Global warming	kg CO2 eq	4513.99	3561.18
Acidification	H+ moles eq	1340.62	912.79
Eutrophication	kg N eq	3.78	3.66
Ozone depletion	kg CFC-11 eq	9.71E-05	9.71E-05
Smog	kg NOx eq	13.28	9.69
Total energy	MJ eq	92400.48	76091.07
Non renewable, fossil	MJ eq	82689.48	69629.07
Non-renewable, nuclear	MJ eq	9142.44	5893.43
Renewable, biomass	MJ eq	312.05	312.05
Renewable, other	MJ eq	256.52	256.52

Ceramic Tiles

In the contribution analysis we found that roughly 1/3 of the impacts occur during installation/use. The latex in the mortar mixture was found to be responsible for most of the impacts. An alternative thinset mortar mix was assessed to check the sensitivity of the model to this material. The composition of the thinset mortar mix is shown in Table ***56***.

Table 56 Composition of thinset mortar

Material	Composition (%)
Sand	40-50%
Portland cement	30-40%
Latex polymer	5-10%
Dolomite	0-5%
Sodium naphthalene sulfonate	0-1%

Source: Super Tek High Performance Products, 2002

In addition, an alternative end of life scenario was created for ceramic tile installation over a wood subsurface. The end of life impacts were tested assuming that plywood underlayment is recycled for bioenergy at the end of the service life. ***Table*** 57 shows a summary of the two sensitivity scenarios for ceramic tiles. Significant improvements in energy use, global warming, and acidification impacts occur with the revised installation and end of life scenarios.

Table 57 Summary results of the base case verses sensitivity analysis on an absolute value basis

Impact category	Unit	Concrete subfloor		Wood subfloor		
		Base case	**Revised installation**	**Base case**	**Revised installation**	**Revised EOL**
Global warming	kg CO2 eq	716.07	548.25	634.80	466.98	288.82
Acidification	H+ moles eq	230.73	176.78	367.25	313.30	129.30
Eutrophication	kg N eq	0.34	0.25	0.29	0.20	0.28
Ozone depletion	kg CFC-11 eq	5.05E-05	5.06E-05	5.07E-05	5.09E-05	5.04E-05
Smog	kg NOx eq	2.82	2.13	4.15	3.46	4.12
Total energy	MJ eq	17908.02	11171.62	23581.91	16845.50	21411.42
Non renewable, fossil	MJ eq	16763.40	10205.76	21956.96	15399.32	11249.74
Non-renewable, nuclear	MJ eq	535.06	375.70	1015.36	856.00	984.41
Renewable, biomass	MJ eq	579.52	575.46	579.52	575.47	9147.22
Renewable, other	MJ eq	30.05	14.70	30.06	14.71	30.04

VCT Flooring System

In the contribution analysis it was found that plywood underlayment is a significant contributor for global warming when VCT is installed over a wood subfloor. An alternative end of life scenario was created to test the significance of base case findings if plywood underlayment is recycled for bioenergy at the end of life. Summary results are shown in Table ***58*** on an absolute value basis. Note that considerable improvements occur in the energy use (both total energy and non-renewable fossil fuel consumption), global warming, and acidification impact categories when the plywood underlayment is recovered for bioenergy at the end of the service life.

Table 58 Sensitivity results summary of the VCT flooring system against the baseline – absolute value basis

Impact category	Unit	VCT – Default EOL (Wood subfloor)	VCT - Revised EOL (Wood subfloor)
Global warming	kg CO2 eq	304.82	207.99
Acidification	H+ moles eq	140.28	73.91
Eutrophication	kg N eq	0.10	0.10
Ozone depletion	kg CFC-11 eq	1.57E-05	1.56E-05
Smog	kg NOx eq	1.37	1.36
Total energy	MJ eq	9785.55	9170.64
Non renewable, fossil	MJ eq	8115.95	5129.95
Non-renewable, nuclear	MJ eq	1605.75	1596.95
Renewable, biomass	MJ eq	5.34	2385.26
Renewable, other	MJ eq	58.51	58.47

Cork Flooring System

Like hardwood flooring, significant amounts of GHG emissions occur at the end of life. Therefore, an alternative end of life was developed to test if there is any difference in the final results when cork boards and plywood underlay (used only for wood subfloors) is recycled for bionergy at the end of the service life. Summary results with and without sensitivities are shown in Table ***59***. Recycling wood materials for bioenergy avoids landfill gas generation and thus significantly reduces global warming impacts. In addition, considerable reductions also occur in the total energy and fossil fuel use and acidification impact categories as well for the same reason.

Table 59 Cork flooring summary results with and without sensitivities on an absolute value basis

Impact category	Unit	Concrete subfloor		Wood subfloor	
		Base case	**With revised EOL**	**Without sensitivity**	**With Revised EOL**
Global warming	kg CO2 eq	-105.10	-400.40	-155.68	-603.32
Acidification	H+ moles eq	262.73	78.50	303.18	13.72
Eutrophication	kg N eq	0.98	0.96	1.00	0.98
Ozone depletion	kg CFC-11 eq	8E-05	7.98E-05	8.02E-05	7.99E-05
Smog	kg NOx eq	2.44	2.40	2.99	2.96
Total energy	MJ eq	18095.95	16398.47	19626.97	16985.58
Non renewable, fossil	MJ eq	13051.33	4765.28	14379.44	1355.19
Non-renewable, nuclear	MJ eq	1546.18	1522.10	1748.89	1711.23
Renewable, biomass	MJ eq	2944.31	9556.99	2944.32	13364.88
Renewable, other	MJ eq	554.12	554.10	554.32	554.29

Linoleum Flooring System

Currently there is no scientific literature to support the claims by the manufacturers that linoleum biodegrades in landfills. Linoleum may behave like plastic polymers in landfills (Barlaz, Morzen, 2010), and hence, an alternative disposal profile was created based on the assumption that linoleum does not biodegrade (i.e., behave like plastic) when landfilled at the end of the service life. Two end of life scenarios were separately created for both concrete and wood subfloors to test the significance of this assumption.

In creating the end of life sensitivity scenarios, the plywood underlayment was assumed to be recovered for bionergy. Sensitivity results against the baseline are presented in Table ***60***. Note that global warming impacts change from positive to a net negative when linoleum is assumed to remain intact in the landfill.

Table 60 Sensitivity results summary – Linoleum flooring system

Impact category	Unit	Concrete subfloor		Wood subfloor	
		Base case	**Sensitivity with revised EOL**	**Without sensitivity**	**Revised EOL**
Global warming	kg CO2 eq	146.65	-26.91	107.44	-549.33
Acidification	H+ moles eq	357.08	357.08	390.53	287.15
Eutrophication	kg N eq	1.62	1.62	1.64	1.62
Ozone depletion	kg CFC-11 eq	1.39E-05	1.39E-05	1.41E-05	1.44E-05
Smog	kg NOx eq	3.69	3.68	4.15	3.73
Total energy	MJ eq	12914.05	12914.05	14181.55	10097.07
Non renewable, fossil	MJ eq	11341.29	11341.29	12439.82	8383.24
Non-renewable, nuclear	MJ eq	690.65	690.65	859.45	831.23
Renewable, biomass	MJ eq	853.15	853.15	853.17	853.21
Renewable, other	MJ eq	28.96	28.96	29.11	29.39

7.2.2.2 Sensitivity analysis across the flooring systems

Summary results of the use phase and end of life sensitivity analysis are presented in Table ***61*** and Figure ***16*** on an absolute value and percent basis respectively. Compared to the base case, hardwood flooring causes significantly less acidification and non-renewable fossil fuel use, such that it is now lower than the other flooring types in these impact categories.

Table 61 Hardwood base case verses use phase and end of life sensitivity analysis summary results across the flooring systems – absolute value basis

Impact category	Unit	Hardwood Base Case	Hardwood with Revised EOL	Carpet with 25% Electricity	Ceramic Tile with Thin Motar	VCT Base Case	Cork (with Revised EOL	Linoleum with Revised EOL
Global warming	kg CO2 eq	-444.72	-1237.20	3561.18	548.25	335.22	-400.40	-26.91
Acidification	H+ moles eq	455.88	-142.61	912.79	176.78	114.52	78.50	357.08
Eutrophication	kg N eq	0.49	0.42	3.66	0.25	0.09	0.96	1.62
Ozone depletion	kg CFC-11 eq	4.34E-06	3.66E-06	9.71E-05	5.06E-05	1.48E-05	7.98E-05	1.39E-05
Smog	kg NOx eq	7.87	7.05	9.69	2.13	1.01	2.40	3.68
Total energy	MJ eq	44630.41	38416.77	76091.07	11171.62	8770.17	16398.47	12914.05
Non renewable, fossil	MJ eq	14909.01	-11383.97	69629.07	10205.76	7230.49	4765.28	11341.29
Non-renewable, nuclear	MJ eq	1788.46	1597.45	5893.43	375.70	1476.55	1522.10	690.65
Renewable, biomass	MJ eq	24208.43	44478.84	312.05	575.46	5.24	9556.99	853.15
Renewable, other	MJ eq	3724.50	3724.45	256.52	14.70	57.89	554.10	28.96

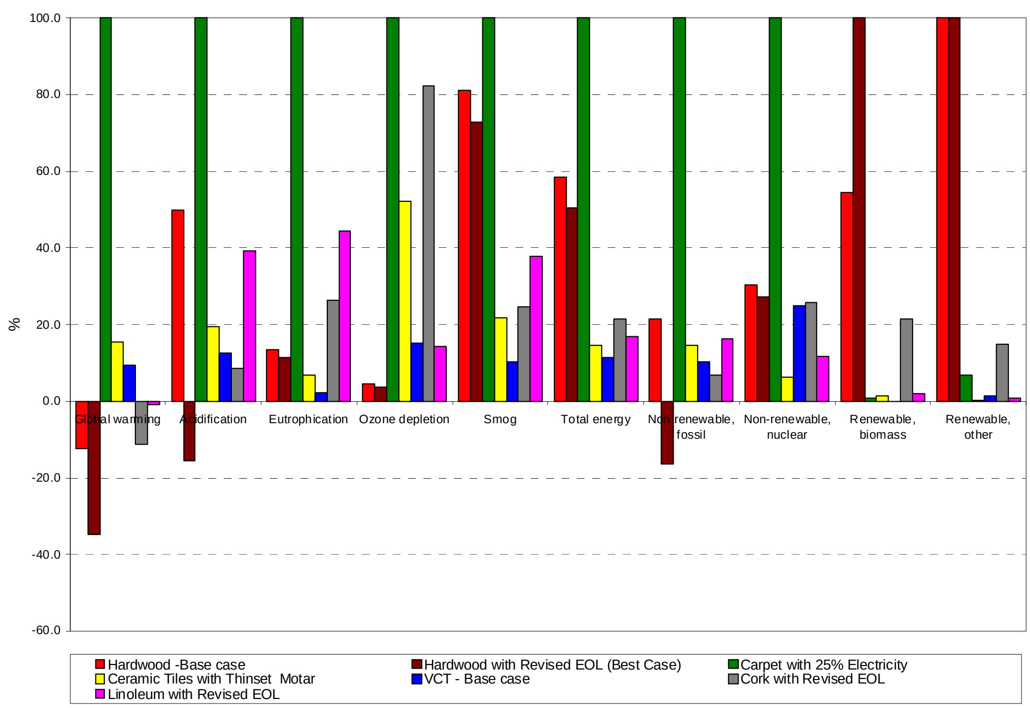

Figure 16 Hardwood base case and best case verses use phase and end of life sensitivity across the other flooring systems – percent basis

7.2.3 Significance of the Default Building Location

A default building location was chosen based on the hardwood flooring shipments from eastern Canada to the US states and cities. The validity of the base case comparative LCIA results across various states was tested in the sensitivity analysis by assessing the significance of an alternative building site in Seattle, which is the farthest away city in the US from both the Canadian mills and default building site.

In this sensitivity scenario, the two flooring products imported from Europe (cork and linoleum) were assumed to be received at distribution facilities in the eastern US. first and then shipped to the building site in Seattle. Also, since ceramic tile manufacturing occurs in Texas as well as the Northeast, the tiles used in Seattle are assumed to be manufactured at the closer facility in Texas. All the other materials are assumed to be manufactured in the same locations as the default scenario. Rail was assumed as the mode of shipping across the country. A single diesel truck was assumed to be used to deliver flooring from the supplier to the building site. The rail transportation and trucking distances when flooring is transported to the Seattle building site are shown in Table ***62***.

Table 62 Flooring transportation modes and distances to Seattle consumer

Flooring type	**Unit**	**Rail distance***	**Trucking distance****
Hardwood	km	3280	15
Carpet	km	3369	5
Ceramic tiles	km	2748	15
VCT	km	3137	12
Cork	km	3152	18
Linoleum	km	3137	5

Note: * Distance from Seattle to the major manufacturing cities obtained from Canadian National Railway
** Distances to major supplier locations in Seattle city obtained from Google maps

Results of this sensitivity analysis are summarized Table ***63*** and presented in Figure ***17***. When compared with the baseline results, emissions from the hardwood flooring system increased by a small quantity due to the extra transport of flooring added to the system. However, the sensitivity analysis results across the flooring systems exhibits the same pattern as they do in the base case analysis.

Table 63 Base case verses the sensitivity analysis summary results for the building location in Seattle, Washington – absolute value basis

Impact category	Unit	Hardwood - baseline	Hardwood Flooring - Seattle	Carpet	Ceramic tiles	VCT	Cork	Linoleum
Global warming	kg CO2 eq	-444.72	-476.52	4473.38	740.99	347.33	-154.34	169.24
Acidification	H+ moles eq	455.88	503.48	1354.41	301.63	137.24	278.93	384.55
Eutrophication	kg N eq	0.49	0.55	3.80	0.42	0.11	1.00	1.64
Ozone depletion	kg CFC-11 eq	4.34E-06	4.34E-06	9.71E-05	5.05E-05	1.48E-05	8E-05	1.44E-05
Smog	kg NOx eq	7.87	9.09	13.67	4.53	1.55	2.90	4.07
Total energy	MJ eq	44630.41	44196.84	91845.70	18250.40	8936.17	17423.14	13760.31
Non renewable, fossil	MJ eq	14909.01	14479.12	82139.40	17102.88	7395.09	12384.22	12165.70
Non-renewable, nuclear	MJ eq	1788.46	1784.79	9137.74	537.96	1477.95	1540.49	710.71
Renewable, biomass	MJ eq	24208.43	24208.43	312.05	579.52	5.24	2944.31	853.70
Renewable, other	MJ eq	3724.50	3724.50	256.52	30.05	57.89	554.12	30.20

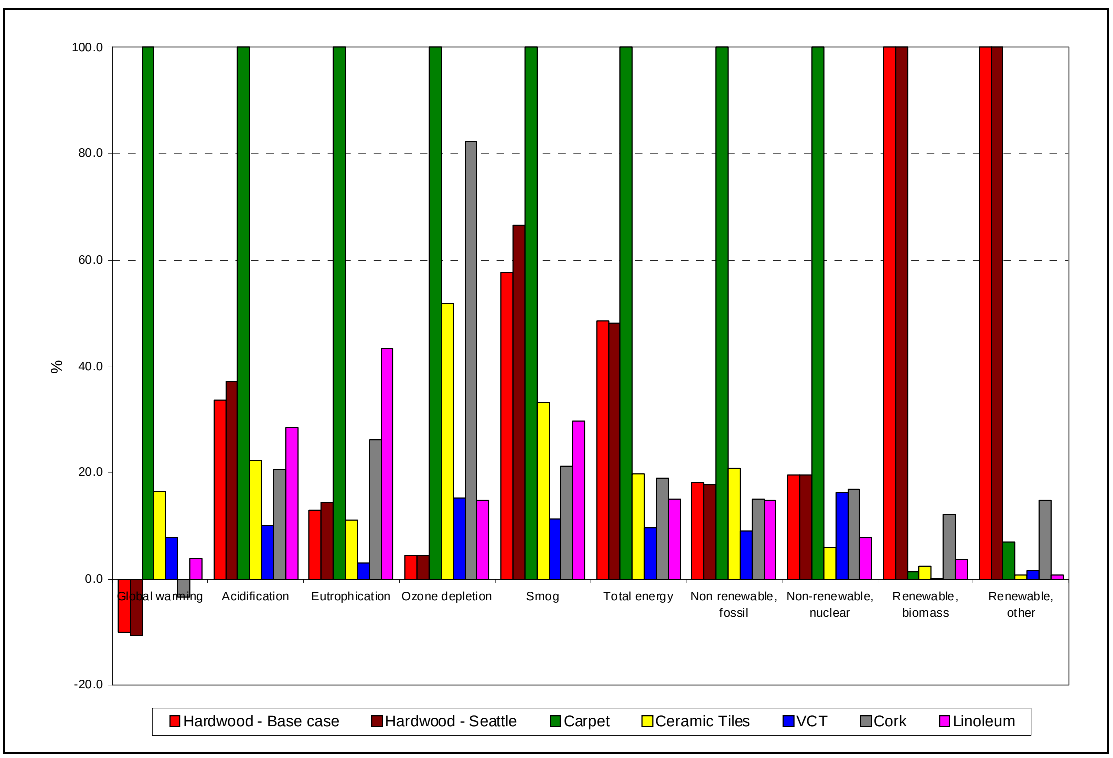

Figure 17 Hardwood flooring base case verses building location sensitivity results across the flooring types – percent basis

7.2.4 Service Life Sensitivity

The study team used service life data available in BEES and warranties given by major flooring manufactures to develop LCI models. We know that individual use is also a primary driver of replacement and may occur for aesthetic or other reasons unrelated to warranties or manufacturers' expectations. There is empirical evidence on consumer behavior with regard to flooring use in a survey conducted in the US in 1971[17]. Since this study was out of date, the study team used the flooring wear life data used by some of the U.S. counties for landlord tenant affairs (for example, Montgomery County in Maryland) and information available in consumer awareness websites and other LCA studies.

Uncertainty surrounding the findings due to service life uncertainties was addressed in the sensitivity analysis with the alternative wear lives listed in Table ***64***. To retain a conservative posture in regards to hardwood flooring, the hardwood was only credited with a 50 year service life (despite many examples of much longer service lives). On the other hand, wherever a range was given for the other flooring types, the study team used a more conservative approach by selecting the upper limit for the sensitivity check.

Table 64 Flooring baseline and sensitivity service lives

Flooring type	Service life in years		
	Base case	**Alternative wear lives**	**Wear life chosen for sensitivity analysis**
Hardwood	25	25 - 100[+, 1]	50
Carpet	11	5 - 15[1,4,5]	15
Ceramic tiles	50	25 - 30[2]	30
VCT	40	15[1]	15
Cork	25	30 - 40[4]	40
Linoleum	30	20[3]	20

Sources: 1. Montgomery County Maryland, 2007, p. 13
2. Hubpages, 2010.
3. Gorree M. et.al., 2000, p.5
4. Minnesota Sustainable Housing Initiative, 2007-10.
5. Lippiatt, Barbara, 2007.

The results of the service life sensitivity analysis for each of the flooring systems are presented in Table ***65*** and Figure ***18***. Compared to the baseline results, considerable changes in the environmental burdens occur when the service lives of flooring change. If the service life is extended, the embodied effects as well as installation effects are reduced.

Note that the impacts of hardwood, carpet, and cork flooring systems in the sensitivity analysis are significantly reduced. Environmental burdens of linoleum, on the other hand, significantly go up as a result of more frequent flooring replacement needed within the considered timeframe. When the durability is doubled, hardwood flooring outperforms all the other flooring types in the non-renewable fossil fuel consumption and some improvements occur in the terms of acidification, eutrophication, and smog. However, it is interesting to note that when there is no replacement to flooring at the end of the 25 year service life the climate change benefits go down by half, indicating a potential trade-off between the durability and life cycle fossil fuel use.

[17] See http://www.fs.fed.us/ne/newtown_square/publications/research_papers/pdfs/scanned/OCR/ne_rp200.pdf.

Table 65 Summary results of service life sensitivity check against the baseline results – absolute value basis

Impact category	Unit	Baseline results						Service life sensitivity					
		Hardwood	Carpet	Ceramic tiles	VCT	Cork	Linoleum	Hardwood	Carpet	Ceramic tiles	VCT	Cork	Linoleum
Global warming	kg CO2 eq	-444.72	4513.99	716.07	335.22	-105.10	146.65	-222.36	3310.26	1193.45	893.92	-65.69	-48.07
Acidification	H+ moles eq	455.88	1340.62	230.73	114.52	262.73	357.08	227.94	983.12	384.55	305.38	164.21	532.85
Eutrophication	kg N eq	0.49	3.78	0.34	0.09	0.98	1.62	0.25	2.77	0.57	0.23	0.61	2.43
Ozone depletion	kg CFC-11 eq	4.34E-06	9.71E-05	5.05E-05	1.48E-05	8E-05	1.39E-05	2.17E-06	7.12E-05	8.41E-05	3.95E-05	5E-05	2.08E-05
Smog	kg NOx eq	7.87	13.28	2.82	1.01	2.44	3.69	3.94	9.74	4.70	2.69	1.52	5.46
Total energy	MJ eq	44630.41	92400.48	17908.02	8770.17	18095.95	12914.05	22315.20	67760.35	29846.70	23387.11	11309.97	19264.49
Non renewable, fossil	MJ eq	14909.01	82689.48	16763.40	7230.49	13051.33	11341.29	7454.51	60638.95	27939.00	19281.30	8157.08	16906.26
Non-renewable, nuclear	MJ eq	1788.46	9142.44	535.06	1476.55	1546.18	690.65	894.23	6704.45	891.76	3937.46	966.36	1035.08
Renewable, biomass	MJ eq	24208.43	312.05	579.52	5.24	2944.31	853.15	12104.22	228.83	965.86	13.98	1840.20	1279.73
Renewable, other	MJ eq	3724.50	256.52	30.05	57.89	554.12	28.96	1862.25	188.11	50.08	154.37	346.33	43.42

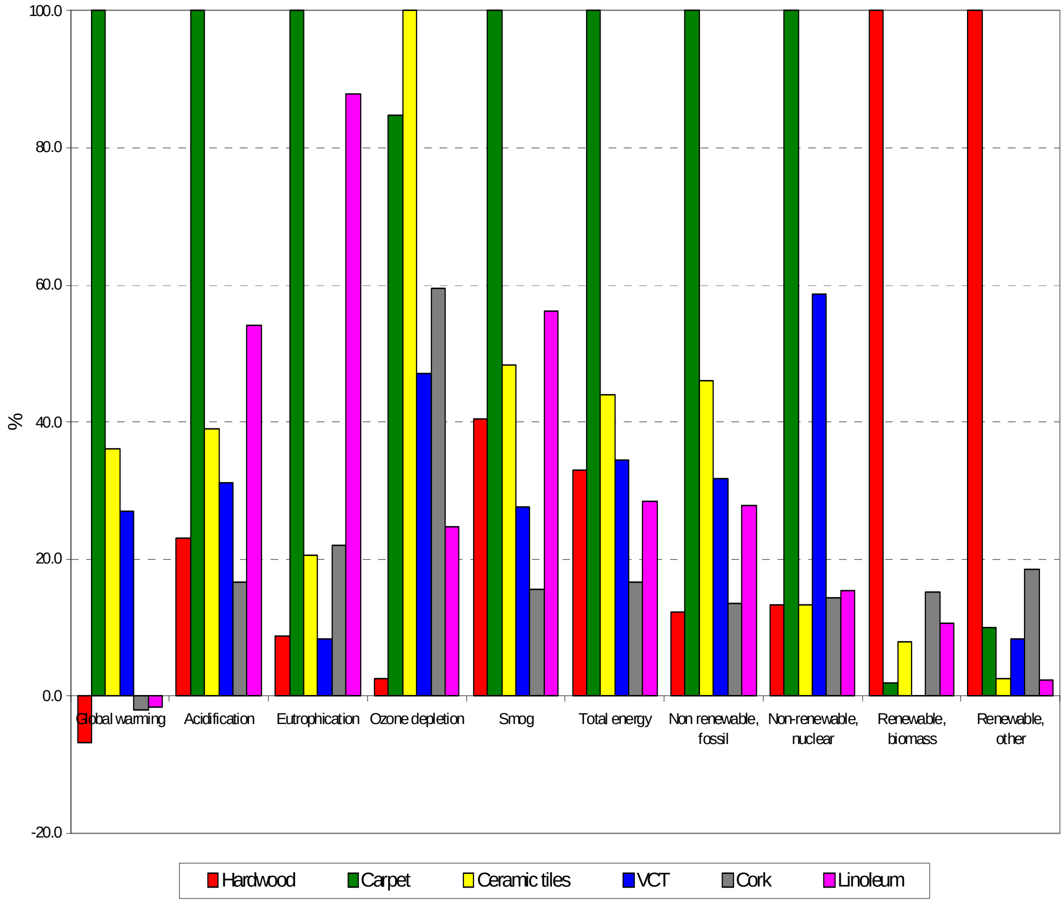

Figure 18 Service life sensitivity check across the flooring systems – percent basis

7.2.5 Sensitivity on Allocation Rules

Sensitivity analysis was performed in line with the physical allocation principles. The environmental burden from lumber and flooring manufacturing was partitioned between their main product and co-products based on the oven dry masses of the main product (lumber and flooring) and co-products. Results of this sensitivity analysis are depicted in Table ***66*** and Figure ***19*** against the hardwood base case and the base cases of other flooring types. Considerable improvements in global warming, acidification, and total energy use impact categories occur with the physical allocation, indicating that the environmental performance of hardwood flooring could be improved by selling wood wastes in higher value uses and markets. The comparative LCIA results with the other floorings, however, exhibits a similar pattern as found in the economic allocation.

Table 66 Hardwood flooring allocation sensitivity against its base case and other flooring types – absolute value basis

Impact category	Unit	Hardwood - baseline	Hardwood - physical allocation	Carpet	Ceramic tiles	VCT	Cork	Linoleum
Global warming	kg CO2 eq	-444.72	-563.51	4513.99	716.07	335.22	-105.10	146.65
Acidification	H+ moles eq	455.88	389.45	1340.62	230.73	114.52	262.73	357.08
Eutrophication	kg N eq	0.49	0.43	3.78	0.34	0.09	0.98	1.62
Ozone depletion	kg CFC-11 eq	4.34E-06	4.23E-06	9.71E-05	5.05E-05	1.48E-05	8.00E-05	1.39E-05
Smog	kg NOx eq	7.87	6.59	13.28	2.82	1.01	2.44	3.69
Total energy	MJ eq	44630.41	40768.54	92400.48	17908.02	8770.17	18095.95	12914.05
Non renewable, fossil	MJ eq	14909.01	13199.90	82689.48	16763.40	7230.49	13051.33	11341.29
Non-renewable, nuclear	MJ eq	1788.46	1426.32	9142.44	535.06	1476.55	1546.18	690.65
Renewable, biomass	MJ eq	24208.43	23944.85	312.05	579.52	5.24	2944.31	853.15
Renewable, other	MJ eq	3724.50	2197.47	256.52	30.05	57.89	554.12	28.96

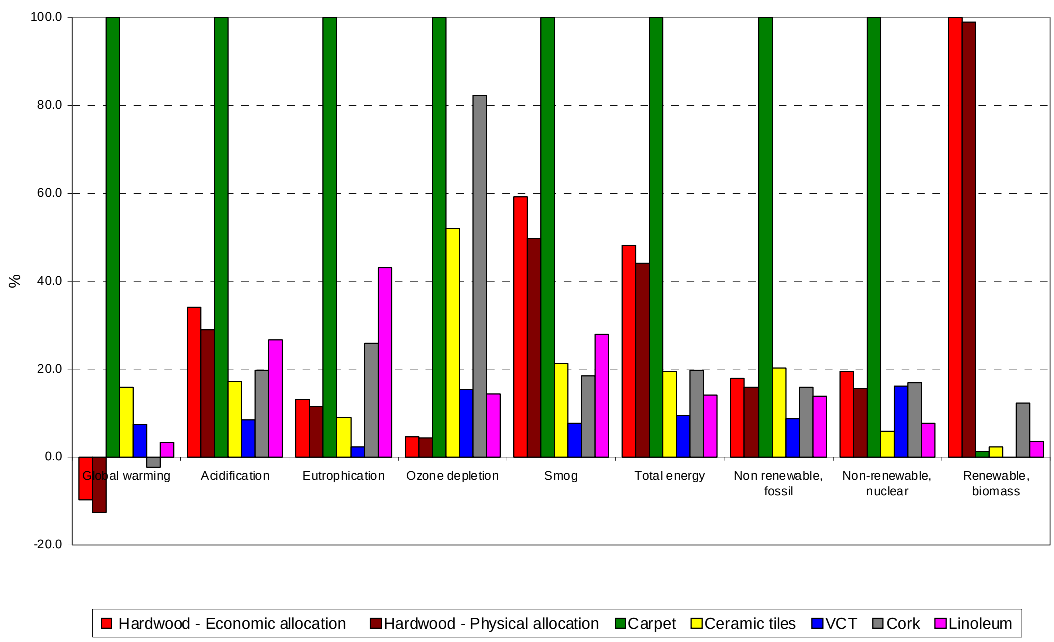

Figure 19 Hardwood flooring allocation sensitivity against its base case and other flooring types – percent basis

7.2.6 Floor Cleaning Sensitivities

Frequent Floor Cleaning – Vacuuming

A 50/50 scenario for sweeping with broom vs vacuum cleaning for the flooring systems other than carpet (i.e., hardwood, ceramic tiles, VCT, cork, and linoleum) was used to test the validity of base case comparative LCA findings. Results are presented in Table ***67*** and Figure ***20*** against carpet base case on an absolute and percent basis respectively. The total energy and non-renewable fossil energy consumption of hardwood and other floorings go up considerably due to electricity use for vacuuming. As a result, significant increases in global warming and smog impact categories also occur. Despite these changes, comparative LCA results exhibit a similar pattern found in the base case analysis.

Table 67 Sensitivity of hardwood and other floorings for vacuuming against carpet base case – absolute value basis

Impact category	Unit	Hardwood - baseline	Hardwood - vacuuming	Carpet - baseline	Ceramic tiles - vacuuming	VCT - vacuuming	Cork - vacuuming	Linoleum - vacuuming
Global warming	kg CO2 eq	-444.72	190.49	4513.99	1351.27	970.43	530.11	781.86
Acidification	H+ moles eq	455.88	741.11	1340.62	515.95	399.74	547.96	642.30
Eutrophication	kg N eq	0.49	0.57	3.78	0.42	0.17	1.06	1.70
Ozone depletion	kg CFC-11 eq	4.34E-06	4.34E-06	9.71E-05	5.05E-05	1.48E-05	8.00E-05	1.39E-05
Smog	kg NOx eq	7.87	10.26	13.28	5.21	3.40	4.82	6.08
Total energy	MJ eq	44630.41	55503.35	92400.48	28780.96	19643.11	28968.89	23786.99
Non renewable, fossil	MJ eq	14909.01	23615.95	82689.48	25470.33	15937.42	21758.27	20048.22
Non-renewable, nuclear	MJ eq	1788.46	3954.46	9142.44	2701.06	3642.55	3712.18	2856.66
Renewable, biomass	MJ eq	24208.43	24208.43	312.05	579.52	5.24	2944.31	853.15
Renewable, other	MJ eq	3724.50	256.52	30.05	57.89	554.12	28.96	0.00

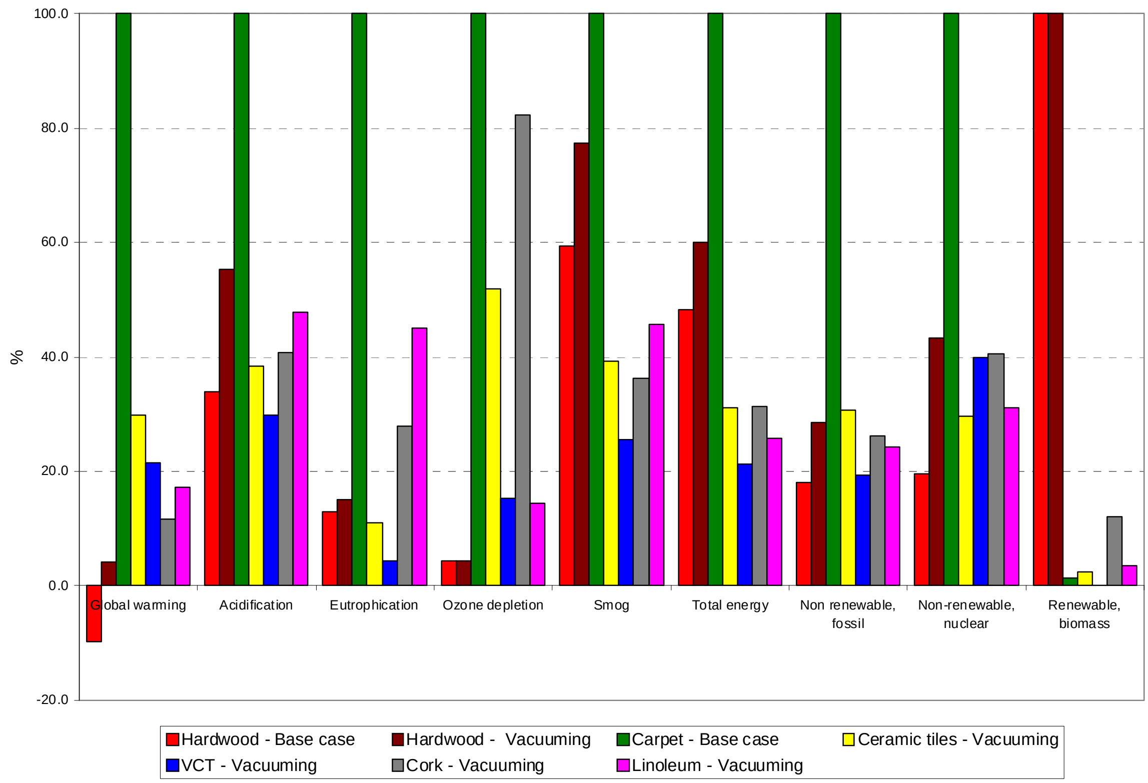

Figure 20 Sensitivity of hardwood and other floorings for vacuuming against carpet base case – percent basis

Periodic Floor Cleaning

A sensitivity analysis was performed to address the exclusion of periodic floor cleaning because of no existing data for periodic floor cleaners used in a typical residential application in N.America. This was tested by adding periodic floor cleaner use to the hardwood input/out profile and comparing this revised profile against the base cases of both hardwood and other flooring types. Periodic hardwood floor cleaning is done manually with a dust mop. The details about the floor cleaner and secondary LCI data sources used in the analysis are shown in ***Table 68***. The name of the non-ionic surfactant used to manufacture wood floor cleaners was proprietary, and hence this information was not available for the study. As a result, ethylene glycol available in the US-EI database was used as surrogate LCI data in modeling the environmental impacts of the surfactant.

Table 68 Hardwood floor cleaner and secondary LCI data source

Name	Content	Quantity/1000 sq.ft. floor/annum	Secondary LCI data source	Comments
Non-ionic surfactant*	0.5-1% (w/w)*	4 liters**	US-EI	Surrogate LCI data - ethylene glycol

Source: * Finitec Canada, 2009.
** Pierre Blanchet, 2010.

Results of this sensitivity analysis are presented in Table ***69*** Figure ***21*** on an absolute value and percent basis respectively. With the inclusion of periodic cleaning, the environmental impacts of hardwood flooring went up by a very small amount, but overall, the impact contributions from periodic floor cleaning were very minor. As a result, the comparative performance of hardwood flooring against the other competitive floorings remained the same as found in the base case analysis.

Table 69 Periodic hardwood floor cleaning vs the base cases of all the flooring types – absolute value basis

Impact category	Unit	Hardwood - base case	Hardwood - periodic cleaning	Carpet	Ceramic tiles	VCT	Cork	Linoleum
Global warming	kg CO2 eq	-444.72	-443.43	4513.99	716.07	335.22	-105.10	146.65
Acidification	H+ moles eq	455.88	456.17	1340.62	230.73	114.52	262.73	357.08
Eutrophication	kg N eq	0.49	0.50	3.78	0.34	0.09	0.98	1.62
Ozone depletion	kg CFC-11 eq	4.34E-06	4.35E-06	9.71E-05	5.05E-05	1.48E-05	8.00E-05	1.39E-05
Smog	kg NOx eq	7.87	7.88	13.28	2.82	1.01	2.44	3.69
Total energy	MJ eq	44630.41	44669.67	92400.48	17908.02	8770.17	18095.95	12914.05
Non renewable, fossil	MJ eq	14909.01	14944.79	82689.48	16763.40	7230.49	13051.33	11341.29
Non-renewable, nuclear	MJ eq	1788.46	1791.53	9142.44	535.06	1476.55	1546.18	690.65
Renewable, biomass	MJ eq	24208.43	24208.60	312.05	579.52	5.24	2944.31	853.15
Renewable, other	MJ eq	3724.50	3724.76	256.52	30.05	57.89	554.12	28.96

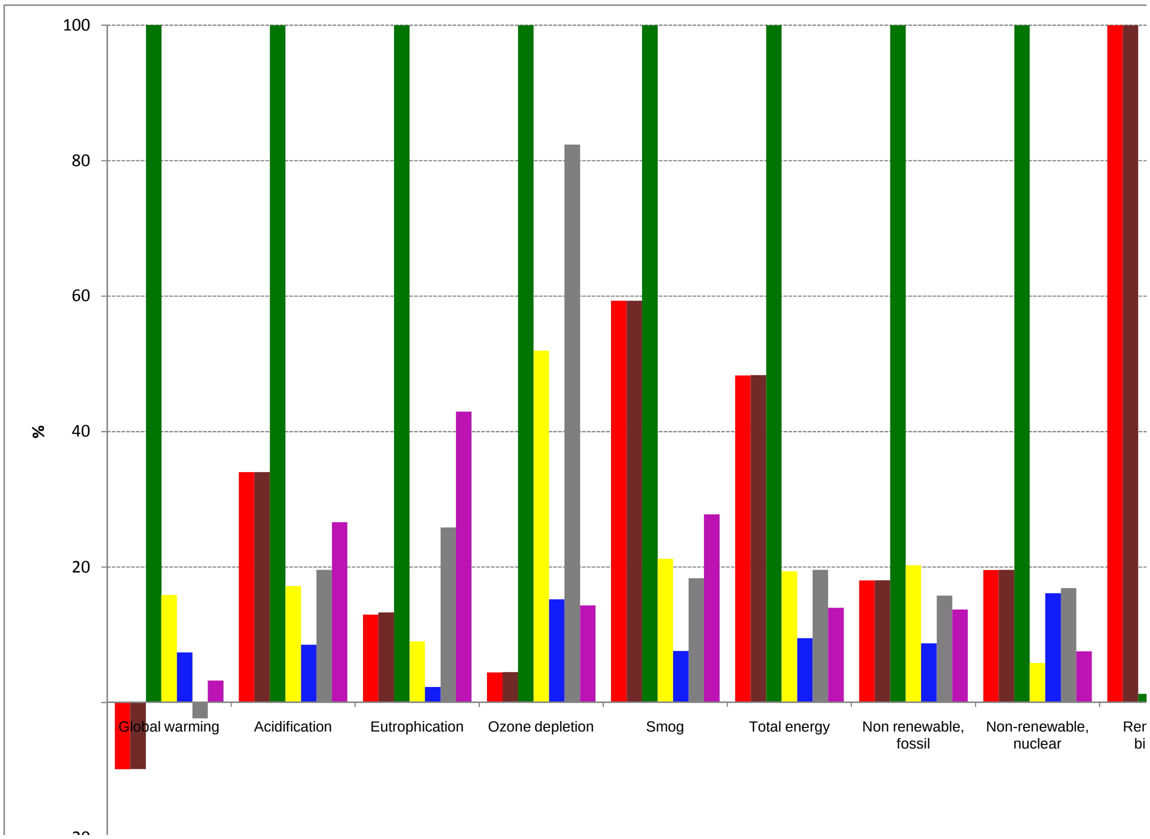

Figure 21 Periodic floor cleaning of hardwood flooring vs the base cases of other flooring types – percent basis

7.2.7 Sensitivity of Excluded Data – Capital Equipment

The significance of capital equipment in the comparative LCA findings was tested by adding generic data on capital equipment available in the US EI database to the hardwood flooring system and comparing its results against the base cases of all the floorings. The details on generic infrastructure processes are shown in Table ***70***. Table ***71*** and
Figure 22 depict the results of this sensitivity on an absolute value and percent basis respectively. With the inclusion of capital equipment, slight increases in all the impact categories occur in the hardwood flooring system. However, the base case findings are still valid as the comparative LCIA results exhibit the same pattern even after including capital equipment in the hardwood flooring system.

Table 70 Generic infrastructure processes added to the hardwood flooring system

Capital equipment	Data source	Generic process used in the model
Chainsaws used for logging	US EI	Power sawing with catalytic converter
Sawmill	US EI	Sawmill/RER/I with US electricity U
Planning mill	US EI	Planing mill/RER/I with US electricity U
Kiln dryer	US EI	Technical wood drying, infrastructure/RER/I with US electricity U

Table 71 Hardwood flooring sensitivity to capital equipment against its base case and other flooring types – absolute value basis

Impact category	Unit	Hardwood Base Case	Hardwood with Capital equipment	Carpet	Ceramic Tile	VCT	Cork	Linoleum
Global warming	kg CO2 eq	-444.72	-436.31	4513.99	716.07	335.22	-105.10	146.65
Acidification	H+ moles eq	455.88	458.49	1340.62	230.73	114.52	262.73	357.08
Eutrophication	kg N eq	0.49	0.53	3.78	0.34	0.09	0.98	1.62
Ozone depletion	kg CFC-11 eq	4.34E-06	5.42E-06	9.71E-05	5.05E-05	1.48E-05	8.00E-05	1.39E-05
Smog	kg NOx eq	7.87	7.92	13.28	2.82	1.01	2.44	3.69
Total energy	MJ eq	44630.41	44781.79	92400.48	17908.02	8770.17	18095.95	12914.05
Non renewable, fossil	MJ eq	14909.01	15038.97	82689.48	16763.40	7230.49	13051.33	11341.29
Non-renewable, nuclear	MJ eq	1788.46	1790.27	9142.44	535.06	1476.55	1546.18	690.65
Renewable, biomass	MJ eq	24208.43	24227.80	312.05	579.52	5.24	2944.31	853.15
Renewable, other	MJ eq	3724.50	3724.76	256.52	30.05	57.89	554.12	28.96

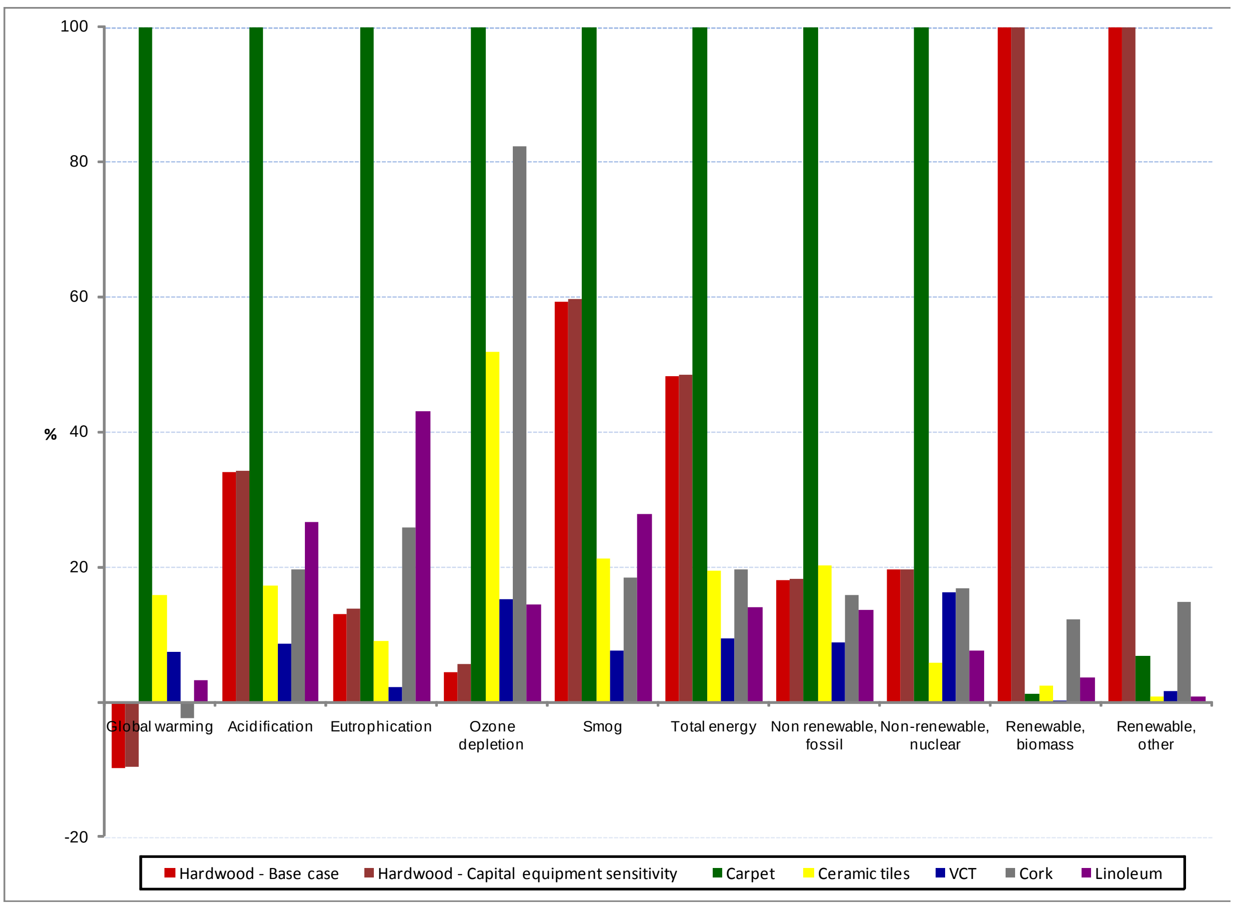

Figure 22 Hardwood flooring sensitivity to capital equipment against its base case and other flooring types – percent basis

7.2.8 Sensitivity of the Impact Assessment Method Used

The impact assessment method “EPD 2008” published by the Swedish Environmental Management Council was chosen because this particular LCIA method contained most of the impact categories used to generate the base case findings. LCIA results calculated using EPD 2008 for the flooring base case are shown in Table ***72*** against the base case TRACI results on an absolute value basis. Significant increase in non-renewable fossil fuel consumption and global warming occur when EPD 2008 is applied to characterize base case floorings. Comparative LCIA results obtained from EPD 2008 are depicted in Figure ***23***. Despite the significant changes noted in global warming and fossil fuel consumption impact categories, comparative LCIA results obtained using EPD 2008 generally exhibits a similar pattern that has been noticed in the base case assessment with TRACI.

Table 72 LCIA results – TRACI vs EPD (2008) on an absolute value basis

Impact category	Method	Unit	Hardwood	Carpet	Ceramic tiles	VCT	Cork	Linoleum
Global warming	EPD	kg CO2 eq	-1638.86	4476.60	643.62	331.87	-273.57	127.68
	TRACI		-444.72	4513.99	716.07	335.22	-105.10	146.65
Ozone depletion	EPD	kg CFC-11 eq	4.88E-06	8.42E-05	7.07E-05	2.32E-05	6.40E-05	1.72E-05
	TRACI		4.34E-06	9.71E-05	5.05E-05	1.48E-05	8E-05	1.39E-05
Acidification	EPD	kg SO2 eq	6.95	22.61	3.72	1.98	4.47	5.99
	TRACI	kg H+ eq	455.88	1340.62	230.73	114.52	262.73	357.08
Eutrophication	EPD	kg PO4$_{-3}$ eq	0.97	2.92	0.43	0.13	0.60	1.04
	TRACI	kg N eq	0.49	3.78	0.34	0.09	0.98	1.62
Non renewable, fossil	EPD	MJ eq	15172.58	87398.78	17029.65	8276.60	14569.71	11574.71
	TRACI		14909.01	82689.48	16763.40	7230.49	13051.33	11341.29

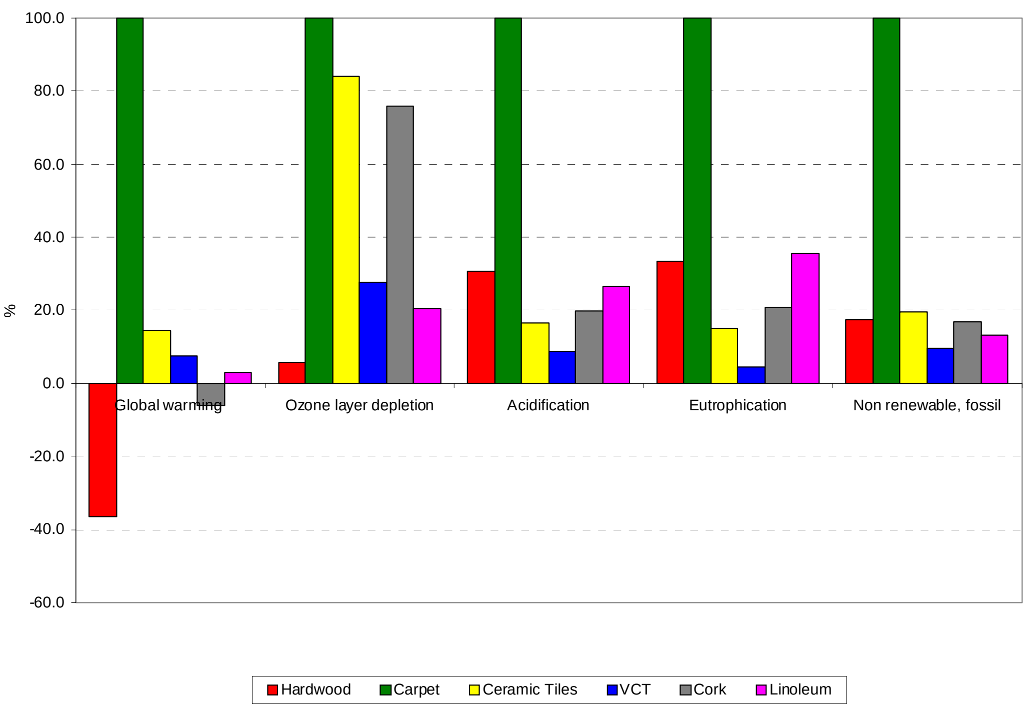

Figure 23 LCIA results with EPD (2008) on a percent basis

7.3 Study Conclusions

The following conclusions were drawn regarding the contribution and sensitivity analysis of the hardwood flooring system and its comparative assertion against the selected alternative flooring products:

Hardwood flooring system

- In the cradle-to-grave product system, flooring manufacturing is the most dominant life cycle stage in terms of life cycle energy use, non-renewable fossil fuel consumption, and environmental emissions. Mostly the impacts occur during the flooring drying process.
- Impact contributions from cradle-to-gate lumber manufacturing (the input to the flooring manufacturing process) is comparatively small, however it is another area of potential improvement of the product environmental performance.
- Some of the lumber mills and flooring mills participated in the surveys internally recycle wood waste for energy, and as a result, fossil fuel consumption of hardwood flooring is proportionately too low to its total energy use.
- Considerable amount of GHG emissions can occur from landfilling flooring at the end of life mainly due to methane emissions that are not captured for energy recovery during landfill operations.
- Despite the emissions and significant amounts of energy use, there are climate change benefits of using hardwood flooring when taking into account the C sequestered in flooring boards.
- Environmental burden of hardwood flooring can be reduced through manual cleaning (i.e., by sweeping with a broom) rather than vacuuming the floor to remove dust and grit.
- Selling co-products (wood waste) in alternative higher value markets would move more of the environmental burden to the co-products, lowering the impacts of hardwood flooring.
- Significant improvements to the environmental performance occur when post consumer hardwood flooring waste (flooring boards and plywood) are recycled for bioenergy instead of landfilling at the end of life. In addition, considerable amount of fossil fuel can be displaced through recycling post consumer hardwood flooring waste for energy.

Comparative assertion against the alternative flooring types

- While considering environmental emissions, hardwood flooring substantially outperforms all the alternative floorings selected for the comparison, in the global warming and ozone depletion impact categories, and there are more climate change benefits of using hardwood compared to the two other organic flooring types, cork and linoleum.
- Compared to carpet, hardwood performs better in the total energy use and non-renewable fossil fuel consumption impact categories, however, its energy consumption performance is worse compared the other four flooring types (hardwood consumes 2.5-5 times higher amounts of energy when compared with ceramic tiles, VCT, cork, and linoleum).
- Fossil fuel consumption of hardwood flooring is comparable with ceramic, cork, and linoleum and worse compared to VCT.
- Fossil fuel consumption of hardwood flooring is comparable with ceramic, cork, and linoleum and worse compared to VCT. However, hardwood performs better in terms of life cycle fossil fuel use with longer use or increased durability.
- Environmental performance of hardwood flooring system can be significantly improved by recycling post-consumer flooring waste (flooring boards and plywood underlayment) at the flooring end of life for bioenergy. About 26,293 MJ of fossil fuel (on a basis of 1000 sq.ft. of

installed flooring) could be displaced through recycling for bioenergy, and this displaced fossil fuel amount even surfaces (by 11384 MJ) fossil fuel consumption during the complete life cycle.

7.4 Recommendations

The following actions would be useful in improving the product environmental profile of hardwood flooring:

- More use of wood waste produced during sawmilling and flooring milling to substitute for fossil fuel use in the mills
- Find alternative higher value markets to sell wood waste from lumber and flooring manufacturing in order to lower the environmental burden of flooring by moving more of the environmental impacts to co-products
- Improve logs to lumber conversion efficiency during sawmilling
- Encourage consumers to minimize vacuuming and manually clean hardwood floors as much as possible in removing dust and grit
- Recycle post-consumer flooring waste for bioenergy at end-of-life rather than disposing in landfills
- Extend the service life

7.5 Study Limitations

LCIA results of the alternative floorings underrepresent their actual life cycle environmental burden because of some missing LCI flows that were not included in the characterization. This is a major limitation of this study. We could not comment on the significance of those LCI flows because there was no proxy data to address the issue. Therefore, caution should be exercised in drawing strong conclusions from the comparative assertion, especially when the selected alternative floorings outperform hardwood by a narrow margin.

8 Work Cited

Amitico International, 2010. Installation Guidelines. http://www.amtico.com/uploadedFiles/Resources/UK/Information_and_Advice/Amtico%20Installation%20Guidelines.pdf

Barlaz, Morzen, Email communication with the author, October 24, 2010.

Black and Decker, 2009. Project Center: Removing Underlayment. http://webcache.googleusercontent.com/search?q=cache:pGKUXC5sq3MJ:www.blackanddecker.com/ProjectCenter/ProjectDetail.aspx%3FDOC_ID%3Dp_2_30_12346_12353.html+flooring+underlayment+change&cd=29&hl=en&ct=clnk&gl=ca

Boa-Franc. (published year not known). Installation Guide: Solid Pre-finished Hardwood Floors. Quebec, Canada.

Bobia M. D. *et al.*, 2009. Environmental Performance of Ceramic Tiles: Improvement Proposals. Materials and Design 31: 35-41.

BuildingDirect, 2001-2010. Cork Flooring Articles: The Manufacturing Process of Cork Flooring. BuildingDirect Technologies Inc., Vancouver, Canada. http://www.builddirect.com/Cork-Flooring/Cork-Floors-Articles/The_Manufacturing_Process_of_Cork_Flooring.aspx.

Building Direct, 2001-2010. Cork Flooring Frequently Asked Questions – How Long will My Cork Flooring Last Evora cork flooring through BuildDirect has a 25-year structural warranty. http://www.builddirect.com/Cork-Flooring/Cork-Floors-FAQ_9089.aspx#How%20long%20will%20my%20cork%20flooring%20last

Ceramic tile floor information, 2010. Preparing the Subfloor for Tile Installation. http://www.ceramic-tile-floor.info/ceramic-tile-installation/prepare-subfloor/.

Cohen Steve, 2008. Wanted: New York City's Giant Garbage Problem. New York Observer, New York. http://www.observer.com/2008/wasted-new-york-citys-giant-garbage-problem

Easy2.Com.,Inc.2001-2010. Ceramic Tile Calculator: http://www.easy2diy.com/cm/easy/diy_ht_calc_index.asp?page_id=35720762

ECEEE, 2010. Working document: Highlighting Options for a Possible Commission Regulation Implementing Ecodesign Directive 2009/125/EC and Energy Labelling Directive 2010/30/EU with regard to Vacuum Cleaners. www.eceee.org/Eco_design/.../vacuum_cleaners/WD_CF25June2010.

Extonet Ltd., 2010. Abacus Construction Index: Linoleum Flooring Manufacturers. http://www.construction-index.com/usa-linoleum-flooring.asp

FindAnyFloor.com, 2008. Installing Linoleum Flooring. http://www.findanyfloor.com/pub/pdf/InstallingLinoleumFlooring-FullGuide.pdf

Finitec Canada, 2009. Material Safety Data Sheet: Mirage Hardwood Floor Cleaner. Finitec Hardwood Flooring Inc., Quebec.

Floortransformed.com, 2010. Tile Floors: Choosing Tile Grout Motar. http://www.floorstransformed.com/choosegrout.html

Gorree M. et.al., 2000. Environmental Life Cycle Assessment of Linoleum. Centre of Environmental Science – Leiden University (CML-UL). http://www.leidenuniv.nl/cml/ssp/publications/lcalinoleum.pdf

Globas Cork, 2010. Cork Floating Floor Installation Guide. http://www.corkfloor.com/floatinginstructions.html

GreenFloors 2003. Checklist for Bamboo Flooring Job Conditions. http://www.greenfloors.com/HP_Bamboo_Installation.htm#CHECKLIST%20FOR%20YOUR%20JOB%20CONDITIONS:

Ham, R.K., and Bookter T.J. 1982. "Decomposition of solid waste in test lysimeters." *J.Env. Eng*. 108: 1147.

HighBeam Business, 2010. Industry Report: Ceramic Wall and Floor Tiles. http://business.highbeam.com/industry-reports/chemicals/ceramic-wall-floor-tile

Home-Improvement-and-Financing.Com, 2004-2010. Ceramic Floor Tile: Why Ceramic Floor Tile is Right for You. http://www.home-improvement-and-financing.com/ceramic-floor-tile.html

HQ Air Force Centre for Environmental Excellence. 2001. *Construction and Demolition Waste Management Pocket Guide*. http://www.p2pays.org/ref/19/18363.pdf.

Hubpages, 2010. Ceramic Tile Flooring. http://hubpages.com/hub/Ceramic-Tile-Flooring.

Jobin Jerome, 2010. Model Hardwood Inc. Email communication with the author. January 11, 2010.

Lauzon, 2006. Classic Collection: Step by Step Installation Guide and Warranty. http://www.plancherslauzon.com/pdf/Installation_Classics.pdf

Laminateflooring.net. (Year not known). How to Install Laminate Flooring. http://www.laminatefloorings.net/lm_floors_install.htm.

Lippiatt C. Barbara, 2007. Building for Environmental and Economic Sustainability Technical Manual and User Guide. National Institute of Standards and Technology, US Department of Commerce.

Micales J. A. Skog, K. E. (1997): The Decomposition of Forest Products in Landfills. International Biodeterioration and Biodegredation, Elsevier, 39:2-3, p. 145-158.

Mishulovic, Alex and Evanco James, 2003. Ceramic Tiles from High Carbon Fly Ash. International Ash Utilization Symposium, 2003, Center for Applied Energy Research, University of Kentucky. http://www.flyash.info/2003/18mish.pdf.

Natural Interiors 2010. Non-Toxic Finishes and Stains. http://naturalinteriors.us/products/non-toxic-stains-finishes.

PG Model Hardwood Inc., (published year not known). Installing Hardwood Flooring Boards in a Condo. http://www.pgflooring.com/ressources/sync/public/installation_condo_web.pdf.

Pierre Blanchet, 2010. FPInnovations. Email communication with the author. January 21, 2010.Sandia National Laboratories. 2009. Construction Standard Specification Section 09300: Tile. http://www.sandia.gov/engstds/ConstSpecs/Div_09/09300_Tile_0606.doc.

Skog, K. 2008. Sequestration of carbon in harvested wood products for the United States. Forest Products Journal. 58: 56-72.

Stenius, Per, ed. (2000), Papermaking Science and Technology 3: *Forest Products Chemistry*, Fapet Oy, Finland.

Super Tek High Performance Products, 2002. One-Step Thin-set MSDS. http://www.super-tek.com/onestepmsds.htm.

The Carpet and Rug Institute, 2009. Standard for Installation of Residential Carpet http://www.carpet-rug.org/pdf_word_docs/CRI_Carpet_Installation_Standard_2009.pdf.

The Carpet and Rug Institute. 2008. The impact of the carpet industry in Georgia (Based on 2007 statistics) http://www.carpet-rug.org/carpet-and-rug-industry/carpet-and-rug-industry-statistics.cfm

The Flooring Professor, 2007. Cork Flooring. Besco Enterprises. http://www.flooringprofessor.com/cork_flooring.html

Themelis and Ulloa, 2007. Themelis, N. and P. Ulloa.. 2007. Methane generation in landfills. Renewable Energy. 32: P.1243-1257.

Tile Council of America, 2001. Handbook for Ceramic Tile Installation. Tile Council of America Inc., Anderson.

Time4 Media Inc., 2006. Tile Underlayment Membrane. http://www.dannylipford.com/home-improvement-video/tile-underlayment-membrane/

Tootoo, 2008. Rubber Carpet Underlay. http://www.tootoo.com/buy-rubber_carpet_underlay/http://www.zepcommercial.com/msds/united_states/english/ZUCC24.pdf.

US Department of the Army, 2003. Public Works Technical Bulletin: Recycling Interior Finish Materials – Carpet and Ceiling Tiles. The U.S. Army Corps of Engineers, Washington, DC. http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_17.pdf

USEPA. 1995. The role of recycling in integrated waste management in the US. Franklin Associates. Municipal Industrial Waste Division, Washington, DC, EPA/530-R-96-00.

USEPA, 2006. Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks. http://www.epa.gov/climatechange/wycd/waste/downloads/fullreport.pdf

USEPA 2009a. Estimating 2003 *Building-Related* Construction and Demolition Materials Amounts. http://www.epa.gov/osw/conserve/rrr/imr/cdm/pubs/cd-meas.pdf

USEPA 2009b. Inventory of U.S. Greenhouse Gas Emissions and Sinks:

1990 – 2007. http://www.epa.gov/climatechange/emissions/downloads09/GHG2007entire_report-508.pdf

Vinyl Institute, 2010. Vinyl in Design: Uses for Vinyl/Flooring. http://www.vinylindesign.com/site/page.asp?CID=13&DID=14

West Sarah, 2008. Carpet Underlay: Comfort & Protection. http://www.icarpets.ca/articles/carpet_underlay/foam-sponge/

World Floor Covering Association, 2010. How Carpet is Made. USA. http://74.125.93.132/search?q=cache:iwfSbn23FE0J:www.wfca.org/carpet/howmade.aspx+nylon+carpet+manufacturing+process&cd=2&hl=en&ct=clnk&gl=ca.

Appendix I: Developing functions, functional unit and reference flows

Product	Hardwood flooring	Carpets	Ceramic floor tiles	Vinyl flooring	Cork flooring	Linoleum flooring
Product specifics	Made in Eastern Canada; Type – Generic hardwood flooring Specific density- 2.49 lb/sq.ft. Generic dimensions: 28”x3¼”x¾” Service life=25 yrs	Made in Georgia, US; Type – Generic carpet Specific density- 0.45 lb/sq.ft Generic dimensions: 12’x44’ Service life=11 yrs	Made in US Type- Generic ceramic floor tiles Specific density- 5.58 lb/sq.ft Generic dimensions: 1’x1’x 1/2” Service life=50 yrs	Made in Eastern, US; Type- Generic vinyl flooring Specific density- 1.35 lb/sq.ft Generic dimensions: (1’x1’x0.12” Service life=50 yrs	Made in Portugal Type- Generic cork flooring Specific density- 1.52 lb/sq.ft Generic dimensions: 11 13/16 " x 35 13/16" and 7/16" Service life=50 yrs	Made in Europe Type- Generic linoleum flooring Specific density- 0.62 lb/sq.ft Generic dimensions: 12’x6’x0.098” sheets Service life=50 yrs
Functions	(a) floor covering living space and durability); (b) warmth, (c) sound absorption, (d) aesthetic functions etc	(a) floor covering living space and durability); (b) warmth, (c) sound absorption, (d) aesthetic functions etc	(a) floor covering living space and durability); (b) warmth, (c) sound absorption, (d) aesthetic functions etc	(a) floor covering living space and durability); (b) warmth, (c) sound absorption, (d) aesthetic functions etc	(a) floor covering living space and durability); (b) warmth, (c) sound absorption, (d) aesthetic functions etc	(a) floor covering living space and durability); (b) warmth, (c) sound absorption, (d) aesthetic functions etc
Relevant functions for this particular LCA	(a) Provision of “floor covering” (living space and durability);					
Functional unit	Provision of 1,000 sq.ft floor covering for a typical residential building in New York, US over 25-year life span					
Performance of the product	1050 sq.ft of hardwood flooring product with 1662 standard pieces/1,000 sq.ft finished flooring,	1,057 sq. ft of carpets (2 standard pieces)/ 1,000 sq.ft finished flooring, with generic product dimensions	1,100 sq. ft of ceramic flooring product (1,100 standard pieces)/ 1,000 sq.ft finished flooring, with	1,050 sq. ft of vinyl flooring product (1050 standard pieces)/ 1,000 sq.ft finished flooring, with generic product	1,050 sq. ft of cork flooring product (358 standard pieces)/ 1,000 sq.ft finished flooring, with generic product	1,050 sq. ft of linoleum flooring product (22 standard pieces)/ 1,000 sq.ft finished flooring, with generic product

Product	Hardwood flooring	Carpets	Ceramic floor tiles	Vinyl flooring	Cork flooring	Linoleum flooring
	with generic product dimensions (28”x3¼”x¾”) and a life span of 25 years;	(12’x44’) and a life span of 11 years;	generic product dimensions (long*wide*thickness) and a life span of 50 years;	dimensions (long*wide*thickness) and a life span of 40 years;	dimensions (long*wide*thickness) and a life span of 25 years;	dimensions (long*wide*thickness) and a life span of 30 years;
Reference flows	1 cradle-to-grave life cycle = 25/25 of 1,000 sq. ft of Canadian hardwood flooring with a life span of 25 years;	2.3 cradle-to-grave life cycles = 25/11 of 1,000 sq. ft of carpet with a life span of 11 years; Technosphere flows of all the life cycle stages (i.e., resource extraction and product manufacturing, transportation to consumer, use, and EOL) are normalized on a proportionate basis to fulfill the default service life of 25 years (coefficient 2.3 cycles applied)	0.5 cradle-to-grave life cycles =25/50 of 1,000 sq. ft of ceramic tiles flooring with a life span of 50 years; Technosphere flows of all the life cycle stages (i.e., resource extraction and product manufacturing, transportation to consumer, use, and EOL) are normalized on a proportionate basis to fulfill the default service life of 25 years (coefficient 0.5 cycles applied)	0.63 cradle-to-grave life cycles = 25/40 of 1,000 sq. ft of VCT flooring with a life span of 40 years; Technosphere flows of all the life cycle stages (i.e., resource extraction and product manufacturing, transportation to consumer, use, and EOL) are normalized on a proportionate basis to fulfill the default service life of 25 years (coefficient 0.63 cycles applied)	1 cradle-to-grave life cycle = 25/25 of 1,000 sq. ft of cork flooring with a life span of 25 years;	0.83 cradle-to-grave life cycles = 25/30 of 1,000 sq. ft of linoleum flooring with a life span of 30 years; Technosphere flows of all the life cycle stages (i.e., resource extraction and product manufacturing, transportation to consumer, use, and EOL) are normalized on a proportionate basis to fulfill the default service life of 25 years (coefficient 0.83 cycles applied)

Appendix II: Cradle-to-grave LCI Ecosphere Flows for the Base Case Hardwood Flooring System

No	Substance	Compartment	Unit	Total	Logging	Lumber manufacturing	Flooring manufacturing	Transportation to consumer	Use	End-of-life
1	Coal, 26.4 MJ per kg, in ground	Raw	lb	1.88E+02	2.90E+00	3.42E+00	3.35E+01	2.87E+00	1.44E+02	1.07E+00
2	Coal, brown, in ground	Raw	oz	9.16E+01	3.63E-01	6.42E-01	7.65E+01	0.00E+00	1.39E+01	2.22E-01
3	Coal, hard, unspecified, in ground	Raw	oz	4.50E+02	1.69E+00	6.04E+00	3.42E+02	0.00E+00	9.76E+01	2.04E+00
4	Energy, from hydro power	Raw	MJ	3.71E+03	0.00E+00	9.35E+02	2.77E+03	0.00E+00	4.89E-01	0.00E+00
5	Energy, from wood	Raw	kWh	3.27E+03	0.00E+00	1.02E+02	3.17E+03	0.00E+00	0.00E+00	0.00E+00
6	Energy, gross calorific value, in biomass	Raw	MJ	1.83E+03	1.63E-01	7.48E-02	1.81E+03	0.00E+00	1.77E+01	2.25E-02
7	Energy, kinetic (in wind), converted	Raw	kJ	4.12E+02	4.33E+00	7.80E+00	3.59E+02	0.00E+00	3.83E+01	2.71E+00
8	Gas, natural, 46.8 MJ per kg, in ground	Raw	oz	8.41E+01	5.20E+01	2.67E+01	7.51E-03	0.00E+00	5.35E+00	0.00E+00
9	Gas, natural, in ground	Raw	yd3	1.19E+02	1.37E+00	2.34E+00	4.68E+01	1.75E+00	6.60E+01	7.65E-01
10	Limestone, in ground	Raw	g	4.02E+02	2.10E+01	1.21E+01	5.38E-01	0.00E+00	3.68E+02	0.00E+00
11	Oil, crude, 42 MJ per kg, in ground	Raw	lb	7.12E+01	4.68E+01	2.40E+01	4.00E-04	0.00E+00	2.76E-01	0.00E+00
12	Oil, crude, in ground	Raw	kg	1.62E+02	1.81E+01	2.48E+01	6.40E+01	2.44E+01	2.04E+01	1.07E+01
13	Uranium oxide, 332 GJ per kg, in ore	Raw	g	4.59E+00	2.27E-02	2.40E-01	2.73E+00	3.09E-02	1.56E+00	1.16E-02
14	Uranium, 2291 GJ per kg, in ground	Raw	mg	3.60E+00	1.47E+00	7.65E-01	1.76E-03	0.00E+00	1.36E+00	0.00E+00
15	Water, cooling, unspecified natural origin/m3	Raw	cuft	1.63E+02	2.03E-01	6.44E-01	1.03E+02	0.00E+00	5.88E+01	3.96E-01
16	Water, well, in ground	Raw	dm3	6.88E+01	7.04E-02	1.57E-01	6.40E+01	0.00E+00	4.34E+00	1.95E-01
17	Wood and wood waste, 9.5 MJ per kg	Raw	kg	1.12E+03	1.52E-02	2.47E+01	1.09E+03	0.00E+00	3.33E-04	0.00E+00
18	2-Chloroacetophenone	Air	ng	1.64E+02	1.41E+00	3.53E+00	3.97E+01	1.92E+00	1.17E+02	7.18E-01
19	Acenaphthene	Air	µg	1.99E+01	2.22E-01	3.36E-01	4.60E+00	2.91E-01	1.43E+01	1.20E-01
20	Acenaphthylene	Air	µg	9.05E+00	1.05E-01	1.49E-01	1.66E+00	1.42E-01	6.94E+00	5.32E-02

No	Substance	Compartment	Unit	Total	Logging	Lumber manufacturing	Flooring manufacturing	Transportation to consumer	Use	End-of-life
21	Acetophenone	Air	ng	3.52E+02	3.03E+00	7.56E+00	8.51E+01	4.12E+00	2.51E+02	1.54E+00
22	Acrolein	Air	mg	1.63E+01	1.58E-01	2.24E-01	2.70E+00	1.91E-01	1.29E+01	1.13E-01
23	Aldehydes, unspecified	Air	g	7.94E+00	2.04E+00	1.69E+00	2.19E+00	9.91E-01	6.61E-01	3.70E-01
24	Ammonia	Air	g	1.17E+01	5.00E-01	5.82E-01	7.50E+00	4.98E-01	2.39E+00	2.23E-01
25	Ammonium chloride	Air	mg	2.44E+02	1.21E+00	1.27E+01	1.45E+02	1.64E+00	8.28E+01	6.13E-01
26	Anthracene	Air	µg	7.60E+00	8.79E-02	1.25E-01	1.39E+00	1.20E-01	5.83E+00	4.47E-02
27	Antimony	Air	mg	1.07E+00	1.14E-01	6.65E-02	3.65E-01	1.03E-02	5.13E-01	4.36E-03
28	Arsenic	Air	mg	6.84E+01	4.81E-01	1.63E+00	5.37E+01	3.33E-01	1.21E+01	1.63E-01
29	Barium	Air	g	2.46E+00	5.27E-06	5.43E-02	2.40E+00	0.00E+00	5.30E-05	1.19E-06
30	Benzene	Air	g	4.59E+00	3.30E-03	5.99E-02	4.41E+00	1.08E-03	1.04E-01	1.11E-02
31	Benzene, chloro-	Air	ng	5.16E+02	4.44E+00	1.11E+01	1.25E+02	6.04E+00	3.68E+02	2.26E+00
32	Benzene, ethyl-	Air	mg	1.01E+01	2.75E-01	3.22E-02	7.18E+00	2.58E-05	5.01E-01	2.15E+00
33	Benzo(a)anthracene	Air	µg	2.89E+00	3.35E-02	4.77E-02	5.30E-01	4.56E-02	2.22E+00	1.70E-02
34	Benzo(a)pyrene	Air	µg	2.56E+02	4.78E-01	5.53E-01	2.08E+02	2.16E-02	6.25E+00	4.10E+01
35	Benzo(b,j,k)fluoranthene	Air	µg	3.98E+00	4.61E-02	6.56E-02	7.29E-01	6.27E-02	3.05E+00	2.34E-02
36	Benzo(ghi)perylene	Air	ng	9.77E+02	1.13E+01	1.61E+01	1.79E+02	1.54E+01	7.50E+02	5.75E+00
37	Benzyl chloride	Air	µg	1.64E+01	1.41E-01	3.53E-01	3.97E+00	1.92E-01	1.17E+01	7.18E-02
38	Beryllium	Air	mg	1.23E+00	2.77E-02	2.76E-02	4.91E-01	1.63E-02	6.65E-01	6.55E-03
39	Biphenyl	Air	µg	6.15E+01	7.12E-01	1.01E+00	1.13E+01	9.68E-01	4.72E+01	3.62E-01
40	Bromoform	Air	ng	9.15E+02	7.87E+00	1.97E+01	2.21E+02	1.07E+01	6.52E+02	4.00E+00
41	BTEX (Benzene, Toluene, Ethylbenzene, and Xylene), unspecified ratio	Air	g	1.66E+01	2.43E-01	4.05E-01	4.72E+00	3.30E-01	1.08E+01	1.23E-01
42	Butadiene	Air	mg	2.09E+00	7.93E-03	1.11E-02	3.44E-02	1.08E-02	2.03E+00	4.03E-03
43	Cadmium	Air	mg	4.84E+00	4.04E-01	2.81E-01	1.90E+00	8.22E-02	2.07E+00	1.07E-01
44	Carbon dioxide, biogenic	Air	kg	1.19E+03	6.17E-02	2.60E+01	1.16E+03	5.77E-02	3.45E+00	2.39E-02
45	Carbon dioxide, fossil	Air	kg	9.00E+02	1.30E+02	1.18E+02	2.91E+02	8.50E+01	2.39E+02	3.69E+01
46	Carbon disulfide	Air	mg	1.09E+02	1.44E-01	1.64E-02	1.00E+02	3.57E-05	8.62E+00	5.91E-02
47	Carbon monoxide, biogenic	Air	g	3.11E+00	1.82E-03	1.95E-03	2.59E+00	0.00E+00	5.21E-01	5.95E-04
48	Carbon monoxide, fossil	Air	oz	1.02E+02	1.15E+01	1.55E+01	3.88E+01	1.57E+01	1.43E+01	6.42E+00
49	Chloride	Air	µg	2.45E+00	3.25E-02	4.63E-02	1.31E-01	4.42E-02	2.18E+00	1.65E-02
50	Chlorine	Air	g	8.93E+00	4.31E-03	1.12E-01	6.82E+00	0.00E+00	1.99E+00	1.59E-04
51	Chloroform	Air	µg	2.73E+02	1.62E+00	6.14E+00	2.32E+02	1.62E-02	3.12E+01	2.14E+00
52	Chromium VI	Air	mg	3.44E+00	3.54E-02	5.24E-02	1.07E+00	4.50E-02	2.22E+00	1.89E-02

No	Substance	Compartment	Unit	Total	Logging	Lumber manufacturing	Flooring manufacturing	Transportation to consumer	Use	End-of-life
53	Chrysene	Air	µg	3.62E+00	4.19E-02	5.96E-02	6.63E-01	5.70E-02	2.78E+00	2.13E-02
54	Cobalt	Air	mg	1.13E+01	6.73E-01	9.08E-01	4.44E+00	4.82E-01	4.56E+00	2.46E-01
55	Copper	Air	mg	1.79E+01	5.96E-02	5.24E-02	1.49E+01	4.24E-03	4.64E-01	2.44E+00
56	Cumene	Air	g	3.07E+00	6.56E-05	2.80E-03	3.07E+00	1.45E-09	3.29E-05	1.12E-04
57	Cyanide	Air	mg	4.11E+01	4.15E-02	1.60E-01	2.91E+01	6.86E-04	1.18E+01	5.47E-02
58	Dinitrogen monoxide	Air	g	1.72E+01	1.46E+00	2.11E+00	7.13E+00	1.96E+00	3.64E+00	9.07E-01
59	Ethane, 1,1,1-trichloro-, HCFC-140	Air	µg	6.84E+01	2.00E+00	3.56E+00	5.15E+01	2.29E+00	7.83E+00	1.28E+00
60	Ethane, 1,2-dibromo-	Air	ng	2.82E+01	2.42E-01	6.05E-01	6.81E+00	3.29E-01	2.00E+01	1.23E-01
61	Ethane, 1,2-dichloro-	Air	µg	2.18E+02	5.05E+00	2.67E+00	1.75E+02	1.10E-02	2.77E+01	7.48E+00
62	Ethane, chloro-	Air	ng	9.86E+02	8.47E+00	2.12E+01	2.38E+02	1.15E+01	7.02E+02	4.31E+00
63	Ethanol	Air	mg	9.16E+00	4.35E-02	1.12E-01	8.42E+00	0.00E+00	4.88E-01	9.88E-02
64	Ethene, tetrachloro-	Air	mg	1.83E+00	3.54E-02	4.37E-02	4.57E-01	2.99E-02	1.25E+00	1.21E-02
65	Ethene, trichloro-	Air	µg	2.97E+01	1.23E+01	6.35E+00	1.44E-02	0.00E+00	1.11E+01	0.00E+00
66	Fluoranthene	Air	µg	2.57E+01	2.97E-01	4.23E-01	4.70E+00	4.04E-01	1.97E+01	1.51E-01
67	Fluorene	Air	µg	3.29E+01	3.81E-01	5.43E-01	6.03E+00	5.18E-01	2.53E+01	1.94E-01
68	Fluoride	Air	mg	1.13E+01	3.59E-02	3.09E-01	3.50E+00	4.89E-02	7.36E+00	1.83E-02
69	Formaldehyde	Air	g	3.51E+01	1.88E+01	1.01E+01	4.17E+00	4.35E-03	2.07E+00	2.00E-03
70	Furan	Air	mg	1.42E+00	8.03E-05	5.62E-06	1.42E+00	2.59E-06	1.74E-04	3.40E-04
71	Heat, waste	Air	kWh	4.71E+02	1.16E+00	2.75E+00	3.23E+02	0.00E+00	1.23E+02	2.09E+01
72	Hexane	Air	mg	2.24E+02	0.00E+00	1.12E+01	1.17E+00	1.56E+02	1.84E-05	8.99E+00
73	Hydrazine, methyl-	Air	µg	3.99E+00	3.43E-02	8.57E-02	9.65E-01	4.67E-02	2.84E+00	1.74E-02
74	Hydrocarbons, unspecified	Air	g	1.84E+01	6.96E-03	1.71E+01	8.36E-01	9.47E-03	4.78E-01	3.54E-03
75	Hydrogen chloride	Air	g	5.09E+01	6.33E-01	9.13E-01	1.33E+01	7.36E-01	3.50E+01	3.05E-01
76	Hydrogen fluoride	Air	g	5.97E+00	7.48E-02	1.04E-01	1.42E+00	8.54E-02	4.25E+00	3.56E-02
77	Hydrogen sulfide	Air	mg	4.26E+02	9.41E-01	2.43E+00	4.20E+02	1.43E-06	1.96E+00	6.38E-02
78	Iron	Air	g	2.60E+00	1.47E-04	5.46E-02	2.55E+00	0.00E+00	4.76E-04	3.31E-04
79	Isophorone	Air	µg	1.36E+01	1.17E-01	2.92E-01	3.29E+00	1.59E-01	9.69E+00	5.95E-02
80	Isoprene	Air	g	8.03E+01	1.07E+00	1.52E+00	4.28E+00	1.45E+00	7.14E+01	5.42E-01
81	Kerosene	Air	mg	1.17E+02	8.58E-01	6.25E+00	6.93E+01	7.86E-01	4.00E+01	2.94E-01
82	Lead	Air	mg	7.02E+02	7.02E-01	1.55E+01	6.72E+02	3.66E-01	1.29E+01	2.60E-01
83	Magnesium	Air	mg	5.39E+02	4.87E+00	7.55E+00	2.08E+02	6.27E+00	3.10E+02	2.60E+00
84	Manganese	Air	g	5.05E+00	6.90E-04	1.12E-01	4.92E+00	5.02E-04	1.51E-02	2.03E-04
85	Mercaptans, unspecified	Air	mg	4.94E+00	4.10E-02	1.05E-01	1.20E+00	5.57E-02	3.51E+00	2.08E-02
86	Mercury	Air	mg	7.13E+00	1.28E-01	1.25E-01	3.17E+00	6.31E-02	3.61E+00	4.32E-02
87	Metals, unspecified	Air	mg	1.07E+01	6.94E+00	3.57E+00	2.38E-04	1.64E-07	1.76E-01	6.13E-08

No	Substance	Compartment	Unit	Total	Logging	Lumber manufacturing	Flooring manufacturing	Transportation to consumer	Use	End-of-life
88	Methacrylic acid, methyl ester	Air	ng	4.69E+02	4.04E+00	1.01E+01	1.14E+02	5.49E+00	3.34E+02	2.05E+00
89	Methane, biogenic	Air	g	1.12E+01	2.50E-03	8.14E-03	7.65E+00	0.00E+00	3.49E+00	2.45E-03
90	Methane, bromo-, Halon 1001	Air	µg	3.76E+00	3.23E-02	8.07E-02	9.09E-01	4.39E-02	2.67E+00	1.64E-02
91	Methane, dichloro-, HCC-30	Air	mg	2.03E+01	4.51E-01	7.85E-01	7.63E+00	5.27E-01	1.07E+01	2.03E-01
92	Methane, dichlorodifluoro-, CFC-12	Air	µg	1.84E+01	2.09E+00	2.90E+00	7.77E+00	2.83E+00	1.78E+00	1.06E+00
93	Methane, fossil	Air	g	6.69E+02	4.54E+00	7.04E+00	3.79E+02	5.06E+00	2.68E+02	4.89E+00
94	Methanol	Air	g	1.27E+02	1.65E-03	5.58E-03	1.42E-01	0.00E+00	1.27E+02	4.13E-04
95	Methyl ethyl ketone	Air	mg	7.49E+02	2.88E-02	2.20E-04	1.08E+02	1.07E-04	6.41E+02	1.31E-04
96	N-Nitrodimethylamine	Air	µg	6.66E+00	2.75E+00	1.43E+00	3.21E-03	0.00E+00	2.48E+00	0.00E+00
97	Naphthalene	Air	g	1.34E+00	9.27E-05	2.98E-02	1.31E+00	9.97E-05	9.20E-04	3.72E-05
98	Nickel	Air	mg	4.36E+02	9.45E+00	1.93E+01	3.62E+02	6.15E+00	3.55E+01	3.35E+00
99	Nitrate	Air	µg	5.74E+01	2.90E-01	9.78E-01	5.08E+01	0.00E+00	5.03E+00	3.38E-01
100	Nitrogen oxides	Air	oz	2.41E+02	5.70E+01	5.12E+01	7.52E+01	2.04E+01	2.76E+01	9.80E+00
101	Nitrogen, total	Air	mg	9.52E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.52E+01	0.00E+00
102	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	g	8.66E+02	3.27E+02	1.89E+02	2.04E+02	4.80E+01	7.09E+01	2.70E+01
103	Organic substances, unspecified	Air	g	9.43E+01	8.40E-01	2.51E+00	9.06E+01	3.54E-03	3.30E-01	1.32E-03
104	PAH, polycyclic aromatic hydrocarbons	Air	mg	2.07E+01	6.81E-02	1.42E-01	6.60E+00	4.64E-02	9.26E+00	4.63E+00
105	Particulates	Air	g	8.44E+00	0.00E+00	8.44E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
106	Particulates, < 10 um	Air	g	2.29E+02	8.35E+01	5.30E+01	9.27E+01	0.00E+00	0.00E+00	0.00E+00
107	Particulates, < 2.5 um	Air	g	4.01E+01	3.72E-02	1.31E+00	2.25E+01	0.00E+00	1.05E+01	5.65E+00
108	Particulates, > 10 um	Air	g	4.90E+01	1.10E-01	3.35E-01	3.37E+01	0.00E+00	1.44E+01	5.34E-01
109	Particulates, > 2.5 um, and < 10um	Air	g	1.16E+02	7.58E+00	9.81E+00	4.84E+01	1.04E+01	3.53E+01	4.15E+00
110	Particulates, unspecified	Air	g	7.04E+02	1.02E+01	1.05E+01	3.82E+01	7.56E+00	6.35E+02	2.82E+00
111	Phenanthrene	Air	µg	9.77E+01	1.13E+00	1.61E+00	1.79E+01	1.54E+00	7.50E+01	5.75E-01
112	Phenol	Air	g	2.61E+01	3.34E-04	4.96E-01	2.41E+01	4.39E-09	1.55E+00	4.11E-07
113	Phenols, unspecified	Air	mg	6.33E+00	2.07E-01	4.34E-01	3.38E+00	2.82E-01	1.91E+00	1.05E-01

No	Substance	Compartment	Unit	Total	Logging	Lumber manufacturing	Flooring manufacturing	Transportation to consumer	Use	End-of-life
114	Phthalate, dioctyl-	Air	µg	1.71E+00	1.47E-02	3.68E-02	4.14E-01	2.00E-02	1.22E+00	7.49E-03
115	Potassium	Air	g	4.36E+02	4.74E-04	9.62E+00	4.26E+02	0.00E+00	8.70E-03	4.80E-04
116	Propanal	Air	µg	2.94E+01	1.21E-01	1.93E-01	3.05E+00	1.04E-01	7.34E+00	1.86E+01
117	Propene	Air	g	1.35E+00	1.11E-03	9.32E-03	1.20E+00	7.12E-04	1.39E-01	4.68E-03
118	Pyrene	Air	µg	1.19E+01	1.38E-01	1.97E-01	2.19E+00	1.88E-01	9.16E+00	7.02E-02
119	Radioactive species, unspecified	Air	kBq	2.11E+03	4.35E+01	4.41E+01	3.76E+02	3.23E+01	1.61E+03	1.21E+01
120	Radionuclides (Including Radon)	Air	g	6.53E+00	3.23E-02	3.41E-01	3.88E+00	4.40E-02	2.22E+00	1.64E-02
121	Selenium	Air	mg	5.42E+01	8.16E-01	1.05E+00	1.41E+01	8.00E-01	3.71E+01	3.70E-01
122	Sodium	Air	g	1.01E+01	2.40E-04	2.22E-01	9.92E+00	0.00E+00	5.09E-03	1.46E-03
123	Sulfur dioxide	Air	oz	9.59E+01	1.10E+00	6.58E+00	2.65E+01	1.42E+00	5.95E+01	8.14E-01
124	Sulfur oxides	Air	g	7.91E+02	2.08E+02	1.65E+02	2.24E+02	8.09E+01	8.31E+01	3.02E+01
125	Sulfuric acid, dimethyl ester	Air	µg	1.13E+00	9.69E-03	2.42E-02	2.72E-01	1.32E-02	8.02E-01	4.92E-03
126	t-Butyl methyl ether	Air	mg	2.53E+00	4.47E-05	2.83E-05	2.53E+00	9.61E-06	1.11E-03	7.33E-06
127	Tar	Air	µg	2.75E+00	3.66E-02	5.21E-02	1.47E-01	4.97E-02	2.45E+00	1.86E-02
128	Toluene	Air	mg	2.96E+02	2.87E+00	4.18E+00	2.34E+02	1.13E-01	3.98E+01	1.47E+01
129	Toluene, 2,4-dinitro-	Air	ng	6.57E+00	5.65E-02	1.41E-01	1.59E+00	7.69E-02	4.68E+00	2.87E-02
130	Vinyl acetate	Air	ng	1.78E+02	1.53E+00	3.83E+00	4.31E+01	2.09E+00	1.27E+02	7.79E-01
131	VOC, volatile organic compounds	Air	g	4.07E+02	2.01E+01	2.63E+01	5.86E+01	2.78E+01	2.64E+02	1.04E+01
132	Xylene	Air	mg	1.91E+02	1.83E+00	2.22E+00	1.51E+02	7.87E-02	2.64E+01	9.50E+00
133	Zinc	Air	g	2.49E+00	7.73E-05	5.43E-02	2.43E+00	2.83E-06	2.23E-03	1.49E-03
134	2-Hexanone	Water	mg	4.76E+00	4.37E-01	6.10E-01	1.64E+00	5.94E-01	1.26E+00	2.22E-01
135	Acetone	Water	mg	7.34E+00	6.69E-01	9.35E-01	2.55E+00	9.10E-01	1.94E+00	3.40E-01
136	Acidity, unspecified	Water	mg	1.74E+02	3.54E-02	9.40E-02	1.08E+02	0.00E+00	6.64E+01	1.07E-02
137	Acids, unspecified	Water	µg	1.80E+02	6.83E-01	1.30E+02	2.75E+00	9.29E-01	4.58E+01	3.47E-01
138	Aluminum	Water	g	9.25E+01	5.91E+00	8.42E+00	4.92E+01	7.87E+00	1.80E+01	3.05E+00
139	Ammonia	Water	g	1.26E+01	1.29E+00	1.77E+00	4.41E+00	1.71E+00	2.79E+00	6.37E-01
140	Ammonia, as N	Water	µg	2.58E+01	3.43E-01	4.88E-01	1.38E+00	4.67E-01	2.30E+01	1.74E-01
141	Ammonium, ion	Water	g	-1.41E+01	3.04E-03	-2.20E-02	4.99E+00	3.51E-04	-1.91E+01	8.32E-03
142	Antimony	Water	mg	5.62E+02	3.79E+00	5.29E+00	3.24E+02	4.91E+00	2.22E+02	1.87E+00
143	Arsenic, ion	Water	mg	2.30E+02	1.85E+01	2.60E+01	9.31E+01	2.49E+01	5.76E+01	9.51E+00
144	Barium	Water	g	6.96E+02	7.91E+01	1.10E+02	2.53E+02	1.08E+02	1.07E+02	4.03E+01
145	Benzene	Water	g	6.19E+00	1.13E-01	1.61E-01	5.47E+00	1.53E-01	2.32E-01	6.43E-02

No	Substance	Compartment	Unit	Total	Logging	Lumber manufacturing	Flooring manufacturing	Transportation to consumer	Use	End-of-life
146	Benzene, 1-methyl-4-(1-methylethyl)-	Water	µg	7.29E+01	6.68E+00	9.33E+00	2.51E+01	9.09E+00	1.93E+01	3.40E+00
147	Benzene, ethyl-	Water	mg	7.68E+01	6.62E+00	8.84E+00	2.84E+01	8.58E+00	1.86E+01	5.68E+00
148	Benzene, pentamethyl-	Water	µg	5.47E+01	5.01E+00	7.00E+00	1.88E+01	6.82E+00	1.45E+01	2.55E+00
149	Benzenes, alkylated, unspecified	Water	mg	2.75E+01	3.16E+00	4.39E+00	9.96E+00	4.30E+00	4.04E+00	1.61E+00
150	Benzoic acid	Water	mg	7.40E+02	6.78E+01	9.47E+01	2.55E+02	9.23E+01	1.96E+02	3.45E+01
151	Beryllium	Water	mg	1.26E+01	1.03E+00	1.46E+00	5.72E+00	1.39E+00	2.50E+00	5.34E-01
152	Biphenyl	Water	mg	1.78E+00	2.05E-01	2.84E-01	6.45E-01	2.79E-01	2.62E-01	1.04E-01
153	BOD5, Biological Oxygen Demand	Water	g	3.13E+02	1.57E+01	1.86E+01	1.83E+02	1.66E+01	5.09E+01	2.86E+01
154	Boron	Water	g	2.69E+00	2.89E-01	3.37E-01	9.81E-01	2.86E-01	6.91E-01	1.08E-01
155	Bromide	Water	g	1.56E+02	1.43E+01	2.00E+01	5.38E+01	1.95E+01	4.14E+01	7.28E+00
156	Cadmium, ion	Water	mg	4.22E+01	6.33E+00	5.68E+00	1.50E+01	3.68E+00	1.01E+01	1.40E+00
157	Calcium, ion	Water	oz	1.45E+02	7.60E+00	1.06E+01	6.43E+01	1.03E+01	4.82E+01	3.97E+00
158	Chloride	Water	kg	3.88E+01	2.43E+00	3.39E+00	1.61E+01	3.29E+00	1.23E+01	1.28E+00
159	Chromate	Water	µg	4.22E+02	2.72E+02	1.40E+02	1.25E-02	0.00E+00	9.37E+00	0.00E+00
160	Chromium	Water	g	1.24E+00	1.56E-01	2.13E-01	4.56E-01	2.07E-01	1.34E-01	7.75E-02
161	Chromium VI	Water	mg	3.53E+02	9.88E-01	1.30E+00	2.29E+02	8.73E-01	1.20E+02	5.27E-01
162	Chromium, ion	Water	mg	3.05E+02	1.16E+01	1.71E+01	1.29E+02	1.56E+01	1.26E+02	6.10E+00
163	Cobalt	Water	mg	7.85E+01	1.75E+00	2.29E+00	6.17E+01	2.02E+00	9.95E+00	8.34E-01
164	COD, Chemical Oxygen Demand	Water	g	6.51E+02	2.99E+01	4.73E+01	3.89E+02	3.16E+01	1.19E+02	3.43E+01
165	Copper, ion	Water	g	2.26E+00	1.92E-02	2.92E-02	1.71E+00	2.59E-02	4.68E-01	1.02E-02
166	Cyanide	Water	g	1.16E+00	4.54E-05	1.70E-03	1.14E-02	6.57E-06	1.14E+00	1.98E-04
167	Decane	Water	mg	2.13E+01	1.95E+00	2.72E+00	7.32E+00	2.65E+00	5.63E+00	9.91E-01
168	Dibenzofuran	Water	µg	1.39E+02	1.27E+01	1.78E+01	4.78E+01	1.73E+01	3.67E+01	6.46E+00
169	Dibenzothiophene	Water	µg	1.18E+02	1.09E+01	1.53E+01	4.07E+01	1.49E+01	3.06E+01	5.56E+00
170	DOC, Dissolved Organic Carbon	Water	g	7.56E+01	1.90E+00	3.72E-01	5.20E+01	2.85E-09	1.45E+01	6.81E+00
171	Docosane	Water	µg	7.81E+02	7.15E+01	9.99E+01	2.69E+02	9.73E+01	2.07E+02	3.64E+01
172	Dodecane	Water	mg	4.03E+01	3.70E+00	5.16E+00	1.39E+01	5.03E+00	1.07E+01	1.88E+00
173	Eicosane	Water	mg	1.11E+01	1.02E+00	1.42E+00	3.82E+00	1.39E+00	2.94E+00	5.18E-01
174	Fluorene, 1-methyl-	Water	µg	8.30E+01	7.61E+00	1.06E+01	2.86E+01	1.04E+01	2.20E+01	3.87E+00
175	Fluorenes, alkylated, unspecified	Water	mg	1.59E+00	1.83E-01	2.54E-01	5.77E-01	2.49E-01	2.34E-01	9.32E-02
176	Fluoride	Water	g	1.42E+01	9.58E-03	4.72E-02	1.09E+00	5.71E-03	1.30E+01	8.89E-03

No	Substance	Compartment	Unit	Total	Logging	Lumber manufacturing	Flooring manufacturing	Transportation to consumer	Use	End-of-life
177	Fluorine	Water	µg	7.98E+02	9.05E+01	1.25E+02	2.88E+02	1.23E+02	1.25E+02	4.60E+01
178	Hexadecane	Water	mg	4.40E+01	4.04E+00	5.64E+00	1.52E+01	5.49E+00	1.17E+01	2.05E+00
179	Hexanoic acid	Water	mg	1.53E+02	1.40E+01	1.96E+01	5.28E+01	1.91E+01	4.06E+01	7.14E+00
180	Hydrocarbons, unspecified	Water	g	7.30E+00	2.14E-04	1.97E-03	4.09E+00	3.57E-09	3.21E+00	1.88E-04
181	Iron	Water	g	1.08E+02	1.16E+01	1.62E+01	3.93E+01	1.57E+01	1.97E+01	5.86E+00
182	Iron, ion	Water	g	2.85E+01	5.08E-02	7.12E-02	2.48E+01	0.00E+00	3.62E+00	3.13E-02
183	Lead	Water	mg	8.95E+02	3.88E+01	5.45E+01	3.18E+02	5.24E+01	4.11E+02	2.02E+01
184	Lithium, ion	Water	g	2.34E+02	3.45E+00	5.78E+00	6.92E+01	4.65E+00	1.49E+02	1.77E+00
185	m-Xylene	Water	mg	2.22E+01	2.03E+00	2.83E+00	7.72E+00	2.76E+00	5.87E+00	1.03E+00
186	Magnesium	Water	g	4.76E+02	4.21E+01	5.88E+01	1.72E+02	5.71E+01	1.24E+02	2.19E+01
187	Manganese	Water	g	4.44E+00	1.01E-01	1.45E-01	3.25E+00	1.01E-01	8.07E-01	4.26E-02
188	Mercury	Water	mg	3.41E+00	6.53E-02	9.42E-02	1.87E+00	8.65E-02	1.26E+00	3.34E-02
189	Metallic ions, unspecified	Water	mg	7.59E+02	4.99E+02	2.57E+02	4.33E-03	4.36E-05	2.89E+00	1.63E-05
190	Methane, monochloro-, R-40	Water	µg	2.94E+01	2.69E+00	3.76E+00	1.01E+01	3.66E+00	7.77E+00	1.37E+00
191	Molybdenum	Water	mg	4.42E+01	1.67E+00	2.50E+00	2.65E+01	2.09E+00	1.05E+01	9.13E-01
192	n-Hexacosane	Water	µg	4.87E+02	4.46E+01	6.23E+01	1.68E+02	6.07E+01	1.29E+02	2.27E+01
193	Naphthalene	Water	mg	-6.31E+01	1.22E+00	1.59E+00	4.47E+00	1.66E+00	-7.27E+01	6.19E-01
194	Naphthalene, 2-methyl-	Water	mg	1.16E+01	1.06E+00	1.48E+00	3.98E+00	1.44E+00	3.06E+00	5.38E-01
195	Naphthalenes, alkylated, unspecified	Water	µg	4.50E+02	5.18E+01	7.19E+01	1.63E+02	7.05E+01	6.63E+01	2.64E+01
196	Nickel	Water	mg	1.81E+02	1.81E+01	2.52E+01	6.30E+01	2.46E+01	4.13E+01	9.19E+00
197	Nickel, ion	Water	mg	3.82E+02	4.73E-01	6.69E-01	3.10E+02	0.00E+00	7.01E+01	4.18E-01
198	Nitrate	Water	g	2.00E+02	8.12E-01	3.45E-02	1.49E+02	3.13E-10	5.02E+01	1.26E-02
199	Nitric acid	Water	mg	1.56E+00	2.08E-02	2.96E-02	8.35E-02	2.82E-02	1.39E+00	1.06E-02
200	o-Cresol	Water	mg	2.10E+01	1.92E+00	2.69E+00	7.23E+00	2.62E+00	5.56E+00	9.78E-01
201	Octadecane	Water	mg	1.09E+01	9.97E-01	1.39E+00	3.75E+00	1.36E+00	2.88E+00	5.07E-01
202	Oils, unspecified	Water	g	7.02E+01	4.68E+00	3.40E+00	1.53E+01	2.10E+00	3.70E+01	7.72E+00
203	Organic substances, unspecified	Water	mg	3.87E+02	2.36E+02	1.22E+02	4.02E-02	0.00E+00	2.91E+01	0.00E+00
204	p-Cresol	Water	mg	2.26E+01	2.08E+00	2.90E+00	7.80E+00	2.82E+00	5.99E+00	1.05E+00
205	Phenanthrene	Water	µg	1.75E+02	1.86E+01	2.58E+01	6.21E+01	2.53E+01	3.33E+01	9.45E+00
206	Phenanthrenes, alkylated, unspecified	Water	µg	1.87E+02	2.15E+01	2.98E+01	6.77E+01	2.92E+01	2.75E+01	1.09E+01

No	Substance	Compartment	Unit	Total	Logging	Lumber manufacturing	Flooring manufacturing	Transportation to consumer	Use	End-of-life
207	Phenol	Water	g	2.33E+00	3.13E-02	4.21E-02	2.17E+00	3.86E-02	2.87E-02	2.43E-02
208	Phenol, 2,4-dimethyl-	Water	mg	2.04E+01	1.87E+00	2.62E+00	7.04E+00	2.55E+00	5.41E+00	9.52E-01
209	Phosphate	Water	g	1.51E+01	2.08E-02	1.59E-02	4.73E+00	0.00E+00	1.03E+01	1.98E-02
210	Selenium	Water	mg	3.83E+01	8.22E-01	2.02E+00	2.29E+01	1.07E+00	1.10E+01	4.49E-01
211	Silver	Water	g	1.53E+00	1.40E-01	1.96E-01	5.27E-01	1.91E-01	4.05E-01	7.14E-02
212	Sodium, ion	Water	oz	4.86E+02	2.42E+01	3.38E+01	2.16E+02	3.27E+01	1.66E+02	1.33E+01
213	Solved solids	Water	kg	3.29E+01	3.08E+00	4.21E+00	1.14E+01	4.05E+00	8.68E+00	1.52E+00
214	Strontium	Water	g	4.08E+01	3.67E+00	5.10E+00	1.44E+01	4.96E+00	1.06E+01	2.04E+00
215	Sulfate	Water	g	3.70E+02	9.77E+00	1.45E+01	2.25E+02	7.33E+00	1.10E+02	3.18E+00
216	Sulfide	Water	g	3.39E+00	3.31E-03	1.05E-02	1.59E-02	4.48E-03	3.36E+00	1.79E-03
217	Sulfur	Water	g	2.09E+00	1.80E-01	2.48E-01	8.00E-01	2.41E-01	5.14E-01	1.06E-01
218	Sulfuric acid	Water	mg	3.71E+01	1.92E+01	9.95E+00	1.03E-02	0.00E+00	7.94E+00	0.00E+00
219	Suspended solids, unspecified	Water	oz	8.00E+01	6.35E+00	8.75E+00	3.28E+01	8.53E+00	2.04E+01	3.19E+00
220	Tar	Water	ng	3.94E+01	5.23E-01	7.45E-01	2.10E+00	7.12E-01	3.51E+01	2.66E-01
221	Tetradecane	Water	mg	1.77E+01	1.62E+00	2.26E+00	6.09E+00	2.21E+00	4.68E+00	8.24E-01
222	Thallium	Water	mg	7.62E+00	7.64E-01	1.07E+00	3.28E+00	1.03E+00	1.08E+00	3.97E-01
223	Tin	Water	mg	1.40E+02	1.47E+01	2.04E+01	4.95E+01	2.00E+01	2.75E+01	7.46E+00
224	Titanium, ion	Water	g	2.09E+00	3.00E-01	9.26E-02	1.40E+00	7.54E-02	1.89E-01	3.39E-02
225	Toluene	Water	g	1.20E+00	1.08E-01	1.48E-01	4.23E-01	1.44E-01	3.09E-01	6.69E-02
226	Vanadium	Water	mg	1.98E+01	1.82E+00	2.54E+00	6.82E+00	2.47E+00	5.24E+00	9.23E-01
227	Xylene	Water	mg	6.47E+02	5.83E+01	7.96E+01	2.30E+02	7.74E+01	1.62E+02	3.95E+01
228	Yttrium	Water	mg	4.92E+00	4.51E-01	6.29E-01	1.69E+00	6.13E-01	1.30E+00	2.29E-01
229	Zinc	Water	g	1.31E+00	1.34E-01	1.89E-01	5.24E-01	1.82E-01	2.10E-01	6.79E-02
230	Zinc, ion	Water	mg	8.13E+02	3.39E+00	1.42E+00	6.26E+02	0.00E+00	1.74E+02	8.45E+00
231	Waste, solid	Waste	lb	1.12E+02	8.15E-01	2.87E+00	1.08E+02	0.00E+00	0.00E+00	0.00E+00
232	Wood waste	Waste	tn.lg	1.01E+01	1.01E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Appendix III: Cradle-to-gate LCI Ecosphere Flows for the Base Case Carpet Flooring System

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Carpet Manufacturing	Transport to Consumer	Use	End-of-Life
1	Coal, 26.4 MJ per kg, in ground	Raw	kg	5.46E+02	1.16E+01	1.04E+00	5.33E+02	1.76E-01
2	Coal, brown, in ground	Raw	oz	3.67E+02	4.98E+01	x	3.17E+02	8.05E-02
3	Coal, hard, unspecified, in ground	Raw	lb	5.13E+02	3.52E+02	x	1.61E+02	4.63E-02
4	Energy, from hydro power	Raw	kJ	1.00E+02	1.00E+02	x	x	x
5	Energy, gross calorific value, in biomass	Raw	MJ	3.12E+02	1.95E+02	x	1.17E+02	8.15E-03
6	Energy, gross calorific value, in biomass, primary forest	Raw	kJ	1.20E+00	2.47E-01	x	9.51E-01	6.64E-03
7	Energy, kinetic (in wind), converted	Raw	Wh	7.26E+02	1.50E+01	x	7.11E+02	2.73E-01
8	Gas, natural, in ground	Raw	m3	7.71E+02	5.04E+02	1.07E+00	2.66E+02	2.12E-01
9	Limestone, in ground	Raw	mg	3.47E+02	3.47E+02	x	x	x
10	Uranium oxide, 332 GJ per kg, in ore	Raw	g	1.34E+01	2.81E-01	2.47E-02	1.30E+01	4.19E-03
11	Water, cooling, unspecified natural origin/kg	Raw	g	7.79E+01	7.79E+01	x	x	x
12	Water, cooling, unspecified natural origin/m3	Raw	yd3	2.12E+02	1.64E+02	x	4.80E+01	5.31E-03
13	2-Chloroacetophenone	Air	ng	8.08E+02	1.71E+01	1.54E+00	7.89E+02	2.60E-01
14	Acenaphthene	Air	µg	1.32E+02	2.78E+00	2.32E-01	1.29E+02	4.34E-02
15	Acenaphthylene	Air	µg	5.94E+01	1.26E+00	1.14E-01	5.80E+01	1.93E-02
16	Acetaldehyde	Air	mg	2.46E+02	1.37E+02	1.70E-01	1.10E+02	1.04E-01
17	Acetophenone	Air	µg	1.73E+00	3.67E-02	3.29E-03	1.69E+00	5.58E-04
18	Acrolein	Air	mg	7.58E+01	1.66E+00	1.53E-01	7.39E+01	4.11E-02
19	Aldehydes, unspecified	Air	g	4.88E+00	2.62E+00	7.93E-01	1.33E+00	1.34E-01

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Carpet Manufacturing	Transport to Consumer	Use	End-of-Life
20	Ammonia	Air	g	1.73E+02	1.60E+02	3.99E-01	1.21E+01	8.08E-02
21	Ammonium chloride	Air	mg	7.09E+02	1.49E+01	1.31E+00	6.93E+02	2.22E-01
22	Anthracene	Air	µg	4.99E+01	1.06E+00	9.57E-02	4.87E+01	1.62E-02
23	Antimony	Air	mg	4.77E+00	1.12E-01	8.20E-03	4.65E+00	1.58E-03
24	Arsenic	Air	mg	1.23E+02	1.35E+01	2.67E-01	1.10E+02	5.93E-02
25	Barium	Air	mg	1.43E+00	1.44E-01	x	1.28E+00	4.33E-04
26	Benzene	Air	g	4.86E+00	1.92E+00	8.66E-04	2.94E+00	4.04E-03
27	Benzene, chloro-	Air	µg	2.54E+00	5.39E-02	4.83E-03	2.48E+00	8.18E-04
28	Benzene, ethyl-	Air	mg	1.89E+02	1.30E+02	2.06E-05	5.83E+01	7.81E-01
29	Benzo(a)anthracene	Air	µg	1.90E+01	4.04E-01	3.65E-02	1.86E+01	6.17E-03
30	Benzo(a)pyrene	Air	µg	2.49E+02	3.81E+01	1.73E-02	1.95E+02	1.49E+01
31	Benzo(b,j,k)fluoranthene	Air	µg	2.61E+01	5.55E-01	5.01E-02	2.55E+01	8.49E-03
32	Benzo(ghi)perylene	Air	µg	6.41E+00	1.36E-01	1.23E-02	6.26E+00	2.08E-03
33	Benzyl chloride	Air	µg	8.08E+01	1.71E+00	1.54E-01	7.89E+01	2.60E-02
34	Beryllium	Air	mg	5.75E+00	1.40E-01	1.30E-02	5.59E+00	2.37E-03
35	Biphenyl	Air	µg	4.04E+02	8.58E+00	7.75E-01	3.94E+02	1.31E-01
36	Bromoform	Air	µg	4.50E+00	9.55E-02	8.57E-03	4.40E+00	1.45E-03
37	BTEX (Benzene, Toluene, Ethylbenzene, and Xylene), unspecified ratio	Air	g	1.58E+01	1.04E+00	2.64E-01	1.45E+01	4.48E-02
38	Butadiene	Air	µg	3.04E+02	3.07E+01	8.64E+00	2.63E+02	1.46E+00
39	Cadmium	Air	mg	2.31E+01	7.80E-01	6.58E-02	2.22E+01	3.90E-02
40	Carbon dioxide, biogenic	Air	lb	8.06E+01	1.74E+01	1.02E-01	6.31E+01	1.91E-02
41	Carbon dioxide, fossil	Air	kg	3.99E+03	2.03E+03	6.80E+01	1.88E+03	1.34E+01
42	Carbon dioxide, land transformation	Air	g	1.02E+01	2.23E-01	x	9.98E+00	4.69E-03
43	Carbon disulfide	Air	g	1.40E+00	2.99E-02	2.86E-08	1.37E+00	2.14E-05
44	Carbon monoxide, biogenic	Air	g	1.23E+01	7.82E+00	x	4.44E+00	2.16E-04
45	Carbon monoxide, fossil	Air	oz	1.83E+02	1.14E+02	1.25E+01	5.36E+01	2.33E+00
46	Chlorine	Air	mg	1.44E+02	5.69E+01	x	8.68E+01	5.77E-02
47	Chloroform	Air	mg	2.06E+00	3.86E-02	1.30E-05	2.02E+00	7.75E-04
48	Chromium	Air	mg	3.84E+02	2.95E+02	1.91E-01	8.90E+01	7.25E-02
49	Chromium VI	Air	mg	2.07E+01	4.80E-01	3.60E-02	2.02E+01	6.86E-03

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Carpet Manufacturing	Transport to Consumer	Use	End-of-Life
50	Copper	Air	mg	4.03E+01	1.55E+01	3.40E-03	2.39E+01	8.85E-01
51	Cumene	Air	g	1.28E+00	8.19E-04	1.16E-09	1.28E+00	4.06E-05
52	Cyanide	Air	mg	1.65E+02	3.67E+01	5.49E-04	1.28E+02	1.98E-02
53	Dinitrogen monoxide	Air	g	1.96E+02	1.75E+02	1.57E+00	1.93E+01	3.29E-01
54	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	Air	ng	3.39E+02	3.04E+01	1.23E+00	3.07E+02	3.04E-01
55	Ethane, 1,1,1-trichloro-, HCFC-140	Air	µg	4.24E+02	1.34E+01	1.84E+00	4.09E+02	4.66E-01
56	Ethane, 1,2-dibromo-	Air	ng	1.39E+02	2.94E+00	2.64E-01	1.35E+02	4.46E-02
57	Ethane, 1,2-dichloro-	Air	mg	1.59E+02	2.95E+01	8.79E-06	1.29E+02	2.71E-03
58	Ethane, chloro-	Air	µg	1.73E+01	1.25E+01	9.23E-03	4.74E+00	1.56E-03
59	Ethanol	Air	mg	3.19E+02	2.48E+02	x	7.09E+01	3.58E-02
60	Ethene, chloro-	Air	mg	1.10E+02	3.01E+01	x	8.04E+01	4.79E-04
61	Ethene, tetrachloro-	Air	mg	1.13E+01	2.50E-01	2.39E-02	1.10E+01	4.38E-03
62	Fluoranthene	Air	µg	1.69E+02	3.58E+00	3.24E-01	1.65E+02	5.48E-02
63	Fluorene	Air	µg	2.16E+02	4.59E+00	4.15E-01	2.11E+02	7.02E-02
64	Fluoride	Air	mg	2.11E+01	4.45E-01	3.91E-02	2.06E+01	6.62E-03
65	Fluorine	Air	mg	9.96E+01	3.00E+01	x	6.96E+01	4.48E-04
66	Formaldehyde	Air	mg	9.21E+02	4.09E+02	3.48E+00	5.08E+02	7.24E-01
67	Furan	Air	µg	2.35E+01	4.60E+00	2.08E-03	1.88E+01	1.23E-01
68	Heat, waste	Air	kWh	1.00E+04	6.88E+03	x	3.16E+03	7.57E+00
69	Hexane	Air	g	2.08E+00	6.66E-01	1.47E-08	1.40E+00	1.68E-02
70	Hydrazine, methyl-	Air	µg	1.96E+01	4.16E-01	3.73E-02	1.92E+01	6.32E-03
71	Hydrocarbons, unspecified	Air	g	3.38E+01	2.98E+01	7.58E-03	4.00E+00	1.28E-03
72	Hydrogen chloride	Air	g	3.91E+02	7.58E+01	5.89E-01	3.15E+02	1.11E-01
73	Hydrogen fluoride	Air	g	4.16E+01	3.22E+00	6.84E-02	3.83E+01	1.29E-02
74	Hydrogen sulfide	Air	mg	2.19E+02	4.17E+01	1.14E-06	1.78E+02	2.31E-02
75	Indeno(1,2,3-cd)pyrene	Air	µg	1.45E+01	3.08E-01	2.78E-02	1.41E+01	4.71E-03
76	Iron	Air	mg	7.26E+02	6.76E+02	x	4.97E+01	1.20E-01
77	Isophorone	Air	µg	6.70E+01	1.42E+00	1.27E-01	6.54E+01	2.16E-02
78	Isoprene	Air	g	6.11E+02	1.30E+01	1.16E+00	5.97E+02	1.96E-01
79	Kerosene	Air	mg	3.40E+02	7.15E+00	6.29E-01	3.32E+02	1.07E-01
80	Lead	Air	mg	4.13E+02	1.55E+02	2.92E-01	2.59E+02	9.44E-02

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Carpet Manufacturing	Transport to Consumer	Use	End-of-Life
81	Magnesium	Air	g	2.88E+00	6.85E-02	5.01E-03	2.80E+00	9.42E-04
82	Manganese	Air	mg	1.40E+02	3.65E+00	4.02E-01	1.35E+02	7.36E-02
83	Mercaptans, unspecified	Air	mg	2.41E+01	5.12E-01	4.46E-02	2.35E+01	7.55E-03
84	Mercury	Air	mg	1.24E+02	3.24E+01	5.05E-02	9.20E+01	1.57E-02
85	Metals, unspecified	Air	mg	1.29E+02	1.29E+02	1.31E-07	6.75E-05	2.22E-08
86	Methacrylic acid, methyl ester	Air	µg	2.31E+00	4.90E-02	4.39E-03	2.26E+00	7.44E-04
87	Methane, biogenic	Air	g	4.91E+01	4.26E+01	x	6.51E+00	8.88E-04
88	Methane, bromo-, Halon 1001	Air	µg	1.85E+01	3.92E-01	3.51E-02	1.80E+01	5.95E-03
89	Methane, dichlorodifluoro-, CFC-12	Air	µg	1.37E+01	7.04E+00	2.27E+00	4.02E+00	3.86E-01
90	Methane, fossil	Air	oz	5.24E+02	4.42E+02	1.43E-01	8.20E+01	6.25E-02
91	Methane, tetrachloro-, CFC-10	Air	µg	6.92E+02	5.84E+00	2.27E-01	6.86E+02	1.67E-01
92	Methanol	Air	g	2.98E+00	4.23E-01	x	2.56E+00	1.50E-04
93	Methyl ethyl ketone	Air	µg	1.15E+02	2.10E+01	8.57E-02	9.36E+01	4.74E-02
94	Naphthalene	Air	mg	6.17E+00	3.36E-01	7.97E-02	5.74E+00	1.35E-02
95	Nickel	Air	g	1.33E+00	9.53E-01	4.92E-03	3.74E-01	1.21E-03
96	Nitrogen oxides	Air	oz	4.07E+02	1.97E+02	1.63E+01	1.90E+02	3.55E+00
97	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	oz	9.27E+01	5.59E+01	1.36E+00	3.50E+01	3.45E-01
98	Organic acids	Air	mg	2.61E+00	5.49E-02	4.83E-03	2.54E+00	8.17E-04
99	Organic substances, unspecified	Air	g	1.47E+00	3.13E-02	2.83E-03	1.44E+00	4.80E-04
100	PAH, polycyclic aromatic hydrocarbons	Air	mg	7.63E+01	1.79E+00	3.71E-02	7.28E+01	1.68E+00
101	Paraffins	Air	pg	1.55E+02	4.65E+01	x	1.09E+02	1.13E-02
102	Particulates, < 10 um	Air	g	1.58E+01	1.58E+01	x	x	x
103	Particulates, < 2.5 um	Air	g	3.18E+02	1.69E+02	x	1.47E+02	2.05E+00
104	Particulates, > 10 um	Air	g	4.39E+02	2.33E+02	x	2.06E+02	1.94E-01
105	Particulates, > 2.5 um, and < 10um	Air	g	5.15E+02	3.10E+02	8.30E+00	1.95E+02	1.51E+00

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Carpet Manufacturing	Transport to Consumer	Use	End-of-Life
106	Particulates, unspecified	Air	g	8.17E+02	3.09E+01	6.05E+00	7.79E+02	1.02E+00
107	Phenanthrene	Air	µg	6.41E+02	1.36E+01	1.23E+00	6.26E+02	2.08E-01
108	Phenol	Air	mg	1.88E+02	6.04E-02	3.51E-06	1.88E+02	1.49E-04
109	Phenols, unspecified	Air	mg	1.36E+01	8.90E-01	2.26E-01	1.24E+01	3.82E-02
110	Phthalate, dioctyl-	Air	µg	8.43E+00	1.79E-01	1.60E-02	8.23E+00	2.72E-03
111	Potassium	Air	mg	5.65E+02	2.41E+01	x	5.41E+02	1.74E-01
112	Propanal	Air	µg	5.77E+01	4.77E+00	8.35E-02	4.61E+01	6.75E+00
113	Propane	Air	g	4.15E+00	1.34E+00	x	2.78E+00	3.48E-02
114	Propene	Air	g	1.44E+00	7.70E-01	5.70E-04	6.68E-01	1.70E-03
115	Pyrene	Air	µg	7.84E+01	1.67E+00	1.50E-01	7.65E+01	2.55E-02
116	Radioactive species, unspecified	Air	kBq	1.34E+04	2.86E+02	2.58E+01	1.31E+04	4.37E+00
117	Radionuclides (Including Radon)	Air	g	1.90E+01	4.00E-01	3.52E-02	1.85E+01	5.96E-03
118	Selenium	Air	mg	3.51E+02	1.73E+01	6.40E-01	3.33E+02	1.34E-01
119	Sodium	Air	mg	8.47E+02	6.44E+02	x	2.02E+02	5.30E-01
120	Styrene	Air	mg	2.00E+01	1.76E+01	5.49E-06	2.41E+00	2.67E-04
121	Sulfur dioxide	Air	oz	5.65E+02	1.98E+02	1.13E+00	3.66E+02	2.95E-01
122	Sulfur oxides	Air	g	5.65E+02	2.04E+02	6.47E+01	2.85E+02	1.10E+01
123	Sulfuric acid, dimethyl ester	Air	µg	5.54E+00	1.18E-01	1.05E-02	5.41E+00	1.79E-03
124	t-Butyl methyl ether	Air	µg	1.87E+02	4.96E+00	7.69E-03	1.82E+02	2.66E-03
125	Tar	Air	µg	2.10E+01	4.44E-01	3.98E-02	2.05E+01	6.74E-03
126	Toluene	Air	g	2.02E+00	5.43E-01	9.04E-05	1.47E+00	5.34E-03
127	Toluene, 2,4-dinitro-	Air	ng	3.23E+01	6.86E-01	6.15E-02	3.16E+01	1.04E-02
128	Vinyl acetate	Air	ng	8.78E+02	1.86E+01	1.67E+00	8.57E+02	2.83E-01
129	VOC, volatile organic compounds	Air	g	2.65E+02	6.93E+01	2.22E+01	1.70E+02	3.76E+00
130	Xylene	Air	g	1.19E+00	2.64E-01	6.30E-05	9.21E-01	3.44E-03
131	Zinc	Air	mg	1.92E+02	4.81E+01	2.26E-03	1.44E+02	5.41E-01
132	2-Hexanone	Water	mg	3.82E+00	1.49E+00	4.75E-01	1.77E+00	8.05E-02
133	Acetone	Water	mg	6.17E+00	2.29E+00	7.28E-01	3.03E+00	1.23E-01
134	Acidity, unspecified	Water	g	1.29E+01	5.98E+00	x	6.91E+00	3.87E-06
135	Acids, unspecified	Water	mg	3.42E+00	3.04E+00	7.43E-04	3.83E-01	1.26E-04
136	Aluminum	Water	g	5.50E+02	3.21E+02	6.29E+00	2.22E+02	1.11E+00
137	Ammonia	Water	g	1.01E+01	4.27E+00	1.36E+00	4.26E+00	2.31E-01

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Carpet Manufacturing	Transport to Consumer	Use	End-of-Life
138	Ammonia, as N	Water	µg	1.97E+02	4.17E+00	3.73E-01	1.92E+02	6.32E-02
139	Ammonium, ion	Water	g	4.84E+02	4.57E+02	2.81E-04	2.71E+01	3.02E-03
140	Antimony	Water	g	1.28E+01	1.00E+01	3.93E-03	2.84E+00	6.77E-04
141	Arsenic, ion	Water	mg	6.86E+02	3.32E+02	2.00E+01	3.31E+02	3.45E+00
142	Barium	Water	g	5.43E+02	2.69E+02	8.62E+01	1.73E+02	1.46E+01
143	Benzene	Water	g	4.41E+00	4.42E-01	1.22E-01	3.82E+00	2.33E-02
144	Benzene, 1-methyl-4-(1-methylethyl)-	Water	µg	5.85E+01	2.28E+01	7.27E+00	2.71E+01	1.23E+00
145	Benzene, ethyl-	Water	mg	2.30E+02	4.38E+01	6.87E+00	1.77E+02	2.06E+00
146	Benzene, pentamethyl-	Water	µg	4.38E+01	1.71E+01	5.46E+00	2.03E+01	9.24E-01
147	Benzenes, alkylated, unspecified	Water	Mg	2.08E+01	1.07E+01	3.44E+00	6.02E+00	5.83E-01
148	Benzoic acid	Water	mg	5.93E+02	2.32E+02	7.38E+01	2.75E+02	1.25E+01
149	Beryllium	Water	mg	2.26E+01	3.77E+00	1.11E+00	1.75E+01	1.93E-01
150	Biphenyl	Water	mg	1.34E+00	6.93E-01	2.23E-01	3.90E-01	3.78E-02
151	BOD5, Biological Oxygen Demand	Water	oz	7.69E+01	4.86E+01	4.70E-01	2.75E+01	3.65E-01
152	Boron	Water	g	5.16E+00	2.53E+00	2.28E-01	2.36E+00	3.92E-02
153	Bromide	Water	g	1.25E+02	4.89E+01	1.56E+01	5.82E+01	2.64E+00
154	Cadmium, ion	Water	mg	1.01E+02	6.65E+01	2.95E+00	3.15E+01	5.06E-01
155	Calcium, ion	Water	oz	9.44E+01	3.65E+01	8.25E+00	4.81E+01	1.44E+00
156	Chloride	Water	oz	9.72E+02	3.36E+02	9.27E+01	5.27E+02	1.64E+01
157	Chromium	Water	mg	9.12E+02	5.15E+02	1.66E+02	2.04E+02	2.81E+01
158	Chromium VI	Water	g	7.19E+00	5.50E+00	6.98E-04	1.69E+00	1.91E-04
159	Chromium, ion	Water	mg	1.93E+02	4.39E+01	1.25E+01	1.35E+02	2.21E+00
160	Cobalt	Water	mg	1.39E+02	4.18E+01	1.61E+00	9.53E+01	3.02E-01
161	COD, Chemical Oxygen Demand	Water	oz	2.37E+02	1.80E+02	8.92E-01	5.58E+01	4.39E-01
162	Copper, ion	Water	g	1.25E+01	8.69E+00	2.07E-02	3.79E+00	3.70E-03
163	Decane	Water	mg	1.71E+01	6.66E+00	2.12E+00	7.91E+00	3.59E-01
164	Dibenzofuran	Water	µg	1.11E+02	4.34E+01	1.38E+01	5.16E+01	2.34E+00
165	DOC, Dissolved Organic Carbon	Water	g	9.22E+02	5.62E+02	2.28E-09	3.57E+02	2.47E+00
166	Docosane	Water	µg	6.26E+02	2.44E+02	7.79E+01	2.91E+02	1.32E+01
167	Dodecane	Water	mg	3.24E+01	1.26E+01	4.03E+00	1.50E+01	6.82E-01
168	Eicosane	Water	mg	8.91E+00	3.48E+00	1.11E+00	4.13E+00	1.88E-01

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Carpet Manufacturing	Transport to Consumer	Use	End-of-Life
169	Fluorene, 1-methyl-	Water	µg	6.66E+01	2.60E+01	8.28E+00	3.09E+01	1.40E+00
170	Fluorenes, alkylated, unspecified	Water	mg	1.20E+00	6.20E-01	2.00E-01	3.49E-01	3.38E-02
171	Fluoride	Water	g	2.06E+01	1.36E+01	4.57E-03	6.98E+00	3.22E-03
172	Fluorine	Water	µg	6.06E+02	3.06E+02	9.85E+01	1.85E+02	1.67E+01
173	Hexadecane	Water	mg	3.53E+01	1.38E+01	4.39E+00	1.64E+01	7.44E-01
174	Hexanoic acid	Water	mg	1.23E+02	4.80E+01	1.53E+01	5.70E+01	2.59E+00
175	Hydrocarbons, unspecified	Water	g	5.81E+02	5.39E+02	2.86E-09	4.14E+01	6.83E-05
176	Iron	Water	g	9.25E+01	3.92E+01	1.25E+01	3.85E+01	2.12E+00
177	Iron, ion	Water	g	7.52E+01	2.71E+01	x	4.81E+01	1.14E-02
178	Lead	Water	g	2.79E+00	1.70E+00	4.19E-02	1.04E+00	7.32E-03
179	Lithium, ion	Water	g	2.54E+02	1.53E+01	3.72E+00	2.34E+02	6.44E-01
180	m-Xylene	Water	mg	1.87E+01	6.94E+00	2.21E+00	9.18E+00	3.74E-01
181	Magnesium	Water	g	4.82E+02	1.73E+02	4.57E+01	2.56E+02	7.95E+00
182	Manganese	Water	g	6.93E+00	1.08E+00	8.09E-02	5.76E+00	1.54E-02
183	Mercury	Water	mg	1.51E+02	7.00E+01	6.92E-02	8.04E+01	1.21E-02
184	Metallic ions, unspecified	Water	µg	8.40E+02	8.22E+02	3.49E-02	1.79E+01	5.90E-03
185	Methane, monochloro-, R-40	Water	µg	2.35E+01	9.20E+00	2.93E+00	1.09E+01	4.96E-01
186	Methyl ethyl ketone	Water	µg	4.71E+01	1.84E+01	5.86E+00	2.19E+01	9.92E-01
187	Molybdenum	Water	mg	3.73E+02	1.95E+02	1.67E+00	1.75E+02	3.31E-01
188	n-Hexacosane	Water	µg	3.91E+02	1.53E+02	4.86E+01	1.81E+02	8.23E+00
189	Naphthalene	Water	mg	1.06E+01	4.16E+00	1.33E+00	4.94E+00	2.25E-01
190	Naphthalene, 2-methyl-	Water	mg	9.27E+00	3.62E+00	1.15E+00	4.30E+00	1.95E-01
191	Naphthalenes, alkylated, unspecified	Water	µg	3.40E+02	1.75E+02	5.64E+01	9.86E+01	9.56E+00
192	Nickel	Water	mg	1.40E+02	6.15E+01	1.97E+01	5.60E+01	3.33E+00
193	Nickel, ion	Water	g	5.19E+00	4.23E+00	x	9.66E-01	1.52E-04
194	Nitrate	Water	oz	2.42E+02	2.42E+02	8.83E-12	5.39E-01	1.62E-04
195	Nitric acid	Water	mg	1.19E+01	2.52E-01	2.26E-02	1.16E+01	3.83E-03
196	o-Cresol	Water	mg	1.68E+01	6.57E+00	2.09E+00	7.81E+00	3.55E-01
197	Octadecane	Water	mg	8.73E+00	3.41E+00	1.09E+00	4.05E+00	1.84E-01
198	Oils, unspecified	Water	g	2.24E+02	2.91E+01	1.68E+00	1.90E+02	2.80E+00

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Carpet Manufacturing	Transport to Consumer	Use	End-of-Life
199	Organic substances, unspecified	Water	µg	3.32E+00	3.32E+00	x	x	x
200	p-Cresol	Water	mg	1.82E+01	7.09E+00	2.26E+00	8.43E+00	3.83E-01
201	Phenanthrene	Water	µg	1.35E+02	6.31E+01	2.02E+01	4.82E+01	3.43E+00
202	Phenanthrenes, alkylated, unspecified	Water	µg	1.41E+02	7.27E+01	2.34E+01	4.09E+01	3.96E+00
203	Phenol	Water	g	1.92E+00	6.17E-01	3.09E-02	1.26E+00	8.80E-03
204	Phenol, 2,4-dimethyl-	Water	mg	1.64E+01	6.40E+00	2.04E+00	7.60E+00	3.45E-01
205	Phosphate	Water	g	7.26E+01	5.44E+01	x	1.82E+01	7.16E-03
206	Selenium	Water	mg	2.84E+02	1.56E+02	8.60E-01	1.26E+02	1.63E-01
207	Silver	Water	g	1.23E+00	4.80E-01	1.53E-01	5.69E-01	2.59E-02
208	Sodium, ion	Water	oz	3.27E+02	1.12E+02	2.61E+01	1.85E+02	4.83E+00
209	Solved solids	Water	lb	6.37E+01	2.55E+01	7.15E+00	2.99E+01	1.21E+00
210	Strontium	Water	g	4.79E+01	1.42E+01	3.97E+00	2.90E+01	7.40E-01
211	Sulfate	Water	oz	1.17E+02	8.21E+01	2.07E-01	3.45E+01	4.07E-02
212	Sulfide	Water	mg	1.25E+02	4.21E+01	3.59E+00	7.85E+01	6.49E-01
213	Sulfur	Water	g	2.04E+00	6.17E-01	1.93E-01	1.19E+00	3.86E-02
214	Suspended solids, unspecified	Water	oz	6.32E+01	3.45E+01	6.82E+00	2.07E+01	1.16E+00
215	Tar	Water	ng	3.00E+02	6.36E+00	5.69E-01	2.93E+02	9.64E-02
216	Tetradecane	Water	mg	1.42E+01	5.54E+00	1.76E+00	6.58E+00	2.99E-01
217	Thallium	Water	mg	1.03E+01	3.35E+00	8.27E-01	6.02E+00	1.44E-01
218	Tin	Water	mg	1.08E+02	4.98E+01	1.60E+01	3.97E+01	2.71E+00
219	Titanium, ion	Water	g	5.90E+00	3.43E-01	6.03E-02	5.48E+00	1.23E-02
220	Toluene	Water	g	1.81E+00	4.75E-01	1.15E-01	1.19E+00	2.43E-02
221	Vanadium	Water	mg	1.59E+01	6.20E+00	1.98E+00	7.37E+00	3.35E-01
222	Xylene	Water	g	1.21E+00	2.83E-01	6.20E-02	8.54E-01	1.43E-02
223	Yttrium	Water	mg	3.94E+00	1.54E+00	4.91E-01	1.83E+00	8.31E-02
224	Zinc	Water	g	1.13E+00	4.56E-01	1.45E-01	4.99E-01	2.46E-02
225	Zinc, ion	Water	g	1.33E+01	9.49E+00	x	3.81E+00	3.06E-03
226	Waste, solid	Waste	g	-1.21E+00	-1.21E+00	x	x	x
227	Waste, unspecified	Waste	g	3.94E+01	3.94E+01	x	x	x
228	Wood waste	Waste	µg	1.24E+00	1.24E+00	x	x	x

Appendix IV: Cradle-to-gate LCI Ecosphere Flows for the Base Case Ceramic Floor Tile System

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Ceramic Tile Manufacturing	Transportation to Consumer per FU	Use	End-of-Life
1	Coal, 26.4 MJ per kg, in ground	Raw	lb	8.25E+01	6.75E+01	1.49E+00	1.27E+01	8.13E-01
2	Coal, brown, in ground	Raw	oz	9.44E+01	2.49E+01	x	6.93E+01	1.96E-01
3	Coal, hard, unspecified, in ground	Raw	lb	9.28E+01	7.25E+01	x	2.02E+01	1.12E-01
4	Energy, gross calorific value, in biomass	Raw	MJ	1.08E+01	2.67E+00	x	8.07E+00	1.98E-02
5	Energy, kinetic (in wind), converted	Raw	kJ	3.99E+02	3.69E+02	x	2.79E+01	2.39E+00
6	Gas, natural, 46.8 MJ per kg, in ground	Raw	g	9.40E+01	9.40E+01	x	x	x
7	Gas, natural, in ground	Raw	yd3	3.07E+02	1.75E+02	9.12E-01	1.31E+02	5.85E-01
8	Limestone, in ground	Raw	kg	4.96E+01	3.45E+00	x	4.61E+01	x
9	Oil, crude, 42 MJ per kg, in ground	Raw	g	4.24E+02	4.24E+02	x	x	x
10	Oil, crude, in ground	Raw	kg	1.29E+02	3.21E+01	1.27E+01	7.60E+01	8.18E+00
11	Uranium oxide, 332 GJ per kg, in ore	Raw	mg	8.11E+02	7.49E+02	1.61E+01	3.70E+01	8.77E+00
12	Uranium, 2291 GJ per kg, in ground	Raw	mg	1.43E+00	1.43E+00	x	x	x
13	Water, cooling, unspecified natural origin/m3	Raw	cuft	5.18E+02	3.03E+01	x	4.87E+02	3.26E-01
14	Water, unspecified natural origin/m3	Raw	dm3	9.75E+02	3.83E+01	x	9.34E+02	2.28E+00
15	Water, well, in ground	Raw	dm3	3.89E+01	3.68E+01	x	1.96E+00	1.54E-01
16	Wood and wood waste, 9.5 MJ per kg	Raw	kg	5.99E+01	5.99E+01	x	x	x
17	2-Chloroacetophenone	Air	µg	1.27E+01	4.54E-02	9.98E-04	1.27E+01	5.45E-04
18	Acenaphthene	Air	µg	9.61E+00	7.99E+00	1.51E-01	1.37E+00	9.22E-02

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Ceramic Tile Manufacturing	Transportation to Consumer per FU	Use	End-of-Life
19	Acenaphthylene	Air	µg	4.07E+00	3.33E+00	7.40E-02	6.22E-01	4.04E-02
20	Acetaldehyde	Air	mg	3.00E+02	2.96E+02	1.10E-01	4.25E+00	2.70E-01
21	Acetophenone	Air	µg	2.72E+01	9.72E-02	2.14E-03	2.71E+01	1.17E-03
22	Acrolein	Air	mg	5.34E+00	4.60E+00	9.91E-02	5.43E-01	1.03E-01
23	Aldehydes, unspecified	Air	g	1.40E+00	5.36E-01	5.15E-01	6.51E-02	2.81E-01
24	Ammonia	Air	g	2.71E+00	1.70E+00	2.59E-01	5.81E-01	1.70E-01
25	Ammonium chloride	Air	mg	4.31E+01	3.98E+01	8.53E-01	1.96E+00	4.65E-01
26	Anthracene	Air	µg	3.42E+00	2.80E+00	6.22E-02	5.23E-01	3.39E-02
27	Antimony	Air	mg	1.24E+00	1.18E+00	5.33E-03	5.19E-02	3.37E-03
28	Arsenic	Air	mg	3.40E+01	3.27E+01	1.73E-01	9.89E-01	1.26E-01
29	Arsine	Air	pg	1.75E-01	2.21E-02	x	1.53E-01	4.64E-04
30	Barium	Air	mg	2.03E+02	2.03E+02	x	7.94E-02	1.04E-03
31	Benzene	Air	g	2.54E+00	2.35E+00	5.63E-04	1.90E-01	8.82E-03
32	Benzene, chloro-	Air	µg	3.99E+01	1.43E-01	3.14E-03	3.98E+01	1.71E-03
33	Benzene, ethyl-	Air	mg	2.86E+01	2.62E+01	1.34E-05	6.84E-01	1.69E+00
34	Benzo(a)anthracene	Air	µg	1.30E+00	1.07E+00	2.37E-02	1.99E-01	1.29E-02
35	Benzo(a)pyrene	Air	µg	1.19E+02	8.18E+01	1.12E-02	5.61E+00	3.11E+01
36	Benzo(b,j,k)fluoranthene	Air	µg	1.79E+00	1.47E+00	3.26E-02	2.74E-01	1.78E-02
37	Benzo(ghi)perylene	Air	ng	4.39E+02	3.60E+02	7.99E+00	6.72E+01	4.36E+00
38	Benzyl chloride	Air	mg	1.27E+00	4.54E-03	9.98E-05	1.27E+00	5.45E-05
39	Beryllium	Air	mg	1.12E+00	1.06E+00	8.46E-03	5.07E-02	5.02E-03
40	Biphenyl	Air	µg	2.77E+01	2.27E+01	5.03E-01	4.23E+00	2.74E-01
41	Bromoform	Air	µg	7.08E+01	2.53E-01	5.56E-03	7.05E+01	3.03E-03
42	BTEX (Benzene, Toluene, Ethylbenzene, and Xylene), unspecified ratio	Air	g	1.36E+00	9.71E-01	1.72E-01	1.27E-01	9.37E-02
43	Butadiene	Air	µg	3.40E+01	1.99E+01	5.61E+00	5.47E+00	3.06E+00
44	Cadmium	Air	mg	2.50E+01	2.46E+01	4.27E-02	2.63E-01	8.29E-02
45	Carbon dioxide, biogenic	Air	lb	1.60E+02	1.56E+02	6.61E-02	3.31E+00	4.07E-02
46	Carbon dioxide, fossil	Air	kg	8.25E+02	5.08E+02	4.41E+01	2.44E+02	2.81E+01
47	Carbon monoxide, biogenic	Air	g	1.59E+00	1.18E+00	x	4.06E-01	5.20E-04
48	Carbon monoxide, fossil	Air	g	9.89E+02	4.04E+02	2.31E+02	2.15E+02	1.38E+02

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Ceramic Tile Manufacturing	Transportation to Consumer per FU	Use	End-of-Life
49	Chloride	Air	µg	1.13E+00	1.05E+00	2.30E-02	5.29E-02	1.25E-02
50	Chlorine	Air	mg	2.80E+02	2.36E+02	x	4.37E+01	1.25E-01
51	Chloroform	Air	µg	3.56E+02	2.28E+02	8.41E-03	1.26E+02	1.88E+00
52	Chromium VI	Air	mg	3.17E+00	2.92E+00	2.34E-02	2.18E-01	1.46E-02
53	Chrysene	Air	µg	1.63E+00	1.33E+00	2.96E-02	2.49E-01	1.61E-02
54	Cobalt	Air	mg	2.80E+01	2.71E+01	2.51E-01	4.04E-01	1.89E-01
55	Copper	Air	mg	6.94E+01	6.40E+01	2.20E-03	3.59E+00	1.86E+00
56	Cumene	Air	mg	6.12E+00	1.61E+00	7.56E-07	4.42E+00	8.75E-02
57	Cyanide	Air	mg	9.72E+01	4.50E+01	3.57E-04	5.21E+01	4.81E-02
58	Dinitrogen monoxide	Air	g	7.16E+00	3.95E+00	1.02E+00	1.50E+00	6.90E-01
59	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	Air	µg	3.47E+00	1.06E-01	7.96E-04	3.37E+00	6.45E-04
60	Ethane, 1,1,1-trichloro-, HCFC-140	Air	µg	8.91E+01	4.69E+01	1.19E+00	4.00E+01	1.03E+00
61	Ethane, 1,2-dibromo-	Air	µg	2.18E+00	7.78E-03	1.71E-04	2.17E+00	9.34E-05
62	Ethane, 1,2-dichloro-	Air	mg	4.35E+01	1.90E-01	5.71E-06	4.33E+01	5.93E-03
63	Ethane, chloro-	Air	µg	7.62E+01	2.72E-01	5.99E-03	7.59E+01	3.27E-03
64	Ethanol	Air	mg	5.12E+00	4.49E+00	x	5.50E-01	8.07E-02
65	Ethene, tetrachloro-	Air	µg	8.26E+02	6.85E+02	1.55E+01	1.16E+02	9.27E+00
66	Fluoranthene	Air	µg	1.16E+01	9.46E+00	2.10E-01	1.77E+00	1.15E-01
67	Fluorene	Air	µg	1.48E+01	1.21E+01	2.69E-01	2.26E+00	1.47E-01
68	Fluoride	Air	mg	8.19E+01	1.18E+00	2.54E-02	8.07E+01	1.39E-02
69	Formaldehyde	Air	g	1.12E+00	1.05E+00	2.26E-03	6.77E-02	1.57E-03
70	Furan	Air	µg	1.25E+01	4.26E+00	1.35E-03	8.02E+00	2.65E-01
71	Heat, waste	Air	kWh	2.90E+03	1.88E+03	x	1.01E+03	1.64E+01
72	Hexane	Air	mg	6.37E+02	5.88E+02	9.56E-06	1.28E+01	3.62E+01
73	Hydrazine, methyl-	Air	µg	3.08E+02	1.10E+00	2.42E-02	3.07E+02	1.32E-02
74	Hydrocarbons, unspecified	Air	mg	2.49E+02	2.30E+02	4.92E+00	1.13E+01	2.69E+00
75	Hydrogen chloride	Air	g	5.25E+01	4.31E+01	3.82E-01	8.85E+00	2.35E-01
76	Hydrogen fluoride	Air	g	3.73E+00	3.17E+00	4.44E-02	4.95E-01	2.74E-02
77	Hydrogen sulfide	Air	g	3.18E+00	3.14E+00	7.43E-10	4.64E-02	4.94E-05
78	Indeno(1,2,3-cd)pyrene	Air	ng	9.93E+02	8.13E+02	1.81E+01	1.52E+02	9.85E+00

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Ceramic Tile Manufacturing	Transportation to Consumer per FU	Use	End-of-Life
79	Iron	Air	g	2.73E+00	2.73E+00	x	1.21E-03	2.59E-04
80	Isophorone	Air	mg	1.05E+00	3.76E-03	8.27E-05	1.05E+00	4.51E-05
81	Isoprene	Air	g	3.72E+01	3.43E+01	7.53E-01	1.73E+00	4.11E-01
82	Kerosene	Air	mg	2.06E+01	1.90E+01	4.08E-01	9.40E-01	2.23E-01
83	Lead	Air	mg	1.77E+02	1.26E+02	1.90E-01	5.04E+01	2.02E-01
84	Magnesium	Air	g	2.37E+00	2.33E+00	3.26E-03	3.52E-02	2.00E-03
85	Manganese	Air	mg	2.91E+02	2.89E+02	2.61E-01	1.34E+00	1.56E-01
86	Mercaptans, unspecified	Air	mg	3.94E+02	1.35E+00	2.90E-02	3.92E+02	1.58E-02
87	Mercury	Air	mg	5.16E+01	3.77E+00	3.28E-02	4.78E+01	3.43E-02
88	Metals, unspecified	Air	ng	4.21E+00	3.88E+00	8.52E-02	1.96E-01	4.65E-02
89	Methacrylic acid, methyl ester	Air	µg	3.63E+01	1.30E-01	2.85E-03	3.62E+01	1.56E-03
90	Methane, biogenic	Air	mg	9.07E+02	3.47E+02	x	5.58E+02	2.11E+00
91	Methane, bromo-, Halon 1001	Air	µg	2.90E+02	1.04E+00	2.28E-02	2.89E+02	1.25E-02
92	Methane, dichloro-, HCC-30	Air	mg	6.61E+00	5.35E+00	2.74E-01	8.36E-01	1.55E-01
93	Methane, dichlorodifluoro-, CFC-12	Air	µg	2.64E+01	2.40E+01	1.47E+00	1.09E-01	8.07E-01
94	Methane, fossil	Air	oz	5.81E+01	3.15E+01	9.28E-02	2.64E+01	1.36E-01
95	Methanol	Air	mg	1.40E+02	1.08E+01	x	1.29E+02	3.27E-01
96	Methyl ethyl ketone	Air	µg	7.35E+02	5.93E+00	5.56E-02	7.29E+02	1.02E-01
97	Naphthalene	Air	mg	7.19E+01	7.18E+01	5.18E-02	4.54E-02	2.82E-02
98	Nickel	Air	mg	2.75E+02	2.67E+02	3.20E+00	2.41E+00	2.56E+00
99	Nitrogen oxides	Air	oz	9.38E+01	4.05E+01	1.06E+01	3.53E+01	7.44E+00
100	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	g	4.32E+02	1.30E+02	2.49E+01	2.57E+02	2.05E+01
101	Organic acids	Air	µg	1.58E+02	1.46E+02	3.13E+00	7.21E+00	1.71E+00
102	Organic substances, unspecified	Air	g	5.04E+00	5.02E+00	1.84E-03	1.52E-02	1.00E-03
103	PAH, polycyclic aromatic hydrocarbons	Air	mg	5.03E+01	4.63E+01	2.41E-02	5.35E-01	3.52E+00

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Ceramic Tile Manufacturing	Transportation to Consumer per FU	Use	End-of-Life
104	Particulates, < 10 um	Air	g	5.06E+00	5.06E+00	x	x	x
105	Particulates, < 2.5 um	Air	g	8.56E+01	3.90E+01	x	4.22E+01	4.29E+00
106	Particulates, > 10 um	Air	g	1.41E+02	7.82E+01	x	6.24E+01	4.20E-01
107	Particulates, > 2.5 um, and < 10um	Air	g	1.31E+02	3.05E+01	5.39E+00	9.15E+01	3.15E+00
108	Particulates, unspecified	Air	g	1.41E+02	4.76E+01	3.93E+00	8.73E+01	2.14E+00
109	Phenanthrene	Air	µg	4.39E+01	3.60E+01	7.99E-01	6.72E+00	4.36E-01
110	Phenol	Air	g	1.19E+00	1.19E+00	2.28E-09	3.28E-03	3.58E-07
111	Phenols, unspecified	Air	mg	1.14E+00	8.32E-01	1.46E-01	8.44E-02	7.99E-02
112	Phthalate, dioctyl-	Air	µg	1.32E+02	4.73E-01	1.04E-02	1.32E+02	5.68E-03
113	Potassium	Air	g	2.40E+01	2.40E+01	x	3.60E-02	4.23E-04
114	Propanal	Air	µg	7.18E+02	5.05E+00	5.42E-02	6.90E+02	2.28E+01
115	Propene	Air	mg	3.42E+02	3.35E+02	3.70E-01	3.08E+00	3.68E+00
116	Pyrene	Air	µg	5.37E+00	4.40E+00	9.77E-02	8.21E-01	5.33E-02
117	Radioactive species, unspecified	Air	kBq	8.18E+02	7.54E+02	1.68E+01	3.85E+01	9.15E+00
118	Radionuclides (Including Radon)	Air	g	1.15E+00	1.07E+00	2.28E-02	5.26E-02	1.25E-02
119	Selenium	Air	mg	3.94E+01	3.51E+01	4.15E-01	3.53E+00	2.85E-01
120	Sodium	Air	g	1.53E+00	1.52E+00	x	1.47E-02	1.14E-03
121	Styrene	Air	µg	1.11E+02	5.97E+01	3.57E-03	5.08E+01	6.29E-01
122	Sulfur dioxide	Air	oz	7.99E+01	4.82E+01	7.36E-01	3.04E+01	6.26E-01
123	Sulfur oxides	Air	g	1.25E+02	5.71E+01	4.20E+01	2.61E+00	2.29E+01
124	Sulfuric acid	Air	ng	3.17E+01	3.98E+00	x	2.76E+01	8.36E-02
125	Sulfuric acid, dimethyl ester	Air	µg	8.71E+01	3.11E-01	6.85E-03	8.68E+01	3.73E-03
126	t-Butyl methyl ether	Air	µg	7.74E+01	6.86E-01	4.99E-03	7.67E+01	6.00E-03
127	Tar	Air	µg	1.28E+00	1.18E+00	2.58E-02	5.95E-02	1.41E-02
128	Toluene	Air	g	1.24E+00	1.21E+00	5.87E-05	1.72E-02	1.17E-02
129	Toluene, 2,4-dinitro-	Air	ng	5.08E+02	1.81E+00	3.99E-02	5.06E+02	2.18E-02
130	Vinyl acetate	Air	µg	1.38E+01	4.93E-02	1.08E-03	1.37E+01	5.91E-04
131	VOC, volatile organic compounds	Air	g	4.24E+01	1.61E+01	1.44E+01	4.02E+00	7.87E+00
132	Xylene	Air	mg	3.13E+02	2.96E+02	4.09E-02	9.30E+00	7.50E+00
133	Zinc	Air	mg	1.83E+02	1.78E+02	1.47E-03	4.06E+00	1.14E+00

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Ceramic Tile Manufacturing	Transportation to Consumer per FU	Use	End-of-Life
134	2-Hexanone	Water	µg	8.79E+02	3.79E+02	3.09E+02	2.27E+01	1.68E+02
135	Acetone	Water	mg	1.38E+00	6.16E-01	4.73E-01	3.77E-02	2.58E-01
136	Acidity, unspecified	Water	g	4.32E+00	7.88E-04	x	4.32E+00	9.03E-06
137	Acids, unspecified	Water	µg	2.38E+01	2.20E+01	4.83E-01	1.11E+00	2.63E-01
138	Aluminum	Water	oz	2.37E+02	1.91E+02	1.44E-01	2.08E+00	4.40E+01
139	Ammonia	Water	g	2.47E+00	1.04E+00	8.86E-01	5.63E-02	4.83E-01
140	Ammonia, as N	Water	µg	1.20E+01	1.10E+01	2.42E-01	5.58E-01	1.32E-01
141	Ammonium, ion	Water	g	1.66E+01	1.68E-01	1.82E-04	1.65E+01	6.55E-03
142	Antimony	Water	g	1.71E+00	1.97E-01	2.55E-03	1.48E+00	2.90E-02
143	Antimony-122	Water	µBq	8.37E+00	1.18E-01	x	8.26E+00	3.89E-04
144	Antimony-124	Water	mBq	2.19E+00	1.49E+00	x	6.91E-01	3.46E-03
145	Arsenic, ion	Water	g	1.28E+00	1.20E-01	1.30E-02	8.10E-02	1.07E+00
146	Barium	Water	g	1.52E+02	6.28E+01	5.59E+01	3.03E+00	3.06E+01
147	Benzene	Water	mg	3.31E+02	1.88E+02	7.93E+01	1.49E+01	4.89E+01
148	Benzene, 1-methyl-4-(1-methylethyl)-	Water	µg	1.34E+01	5.80E+00	4.72E+00	3.48E-01	2.58E+00
149	Benzene, ethyl-	Water	mg	4.41E+01	3.44E+01	4.46E+00	8.27E-01	4.36E+00
150	Benzene, pentamethyl-	Water	µg	1.01E+01	4.35E+00	3.54E+00	2.61E-01	1.93E+00
151	Benzenes, alkylated, unspecified	Water	mg	5.93E+00	2.36E+00	2.24E+00	1.07E-01	1.22E+00
152	Benzoic acid	Water	mg	1.37E+02	5.89E+01	4.79E+01	3.53E+00	2.62E+01
153	Beryllium	Water	mg	1.25E+01	1.11E+01	7.21E-01	2.57E-01	4.07E-01
154	Biphenyl	Water	µg	3.84E+02	1.53E+02	1.45E+02	6.91E+00	7.90E+01
155	BOD5, Biological Oxygen Demand	Water	g	4.25E+02	2.97E+02	8.65E+00	9.75E+01	2.20E+01
156	Boron	Water	mg	9.73E+02	4.52E+02	1.48E+02	2.90E+02	8.22E+01
157	Bromide	Water	g	2.88E+01	1.24E+01	1.01E+01	7.45E-01	5.52E+00
158	Cadmium, ion	Water	mg	3.52E+01	2.21E+01	1.91E+00	8.83E+00	2.35E+00
159	Calcium, ion	Water	oz	2.03E+02	9.80E+00	5.36E+00	2.39E+00	1.85E+02
160	Chloride	Water	oz	2.29E+02	1.14E+02	6.02E+01	1.97E+01	3.43E+01
161	Chromium	Water	mg	2.80E+02	1.09E+02	1.08E+02	4.41E+00	5.88E+01
162	Chromium VI	Water	g	2.60E+00	8.56E-02	4.54E-04	8.36E-01	1.67E+00
163	Chromium, ion	Water	mg	3.42E+01	1.99E+01	8.11E+00	1.59E+00	4.64E+00

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Ceramic Tile Manufacturing	Transportation to Consumer per FU	Use	End-of-Life
164	Cobalt	Water	mg	2.25E+02	1.22E+02	1.05E+00	6.78E+00	9.46E+01
165	COD, Chemical Oxygen Demand	Water	g	9.05E+02	3.94E+02	1.64E+01	4.69E+02	2.64E+01
166	Copper, ion	Water	g	4.74E+00	2.72E+00	1.35E-02	1.95E+00	5.44E-02
167	Cyanide	Water	mg	8.89E+01	2.29E+00	3.41E-03	8.65E+01	1.54E-01
168	Decane	Water	mg	3.92E+00	1.69E+00	1.38E+00	1.01E-01	7.52E-01
169	Dibenzofuran	Water	µg	2.56E+01	1.10E+01	8.99E+00	6.62E-01	4.90E+00
170	Dibenzothiophene	Water	µg	2.19E+01	9.41E+00	7.73E+00	5.57E-01	4.22E+00
171	DOC, Dissolved Organic Carbon	Water	g	2.19E+02	1.25E+02	1.48E-09	8.92E+01	5.28E+00
172	Docosane	Water	µg	1.44E+02	6.21E+01	5.06E+01	3.72E+00	2.76E+01
173	Dodecane	Water	mg	7.44E+00	3.21E+00	2.61E+00	1.92E-01	1.43E+00
174	Eicosane	Water	mg	2.05E+00	8.84E-01	7.20E-01	5.30E-02	3.93E-01
175	Fluorene, 1-methyl-	Water	µg	1.53E+01	6.61E+00	5.38E+00	3.96E-01	2.93E+00
176	Fluorenes, alkylated, unspecified	Water	µg	3.43E+02	1.37E+02	1.30E+02	6.18E+00	7.07E+01
177	Fluoride	Water	g	2.70E+00	6.02E-01	2.97E-03	2.09E+00	6.94E-03
178	Fluorine	Water	µg	1.70E+02	6.82E+01	6.40E+01	3.16E+00	3.49E+01
179	Hexadecane	Water	mg	8.12E+00	3.50E+00	2.85E+00	2.10E-01	1.56E+00
180	Hexanoic acid	Water	mg	2.83E+01	1.22E+01	9.93E+00	7.31E-01	5.42E+00
181	Hydrocarbons, unspecified	Water	g	2.56E+01	5.02E-03	1.85E-09	2.56E+01	1.48E-04
182	Iron	Water	g	2.26E+01	9.54E+00	8.15E+00	4.89E-01	4.44E+00
183	Iron, ion	Water	g	5.63E+01	2.62E+01	x	1.44E+01	1.58E+01
184	Lead	Water	g	1.20E+00	6.30E-01	2.72E-02	4.79E-01	6.29E-02
185	Lithium, ion	Water	g	2.31E+01	1.72E+01	2.42E+00	2.07E+00	1.35E+00
186	m-Xylene	Water	mg	4.19E+00	1.87E+00	1.43E+00	1.14E-01	7.82E-01
187	Magnesium	Water	g	1.29E+02	7.18E+01	2.97E+01	1.12E+01	1.67E+01
188	Manganese	Water	g	2.09E+00	1.13E+00	5.25E-02	3.88E-01	5.24E-01
189	Mercury	Water	mg	5.05E+01	8.02E-01	4.49E-02	4.94E+01	2.78E-01
190	Metallic ions, unspecified	Water	µg	1.12E+00	1.03E+00	2.26E-02	5.21E-02	1.24E-02
191	Methane, monochloro-, R-40	Water	µg	5.42E+00	2.34E+00	1.90E+00	1.40E-01	1.04E+00

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Ceramic Tile Manufacturing	Transportation to Consumer per FU	Use	End-of-Life
192	Methyl ethyl ketone	Water	µg	1.08E+01	4.67E+00	3.80E+00	2.80E-01	2.08E+00
193	Molybdenum	Water	mg	8.53E+01	5.25E+01	1.09E+00	3.11E+01	7.07E-01
194	n-Hexacosane	Water	µg	8.98E+01	3.87E+01	3.16E+01	2.32E+00	1.72E+01
195	Naphthalene	Water	mg	2.45E+00	1.06E+00	8.61E-01	6.33E-02	4.70E-01
196	Naphthalene, 2-methyl-	Water	mg	2.13E+00	9.19E-01	7.49E-01	5.51E-02	4.08E-01
197	Naphthalenes, alkylated, unspecified	Water	µg	9.71E+01	3.87E+01	3.66E+01	1.75E+00	2.00E+01
198	Nickel	Water	mg	3.52E+01	1.47E+01	1.28E+01	7.93E-01	6.97E+00
199	Nickel, ion	Water	g	2.58E+00	3.21E-01	x	3.93E-01	1.87E+00
200	Nitrate	Water	g	9.82E+00	2.53E+00	1.62E-10	7.28E+00	1.01E-02
201	Nitric acid	Water	µg	7.25E+02	6.68E+02	1.47E+01	3.38E+01	8.00E+00
202	o-Cresol	Water	mg	3.87E+00	1.67E+00	1.36E+00	1.00E-01	7.42E-01
203	Octadecane	Water	mg	2.01E+00	8.66E-01	7.05E-01	5.19E-02	3.85E-01
204	Oils, unspecified	Water	g	9.73E+01	7.84E+01	1.09E+00	1.18E+01	5.98E+00
205	p-Cresol	Water	mg	4.18E+00	1.80E+00	1.47E+00	1.08E-01	8.00E-01
206	Phenanthrene	Water	µg	3.56E+01	1.46E+01	1.31E+01	7.36E-01	7.17E+00
207	Phenanthrenes, alkylated, unspecified	Water	µg	4.03E+01	1.60E+01	1.52E+01	7.25E-01	8.29E+00
208	Phenol	Water	mg	4.41E+02	1.37E+02	2.01E+01	2.65E+02	1.86E+01
209	Phenol, 2,4-dimethyl-	Water	mg	3.77E+00	1.63E+00	1.32E+00	9.74E-02	7.22E-01
210	Phosphate	Water	g	5.89E+01	9.81E-01	x	8.11E+00	4.98E+01
211	Selenium	Water	mg	6.00E+01	3.58E+01	5.58E-01	2.33E+01	3.45E-01
212	Silver	Water	mg	2.83E+02	1.22E+02	9.93E+01	7.30E+00	5.42E+01
213	Sodium, ion	Water	oz	1.17E+02	3.59E+01	1.70E+01	8.82E+00	5.54E+01
214	Solved solids	Water	oz	2.19E+02	9.69E+01	7.43E+01	7.46E+00	4.06E+01
215	Strontium	Water	g	1.12E+01	6.76E+00	2.58E+00	2.59E-01	1.55E+00
216	Sulfate	Water	oz	1.76E+02	3.83E+00	1.34E-01	8.89E+00	1.63E+02
217	Sulfide	Water	mg	5.32E+01	3.98E+00	2.33E+00	4.56E+01	1.36E+00
218	Sulfur	Water	g	1.10E+00	3.44E-01	1.25E-01	5.47E-01	8.10E-02
219	Suspended solids, unspecified	Water	g	4.50E+02	1.38E+02	1.26E+02	1.18E+02	6.86E+01
220	Tar	Water	ng	1.83E+01	1.68E+01	3.70E-01	8.51E-01	2.02E-01
221	Tetradecane	Water	mg	3.26E+00	1.41E+00	1.15E+00	8.43E-02	6.25E-01
222	Thallium	Water	mg	3.10E+01	8.11E+00	5.37E-01	2.64E-01	2.21E+01
223	Tin	Water	mg	2.82E+01	1.16E+01	1.04E+01	5.95E-01	5.66E+00

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Ceramic Tile Manufacturing	Transportation to Consumer per FU	Use	End-of-Life
224	Titanium, ion	Water	g	3.97E+00	3.84E+00	3.92E-02	6.43E-02	2.64E-02
225	Toluene	Water	mg	3.80E+02	2.46E+02	7.49E+01	8.44E+00	5.11E+01
226	Vanadium	Water	mg	3.65E+00	1.58E+00	1.28E+00	9.45E-02	7.00E-01
227	Xylene	Water	mg	2.49E+02	1.74E+02	4.02E+01	5.14E+00	3.02E+01
228	Yttrium	Water	µg	9.07E+02	3.91E+02	3.19E+02	2.34E+01	1.74E+02
229	Zinc	Water	mg	2.66E+02	1.14E+02	9.45E+01	6.38E+00	5.15E+01
230	Zinc, ion	Water	g	2.93E+00	8.67E-01	x	1.75E+00	3.16E-01
231	Waste, solid	Waste	kg	2.77E+00	2.77E+00	x	x	x
232	2,4-D	Soil	µg	2.20E+00	7.39E-01	x	1.42E+00	4.67E-02

Appendix V: Cradle-to-gate LCI Ecosphere Flows for the Base Case VCT System

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and VCT Manufacturing	Transport to Consumer	Use	End-of-Life
1	Coal, 26.4 MJ per kg, in ground	Raw	lb	1.17E+02	1.14E+02	3.32E-01	2.86E+00	1.99E-01
2	Coal, brown, in ground	Raw	g	8.89E+02	7.04E+02	x	1.84E+02	1.17E+00
3	Coal, hard, unspecified, in ground	Raw	oz	6.38E+02	6.08E+02	x	2.93E+01	3.80E-01
4	Energy, gross calorific value, in biomass	Raw	MJ	5.24E+00	4.80E+00	x	4.39E-01	4.18E-03
5	Energy, kinetic (in wind), converted	Raw	kJ	3.16E+02	3.15E+02	x	3.83E-01	5.04E-01
6	Energy, solar, converted	Raw	kJ	1.24E+01	1.23E+01	x	8.56E-03	2.12E-02
7	Gas, natural, in ground	Raw	Bales	9.25E+02	6.05E+02	1.83E+00	3.17E+02	1.28E+00
8	Limestone, in ground	Raw	kg	3.38E+02	3.38E+02	x	x	x
9	Oil, crude, in ground	Raw	kg	5.38E+01	3.81E+01	2.82E+00	1.08E+01	2.00E+00
10	Uranium oxide, 332 GJ per kg, in ore	Raw	g	1.30E+00	1.26E+00	3.58E-03	3.08E-02	2.15E-03
11	Uranium, in ground	Raw	g	1.87E+00	1.84E+00	x	3.24E-02	2.08E-04
12	Water, cooling, unspecified natural origin/m3	Raw	cuft	1.76E+02	1.29E+02	x	4.67E+01	7.36E-02
13	Water, unspecified natural origin/m3	Raw	dm3	5.61E+02	4.96E+02	x	6.51E+01	5.41E-01
14	Water, well, in ground	Raw	cu.in	8.94E+02	8.88E+02	x	4.12E+00	2.21E+00
15	Wood, hard, standing	Raw	cm3	6.75E+01	6.73E+01	x	5.90E-02	1.12E-01
16	Wood, primary forest, standing	Raw	mm3	1.26E+01	1.22E+01	x	5.33E-02	3.16E-01
17	Wood, soft, standing	Raw	cm3	2.55E+02	2.54E+02	x	5.70E-01	2.95E-01
18	2-Chloroacetophenone	Air	ng	1.21E+02	1.19E+02	2.22E-01	1.92E+00	1.34E-01
19	Acenaphthene	Air	µg	1.30E+01	1.26E+01	3.36E-02	2.90E-01	2.23E-02
20	Acenaphthylene	Air	µg	5.77E+00	5.60E+00	1.65E-02	1.42E-01	9.91E-03
21	Acetaldehyde	Air	mg	9.63E+00	9.35E+00	2.45E-02	2.00E-01	5.32E-02
22	Acetophenone	Air	ng	2.59E+02	2.54E+02	4.76E-01	4.11E+00	2.86E-01
23	Acrolein	Air	mg	7.49E+00	7.26E+00	2.21E-02	1.84E-01	2.11E-02

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and VCT Manufacturing	Transport to Consumer	Use	End-of-Life
24	Aldehydes, unspecified	Air	mg	4.59E+02	1.26E+02	1.15E+02	1.49E+02	6.90E+01
25	Ammonia	Air	g	5.41E+00	5.23E+00	5.77E-02	8.65E-02	4.15E-02
26	Ammonium chloride	Air	mg	6.88E+01	6.69E+01	1.90E-01	1.64E+00	1.14E-01
27	Anthracene	Air	µg	4.85E+00	4.71E+00	1.38E-02	1.19E-01	8.32E-03
28	Antimony	Air	µg	5.57E+02	5.44E+02	1.19E+00	1.05E+01	8.12E-01
29	Arsenic	Air	mg	1.28E+01	1.24E+01	3.86E-02	2.79E-01	3.04E-02
30	Arsine	Air	pg	4.77E-01	4.63E-01	x	1.46E-02	1.10E-04
31	Barium	Air	mg	7.06E+00	7.05E+00	x	4.84E-03	2.22E-04
32	Benzene	Air	mg	4.02E+02	3.99E+02	1.25E-01	1.28E+00	2.07E+00
33	Benzene, chloro-	Air	ng	3.80E+02	3.73E+02	6.99E-01	6.02E+00	4.20E-01
34	Benzene, ethyl-	Air	mg	1.07E+01	1.03E+01	2.99E-06	2.56E-02	4.01E-01
35	Benzo(a)anthracene	Air	µg	1.85E+00	1.79E+00	5.27E-03	4.54E-02	3.17E-03
36	Benzo(a)pyrene	Air	µg	3.60E+01	2.78E+01	2.50E-03	5.02E-01	7.63E+00
37	Benzo(b,j,k)fluoranthene	Air	µg	2.54E+00	2.46E+00	7.25E-03	6.25E-02	4.36E-03
38	Benzo(ghi)perylene	Air	ng	6.23E+02	6.05E+02	1.78E+00	1.53E+01	1.07E+00
39	Benzyl chloride	Air	µg	1.21E+01	1.19E+01	2.22E-02	1.92E-01	1.34E-02
40	Beryllium	Air	µg	6.45E+02	6.27E+02	1.88E+00	1.50E+01	1.22E+00
41	Biphenyl	Air	µg	3.92E+01	3.81E+01	1.12E-01	9.66E-01	6.74E-02
42	Bromoform	Air	ng	6.74E+02	6.61E+02	1.24E+00	1.07E+01	7.45E-01
43	BTEX (Benzene, Toluene, Ethylbenzene, and Xylene), unspecified ratio	Air	g	5.76E+00	1.42E+00	3.82E-02	4.28E+00	2.30E-02
44	Butadiene	Air	µg	4.58E+01	3.57E+01	1.25E+00	8.12E+00	7.51E-01
45	Cadmium	Air	mg	2.21E+00	2.08E+00	9.51E-03	9.85E-02	2.00E-02
46	Carbon dioxide, biogenic	Air	oz	1.18E+02	1.12E+02	2.36E-01	5.62E+00	1.57E-01
47	Carbon dioxide, fossil	Air	kg	2.98E+02	2.51E+02	9.83E+00	3.03E+01	6.87E+00
48	Carbon disulfide	Air	mg	5.14E+00	9.33E-01	4.13E-06	4.19E+00	1.10E-02
49	Carbon monoxide, biogenic	Air	mg	2.57E+02	2.27E+02	x	2.94E+01	1.11E-01
50	Carbon monoxide, fossil	Air	g	3.98E+02	2.40E+02	5.14E+01	7.22E+01	3.39E+01
51	Chloride	Air	µg	1.81E+00	1.76E+00	5.12E-03	4.41E-02	3.08E-03
52	Chlorine	Air	g	1.31E+01	1.31E+01	x	5.29E-03	2.96E-05
53	Chloroform	Air	µg	2.29E+02	2.29E+02	1.87E-03	3.99E-02	3.98E-01

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and VCT Manufacturing	Transport to Consumer	Use	End-of-Life
54	Chromium	Air	mg	6.74E+01	6.71E+01	2.76E-02	2.52E-01	3.72E-02
55	Chromium VI	Air	mg	2.17E+00	2.12E+00	5.21E-03	4.51E-02	3.52E-03
56	Chrysene	Air	µg	2.31E+00	2.24E+00	6.59E-03	5.68E-02	3.96E-03
57	Cobalt	Air	mg	4.81E+00	4.50E+00	5.58E-02	2.03E-01	4.59E-02
58	Copper	Air	mg	2.34E+01	2.29E+01	4.91E-04	3.77E-02	4.54E-01
59	Cumene	Air	µg	8.14E+02	7.90E+02	1.68E-04	3.06E+00	2.09E+01
60	Cyanide	Air	mg	1.14E+01	6.93E+00	7.94E-05	4.50E+00	1.02E-02
61	Dinitrogen monoxide	Air	g	1.55E+00	1.11E+00	2.26E-01	4.75E-02	1.69E-01
62	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	Air	µg	1.50E+02	1.50E+02	1.77E-04	1.78E-03	1.56E-04
63	Ethane, 1,1,1-trichloro-, HCFC-140	Air	µg	4.70E+01	4.62E+01	2.65E-01	3.42E-01	2.39E-01
64	Ethane, 1,2-dibromo-	Air	ng	2.07E+01	2.03E+01	3.81E-02	3.29E-01	2.29E-02
65	Ethane, 1,2-dichloro-	Air	g	1.32E+00	1.32E+00	1.27E-09	4.16E-03	1.39E-06
66	Ethane, chloro-	Air	ng	7.26E+02	7.12E+02	1.33E+00	1.15E+01	8.02E-01
67	Ethanol	Air	mg	7.14E+00	7.12E+00	x	2.55E-03	1.84E-02
68	Ethene, chloro-	Air	g	5.61E+00	5.60E+00	x	4.16E-03	2.46E-07
69	Ethene, tetrachloro-	Air	mg	1.11E+00	1.08E+00	3.45E-03	2.64E-02	2.25E-03
70	Fluoranthene	Air	µg	1.64E+01	1.59E+01	4.68E-02	4.03E-01	2.81E-02
71	Fluorene	Air	µg	2.10E+01	2.04E+01	6.00E-02	5.17E-01	3.61E-02
72	Fluoride	Air	mg	2.32E+00	2.26E+00	5.66E-03	4.88E-02	3.40E-03
73	Formaldehyde	Air	mg	1.20E+02	1.14E+02	5.04E-01	5.12E+00	3.72E-01
74	Heat, waste	Air	kWh	8.59E+02	7.59E+02	x	9.62E+01	3.88E+00
75	Hexane	Air	mg	8.57E+01	7.65E+01	2.13E-06	5.56E-01	8.61E+00
76	Hydrazine, methyl-	Air	µg	2.94E+00	2.88E+00	5.40E-03	4.65E-02	3.25E-03
77	Hydrocarbons, unspecified	Air	mg	3.97E+02	3.86E+02	1.10E+00	9.45E+00	6.59E-01
78	Hydrogen chloride	Air	g	3.63E+01	3.51E+01	8.52E-02	1.13E+00	5.68E-02
79	Hydrogen fluoride	Air	g	4.01E+00	3.89E+00	9.88E-03	1.02E-01	6.63E-03
80	Hydrogen sulfide	Air	mg	3.42E+02	3.37E+02	1.65E-07	4.20E+00	1.19E-02
81	Indeno(1,2,3-cd)pyrene	Air	µg	1.41E+00	1.37E+00	4.02E-03	3.47E-02	2.42E-03
82	Iron	Air	mg	2.47E+02	2.47E+02	x	4.81E-02	6.15E-02
83	Isophorone	Air	µg	1.00E+01	9.83E+00	1.84E-02	1.59E-01	1.11E-02

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and VCT Manufacturing	Transport to Consumer	Use	End-of-Life
84	Isoprene	Air	g	5.94E+01	5.77E+01	1.68E-01	1.45E+00	1.01E-01
85	Kerosene	Air	mg	3.30E+01	3.20E+01	9.10E-02	7.84E-01	5.47E-02
86	Lead	Air	mg	3.01E+01	2.55E+01	4.23E-02	4.48E+00	4.85E-02
87	Magnesium	Air	mg	4.91E+02	4.83E+02	7.25E-01	6.67E+00	4.84E-01
88	Manganese	Air	mg	1.50E+01	1.45E+01	5.81E-02	3.73E-01	3.78E-02
89	Mercaptans, unspecified	Air	mg	3.65E+00	3.59E+00	6.45E-03	5.56E-02	3.88E-03
90	Mercury	Air	mg	1.36E+01	9.34E+00	7.30E-03	4.22E+00	8.05E-03
91	Metals, unspecified	Air	ng	6.72E+00	6.52E+00	1.90E-02	1.64E-01	1.14E-02
92	Methacrylic acid, methyl ester	Air	ng	3.46E+02	3.39E+02	6.35E-01	5.48E+00	3.82E-01
93	Methane, biogenic	Air	g	1.73E+00	1.68E+00	x	4.96E-02	4.56E-04
94	Methane, bromo-, Halon 1001	Air	µg	2.76E+00	2.71E+00	5.08E-03	4.38E-02	3.06E-03
95	Methane, dichloro-, HCC-30	Air	mg	8.65E+00	8.25E+00	6.10E-02	2.95E-01	3.78E-02
96	Methane, dichlorodifluoro-, CFC-12	Air	µg	3.64E+00	2.71E+00	3.28E-01	4.12E-01	1.98E-01
97	Methane, fossil	Air	oz	3.89E+01	3.55E+01	2.07E-02	3.37E+00	3.21E-02
98	Methane, monochloro-, R-40	Air	mg	1.22E+00	1.22E+00	1.68E-05	2.51E-04	2.11E-03
99	Methane, tetrachloro-, CFC-10	Air	mg	1.28E+01	1.28E+01	3.28E-05	8.74E-05	8.56E-05
100	Methanol	Air	mg	4.21E+01	4.20E+01	x	1.74E-02	7.69E-02
101	Methyl ethyl ketone	Air	µg	8.03E+01	7.79E+01	1.24E-02	2.36E+00	2.43E-02
102	Naphthalene	Air	µg	6.39E+02	5.56E+02	1.15E+01	6.53E+01	6.93E+00
103	Nickel	Air	mg	1.45E+02	1.41E+02	7.12E-01	2.26E+00	6.23E-01
104	Nitrogen oxides	Air	g	8.31E+02	6.03E+02	6.68E+01	1.10E+02	5.17E+01
105	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	g	3.22E+02	2.74E+02	5.55E+00	3.70E+01	5.02E+00
106	Organic acids	Air	µg	2.53E+02	2.46E+02	6.98E-01	6.02E+00	4.20E-01
107	Organic substances, unspecified	Air	mg	2.67E+02	1.39E+02	4.09E-01	1.27E+02	2.46E-01

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and VCT Manufacturing	Transport to Consumer	Use	End-of-Life
108	PAH, polycyclic aromatic hydrocarbons	Air	mg	8.04E+00	7.09E+00	5.37E-03	8.05E-02	8.63E-01
109	Particulates, < 2.5 um	Air	g	1.78E+01	1.26E+01	x	4.15E+00	1.05E+00
110	Particulates, > 10 um	Air	g	3.39E+01	2.87E+01	x	5.08E+00	9.95E-02
111	Particulates, > 2.5 um, and < 10um	Air	g	3.33E+01	2.28E+01	1.20E+00	8.57E+00	7.73E-01
112	Particulates, unspecified	Air	g	9.70E+01	9.26E+01	8.74E-01	3.00E+00	5.26E-01
113	Phenanthrene	Air	µg	6.23E+01	6.05E+01	1.78E-01	1.53E+00	1.07E-01
114	Phenol	Air	µg	4.38E+02	4.37E+02	5.08E-04	6.37E-01	7.64E-02
115	Phenols, unspecified	Air	mg	1.44E+00	1.28E+00	3.26E-02	1.07E-01	1.96E-02
116	Phthalate, dioctyl-	Air	µg	1.26E+00	1.24E+00	2.32E-03	2.00E-02	1.39E-03
117	Potassium	Air	mg	1.30E+02	1.29E+02	x	7.74E-01	8.94E-02
118	Propanal	Air	µg	1.07E+01	6.90E+00	1.21E-02	2.90E-01	3.46E+00
119	Propene	Air	mg	1.13E+02	1.12E+02	8.24E-02	5.91E-01	8.71E-01
120	Pyrene	Air	µg	7.62E+00	7.39E+00	2.17E-02	1.87E-01	1.31E-02
121	Radioactive species, other beta emitters	Air	mBq	5.53E+01	5.25E+01	x	2.63E+00	8.01E-02
122	Radioactive species, unspecified	Air	kBq	1.31E+03	1.27E+03	3.73E+00	3.22E+01	2.25E+00
123	Selenium	Air	mg	3.41E+01	3.32E+01	9.25E-02	7.65E-01	6.89E-02
124	Silicon	Air	mg	8.90E+02	8.86E+02	x	4.40E+00	1.09E-02
125	Sodium	Air	mg	5.48E+01	5.35E+01	x	1.10E+00	2.72E-01
126	Styrene	Air	µg	6.51E+01	6.49E+01	7.94E-04	5.83E-02	1.37E-01
127	Sulfur dioxide	Air	oz	5.28E+01	3.88E+01	1.64E-01	1.37E+01	1.51E-01
128	Sulfur oxides	Air	g	5.40E+01	2.82E+01	9.36E+00	1.08E+01	5.63E+00
129	Sulfuric acid	Air	ng	8.61E+01	8.34E+01	x	2.64E+00	1.97E-02
130	Sulfuric acid, dimethyl ester	Air	ng	8.29E+02	8.14E+02	1.52E+00	1.31E+01	9.17E-01
131	t-Butyl methyl ether	Air	µg	2.23E+00	2.19E+00	1.11E-03	4.31E-02	1.36E-03
132	Tar	Air	µg	2.04E+00	1.98E+00	5.76E-03	4.96E-02	3.46E-03
133	Toluene	Air	g	1.52E+01	1.51E+01	1.31E-05	3.80E-04	2.74E-03
134	Toluene, 2,4-dinitro-	Air	ng	4.84E+00	4.75E+00	8.89E-03	7.67E-02	5.35E-03
135	Vinyl acetate	Air	ng	1.31E+02	1.29E+02	2.41E-01	2.08E+00	1.45E-01
136	VOC, volatile organic compounds	Air	g	2.41E+01	5.39E+00	3.21E+00	1.35E+01	1.93E+00

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and VCT Manufacturing	Transport to Consumer	Use	End-of-Life
137	Xylene	Air	mg	1.10E+02	1.08E+02	9.10E-03	1.92E-01	1.77E+00
138	Zinc	Air	mg	2.24E+01	2.21E+01	3.27E-04	3.75E-02	2.78E-01
139	2-Hexanone	Water	µg	7.29E+02	1.78E+02	6.87E+01	4.42E+02	4.13E+01
140	Acetone	Water	mg	1.15E+00	3.07E-01	1.05E-01	6.77E-01	6.33E-02
141	Acidity, unspecified	Water	g	1.32E+00	9.08E-01	x	4.16E-01	1.98E-06
142	Acids, unspecified	Water	µg	3.81E+01	3.70E+01	1.07E-01	9.27E-01	6.46E-02
143	Aluminum	Water	g	5.23E+01	4.32E+01	9.10E-01	7.65E+00	5.68E-01
144	Ammonia	Water	g	1.66E+00	4.28E-01	1.97E-01	9.20E-01	1.19E-01
145	Ammonia, as N	Water	µg	1.91E+01	1.86E+01	5.40E-02	4.65E-01	3.25E-02
146	Ammonium, ion	Water	g	5.06E+00	3.48E+00	4.06E-05	1.58E+00	1.55E-03
147	Antimony	Water	mg	9.22E+02	7.78E+02	5.68E-01	1.44E+02	3.48E-01
148	Arsenic, ion	Water	mg	7.58E+01	4.79E+01	2.89E+00	2.32E+01	1.77E+00
149	Barium	Water	g	6.85E+01	1.74E+01	1.25E+01	3.12E+01	7.51E+00
150	Benzene	Water	mg	2.03E+02	5.95E+01	1.77E+01	1.14E+02	1.20E+01
151	Benzene, 1-methyl-4-(1-methylethyl)-	Water	µg	1.12E+01	2.72E+00	1.05E+00	6.76E+00	6.32E-01
152	Benzene, ethyl-	Water	mg	1.38E+01	5.21E+00	9.93E-01	6.52E+00	1.06E+00
153	Benzene, pentamethyl-	Water	µg	8.37E+00	2.04E+00	7.89E-01	5.07E+00	4.74E-01
154	Benzenes, alkylated, unspecified	Water	mg	2.58E+00	6.18E-01	4.98E-01	1.16E+00	2.99E-01
155	Benzoic acid	Water	mg	1.13E+02	2.76E+01	1.07E+01	6.86E+01	6.42E+00
156	Beryllium	Water	mg	3.34E+00	2.33E+00	1.61E-01	7.48E-01	9.93E-02
157	Biphenyl	Water	µg	1.67E+02	4.00E+01	3.22E+01	7.52E+01	1.94E+01
158	BOD5, Biological Oxygen Demand	Water	g	2.03E+02	1.75E+02	1.93E+00	2.11E+01	5.32E+00
159	Boron	Water	mg	6.39E+02	3.47E+02	3.30E+01	2.38E+02	2.01E+01
160	Bromide	Water	g	2.39E+01	5.83E+00	2.25E+00	1.45E+01	1.36E+00
161	Cadmium, ion	Water	mg	1.07E+01	6.92E+00	4.26E-01	3.12E+00	2.60E-01
162	Calcium, ion	Water	g	7.63E+02	4.85E+02	3.38E+01	2.23E+02	2.10E+01
163	Chloride	Water	oz	3.71E+02	2.62E+02	1.34E+01	8.72E+01	8.41E+00
164	Chromium	Water	mg	9.00E+01	2.13E+01	2.40E+01	3.02E+01	1.44E+01
165	Chromium VI	Water	mg	5.21E+02	4.41E+02	1.01E-01	8.04E+01	9.81E-02
166	Chromium, ion	Water	mg	4.61E+01	1.32E+01	1.80E+00	3.00E+01	1.14E+00
167	Cobalt	Water	mg	1.37E+01	1.13E+01	2.33E-01	2.07E+00	1.55E-01

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and VCT Manufacturing	Transport to Consumer	Use	End-of-Life
168	COD, Chemical Oxygen Demand	Water	g	3.57E+02	2.81E+02	3.66E+00	6.50E+01	6.38E+00
169	Copper, ion	Water	mg	9.91E+02	7.87E+02	3.00E+00	1.99E+02	1.90E+00
170	Cyanide	Water	mg	8.61E+00	2.44E-01	7.60E-04	8.32E+00	3.68E-02
171	Decane	Water	mg	3.26E+00	7.93E-01	3.07E-01	1.97E+00	1.84E-01
172	Dibenzofuran	Water	µg	2.12E+01	5.17E+00	2.00E+00	1.29E+01	1.20E+00
173	Dibenzothiophene	Water	µg	1.77E+01	4.32E+00	1.72E+00	1.07E+01	1.03E+00
174	DOC, Dissolved Organic Carbon	Water	g	1.46E+02	1.36E+02	3.30E-10	8.42E+00	1.27E+00
175	Docosane	Water	µg	1.20E+02	2.91E+01	1.13E+01	7.24E+01	6.77E+00
176	Dodecane	Water	mg	6.18E+00	1.51E+00	5.82E-01	3.74E+00	3.50E-01
177	Eicosane	Water	mg	1.70E+00	4.14E-01	1.60E-01	1.03E+00	9.64E-02
178	Fluorene, 1-methyl-	Water	µg	1.27E+01	3.10E+00	1.20E+00	7.70E+00	7.20E-01
179	Fluorenes, alkylated, unspecified	Water	µg	1.49E+02	3.58E+01	2.89E+01	6.73E+01	1.74E+01
180	Fluoride	Water	g	1.57E+00	1.36E+00	6.60E-04	2.05E-01	1.65E-03
181	Fluorine	Water	µg	7.86E+01	1.89E+01	1.42E+01	3.69E+01	8.56E+00
182	Hexadecane	Water	mg	6.74E+00	1.64E+00	6.35E-01	4.08E+00	3.82E-01
183	Hexanoic acid	Water	mg	2.35E+01	5.72E+00	2.21E+00	1.42E+01	1.33E+00
184	Hydrocarbons, unspecified	Water	g	6.31E+00	3.84E+00	4.13E-10	2.47E+00	3.51E-05
185	Iron	Water	g	1.22E+01	3.86E+00	1.81E+00	5.46E+00	1.09E+00
186	Iron, ion	Water	g	8.54E+00	7.18E+00	x	1.36E+00	5.83E-03
187	Lead	Water	mg	3.22E+02	2.42E+02	6.06E+00	7.07E+01	3.76E+00
188	Lithium, ion	Water	g	8.34E+01	2.34E+01	5.39E-01	5.91E+01	3.30E-01
189	m-Xylene	Water	mg	3.49E+00	9.31E-01	3.19E-01	2.05E+00	1.92E-01
190	Magnesium	Water	g	8.07E+01	2.69E+01	6.61E+00	4.31E+01	4.08E+00
191	Manganese	Water	mg	7.37E+02	6.08E+02	1.17E+01	1.09E+02	7.92E+00
192	Mercury	Water	mg	8.81E+00	4.01E+00	1.00E-02	4.78E+00	6.22E-03
193	Metallic ions, unspecified	Water	µg	1.79E+00	1.73E+00	5.04E-03	4.35E-02	3.03E-03
194	Methane, monochloro-, R-40	Water	µg	4.50E+00	1.10E+00	4.24E-01	2.72E+00	2.55E-01
195	Methyl ethyl ketone	Water	µg	8.99E+00	2.19E+00	8.47E-01	5.45E+00	5.09E-01
196	Molybdenum	Water	mg	3.52E+01	3.04E+01	2.42E-01	4.39E+00	1.70E-01

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and VCT Manufacturing	Transport to Consumer	Use	End-of-Life
197	n-Hexacosane	Water	µg	7.46E+01	1.82E+01	7.03E+00	4.52E+01	4.22E+00
198	Naphthalene	Water	mg	2.03E+00	4.95E-01	1.92E-01	1.23E+00	1.15E-01
199	Naphthalene, 2-methyl-	Water	mg	1.77E+00	4.31E-01	1.67E-01	1.07E+00	1.00E-01
200	Naphthalenes, alkylated, unspecified	Water	µg	4.22E+01	1.01E+01	8.16E+00	1.90E+01	4.91E+00
201	Nickel	Water	mg	2.33E+01	5.65E+00	2.84E+00	1.31E+01	1.71E+00
202	Nickel, ion	Water	mg	2.29E+02	1.92E+02	x	3.74E+01	7.78E-02
203	Nitrate	Water	g	3.95E+00	3.25E+00	3.62E-11	6.92E-01	2.35E-03
204	Nitric acid	Water	mg	1.16E+00	1.12E+00	3.27E-03	2.82E-02	1.96E-03
205	o-Cresol	Water	mg	3.21E+00	7.83E-01	3.03E-01	1.95E+00	1.82E-01
206	Octadecane	Water	mg	1.67E+00	4.06E-01	1.57E-01	1.01E+00	9.44E-02
207	Oils, unspecified	Water	g	1.22E+01	8.00E+00	2.43E-01	2.47E+00	1.44E+00
208	p-Cresol	Water	mg	3.47E+00	8.45E-01	3.27E-01	2.10E+00	1.96E-01
209	Phenanthrene	Water	µg	2.02E+01	4.89E+00	2.93E+00	1.07E+01	1.76E+00
210	Phenanthrenes, alkylated, unspecified	Water	µg	1.75E+01	4.20E+00	3.38E+00	7.89E+00	2.03E+00
211	Phenol	Water	mg	9.23E+01	5.26E+01	4.47E+00	3.07E+01	4.52E+00
212	Phenol, 2,4-dimethyl-	Water	mg	3.13E+00	7.62E-01	2.95E-01	1.90E+00	1.77E-01
213	Phosphate	Water	g	5.65E+00	4.87E+00	x	7.77E-01	3.68E-03
214	Selenium	Water	mg	2.41E+01	2.13E+01	1.24E-01	2.56E+00	8.36E-02
215	Silver	Water	mg	2.34E+02	5.71E+01	2.21E+01	1.42E+02	1.33E+01
216	Sodium, ion	Water	oz	1.95E+02	1.64E+02	3.78E+00	2.48E+01	2.48E+00
217	Solved solids	Water	oz	1.87E+02	5.45E+01	1.65E+01	1.07E+02	9.95E+00
218	Strontium	Water	g	6.69E+00	2.05E+00	5.74E-01	3.69E+00	3.80E-01
219	Sulfate	Water	g	2.56E+02	2.30E+02	8.48E-01	2.48E+01	5.92E-01
220	Sulfide	Water	mg	1.39E+01	8.27E+00	5.19E-01	4.81E+00	3.33E-01
221	Sulfite	Water	mg	1.59E+01	1.59E+01	x	4.85E-03	2.75E-02
222	Sulfur	Water	mg	3.24E+02	9.69E+01	2.79E+01	1.79E+02	1.98E+01
223	Suspended solids, unspecified	Water	g	2.24E+02	9.90E+01	2.80E+01	8.04E+01	1.68E+01
224	Tar	Water	ng	2.91E+01	2.83E+01	8.23E-02	7.10E-01	4.95E-02
225	Tetradecane	Water	mg	2.71E+00	6.60E-01	2.55E-01	1.64E+00	1.53E-01
226	Thallium	Water	mg	1.40E+00	9.19E-01	1.20E-01	2.90E-01	7.40E-02
227	Tin	Water	mg	1.66E+01	4.02E+00	2.31E+00	8.90E+00	1.39E+00
228	Titanium, ion	Water	g	1.50E+00	1.46E+00	8.72E-03	2.07E-02	6.31E-03

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and VCT Manufacturing	Transport to Consumer	Use	End-of-Life
229	Toluene	Water	g	3.59E+01	3.58E+01	1.67E-02	1.08E-01	1.25E-02
230	Vanadium	Water	mg	3.03E+00	7.39E-01	2.86E-01	1.84E+00	1.72E-01
231	Xylene	Water	mg	1.08E+02	3.53E+01	8.96E+00	5.61E+01	7.35E+00
232	Yttrium	Water	µg	7.53E+02	1.83E+02	7.09E+01	4.56E+02	4.26E+01
233	Zinc	Water	mg	1.38E+02	4.98E+01	2.10E+01	5.47E+01	1.26E+01
234	Zinc-65	Water	µBq	2.64E+02	1.36E+02	x	1.27E+02	1.51E-02
235	Zinc, ion	Water	g	1.04E+00	8.74E-01	x	1.68E-01	1.57E-03

Appendix VI: Cradle-to-gate LCI Ecosphere Flows for the Base Case Cork Flooring System

No.	Substance	Compartment	Unit	Total	Resource Extraction and Manufacturing	Transport to Consumer	Use	End-of-Life
1	Coal, 26.4 MJ per kg, in ground	Raw	oz	1.24E+02	x	4.53E+01	7.30E+01	6.15E+00
2	Coal, brown, in ground	Raw	lb	9.47E+01	7.57E+01	4.37E-02	1.90E+01	4.98E-03
3	Coal, hard, unspecified, in ground	Raw	lb	2.22E+02	1.74E+02	4.01E-01	4.76E+01	4.58E-02
4	Energy, kinetic (in wind), converted	Raw	MJ	4.94E+01	4.54E+01	8.53E-03	3.94E+00	9.71E-04
5	Gas, natural, in ground	Raw	yd3	2.08E+02	1.29E+02	2.14E+00	7.68E+01	2.74E-01
6	Oil, crude, in ground	Raw	kg	9.80E+01	3.71E+01	3.06E+01	2.64E+01	3.85E+00
7	Uranium oxide, 332 GJ per kg, in ore	Raw	mg	8.39E+01	x	3.05E+01	4.92E+01	4.15E+00
8	Uranium, in ground	Raw	g	2.71E+00	2.11E+00	3.51E-03	5.99E-01	4.01E-04
9	Water, cooling, unspecified natural origin/m3	Raw	cuft	9.00E+02	6.27E+02	1.45E+00	2.71E+02	1.42E-01
10	Water, unspecified natural origin/m3	Raw	gal*	5.84E+02	5.07E+02	3.08E+00	7.36E+01	2.76E-01
11	Water, well, in ground	Raw	dm3	3.02E+02	1.98E+02	3.47E-01	1.04E+02	6.98E-02
12	2-Chloroacetophenone	Air	ng	5.21E+00	x	1.90E+00	3.06E+00	2.58E-01
13	Acenaphthene	Air	µg	4.15E+00	8.21E-01	3.22E-01	2.96E+00	4.30E-02
14	Acenaphthylene	Air	ng	3.86E+02	x	1.40E+02	2.27E+02	1.91E+01
15	Acetaldehyde	Air	mg	3.03E+02	2.60E+02	6.33E-01	4.22E+01	1.03E-01
16	Acetophenone	Air	ng	1.12E+01	x	4.06E+00	6.55E+00	5.52E-01
17	Acrolein	Air	mg	2.18E+00	8.33E-02	2.16E-01	1.84E+00	4.06E-02
18	Aldehydes, unspecified	Air	g	1.35E+00	2.25E-03	9.78E-01	2.36E-01	1.33E-01
19	Ammonia	Air	g	1.79E+01	1.27E+01	2.96E+00	2.18E+00	7.99E-02
20	Ammonium chloride	Air	mg	4.45E+00	x	1.62E+00	2.61E+00	2.20E-01
21	Anthracene	Air	ng	3.24E+02	x	1.18E+02	1.90E+02	1.60E+01
22	Antimony	Air	mg	2.19E+00	9.04E-01	1.18E-02	1.27E+00	1.56E-03
23	Arsenic	Air	mg	3.66E+01	2.18E+01	2.74E+00	1.20E+01	5.86E-02
24	Barium	Air	mg	5.03E+01	4.43E+01	3.62E-03	5.98E+00	4.29E-04

No.	Substance	Compartment	Unit	Total	Resource Extraction and Manufacturing	Transport to Consumer	Use	End-of-Life
25	Benzene	Air	g	8.78E+00	7.88E+00	1.77E-01	7.20E-01	4.00E-03
26	Benzene, chloro-	Air	ng	1.64E+01	x	5.96E+00	9.61E+00	8.09E-01
27	Benzene, ethyl-	Air	mg	9.07E+01	6.55E+01	8.70E+00	1.57E+01	7.73E-01
28	Benzo(a)anthracene	Air	ng	1.24E+02	x	4.50E+01	7.25E+01	6.11E+00
29	Benzo(a)pyrene	Air	mg	2.87E+00	2.36E+00	7.35E-04	4.99E-01	1.47E-02
30	Benzo(b,j,k)fluoranthene	Air	ng	1.70E+02	x	6.18E+01	9.97E+01	8.40E+00
31	Benzo(ghi)perylene	Air	ng	4.17E+01	x	1.52E+01	2.45E+01	2.06E+00
32	Benzyl chloride	Air	ng	5.21E+02	x	1.90E+02	3.06E+02	2.58E+01
33	Beryllium	Air	µg	3.89E+02	2.08E+02	1.75E+01	1.62E+02	2.35E+00
34	Biphenyl	Air	µg	2.63E+00	x	9.55E-01	1.54E+00	1.30E-01
35	Bromoform	Air	ng	2.90E+01	x	1.06E+01	1.70E+01	1.43E+00
36	BTEX (Benzene, Toluene, Ethylbenzene, and Xylene), unspecified ratio	Air	g	7.22E+00	x	3.26E-01	6.85E+00	4.43E-02
37	Butadiene	Air	µg	2.52E+01	3.78E-03	1.06E+01	1.31E+01	1.45E+00
38	Cadmium	Air	mg	1.03E+01	5.62E+00	4.25E-01	4.24E+00	3.86E-02
39	Carbon dioxide, biogenic	Air	lb	3.70E+02	3.60E+02	1.42E-01	1.07E+01	1.89E-02
40	Carbon dioxide, fossil	Air	kg	6.99E+02	4.42E+02	1.05E+02	1.38E+02	1.32E+01
41	Carbon disulfide	Air	mg	2.18E+02	2.91E+01	2.23E-01	1.89E+02	2.12E-02
42	Carbon monoxide, biogenic	Air	g	2.15E+02	1.64E+02	1.91E-03	5.05E+01	2.13E-04
43	Carbon monoxide, fossil	Air	g	9.80E+02	2.50E+02	4.59E+02	2.05E+02	6.53E+01
44	Chloride	Air	ng	1.20E+02	x	4.36E+01	7.04E+01	5.93E+00
45	Chlorine	Air	g	6.77E+00	6.65E+00	6.36E-04	1.15E-01	5.71E-05
46	Chloroform	Air	µg	6.00E+02	3.44E+01	6.72E+00	5.58E+02	7.66E-01
47	Chromium	Air	mg	7.24E+01	3.76E+01	1.32E+00	3.34E+01	7.17E-02
48	Chromium VI	Air	mg	2.94E+00	1.61E+00	5.10E-02	1.26E+00	6.78E-03
49	Chrysene	Air	ng	1.54E+02	x	5.62E+01	9.06E+01	7.63E+00
50	Cobalt	Air	mg	4.63E+01	4.12E+01	6.81E-01	4.30E+00	8.84E-02
51	Copper	Air	mg	1.47E+02	1.04E+02	2.70E+00	3.87E+01	8.75E-01
52	Cumene	Air	g	7.81E+00	7.72E+00	2.59E-04	9.26E-02	4.02E-05
53	Cyanide	Air	mg	7.05E+01	4.22E+01	2.00E-01	2.81E+01	1.96E-02
54	Dinitrogen monoxide	Air	g	1.73E+01	1.24E+01	2.45E+00	2.13E+00	3.25E-01

No.	Substance	Compartment	Unit	Total	Resource Extraction and Manufacturing	Transport to Consumer	Use	End-of-Life
55	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	Air	ng	1.71E+02	1.29E+02	7.99E+00	3.42E+01	3.00E-01
56	Ethane, 1,1,1-trichloro-, HCFC-140	Air	µg	9.83E+01	3.27E-01	3.61E+00	9.39E+01	4.60E-01
57	Ethane, 1,2-dibromo-	Air	pg	8.93E+02	x	3.25E+02	5.24E+02	4.41E+01
58	Ethane, 1,2-dichloro-	Air	mg	2.18E+01	1.87E-01	1.81E-02	2.16E+01	2.68E-03
59	Ethane, chloro-	Air	ng	3.13E+01	x	1.14E+01	1.83E+01	1.55E+00
60	Ethanol	Air	mg	2.74E+02	2.51E+02	3.69E-01	2.27E+01	3.54E-02
61	Ethene, tetrachloro-	Air	µg	2.81E+02	7.03E-01	3.24E+01	2.43E+02	4.33E+00
62	Fluoranthene	Air	µg	1.10E+00	x	3.99E-01	6.43E-01	5.42E-02
63	Fluorene	Air	µg	1.41E+00	x	5.11E-01	8.25E-01	6.95E-02
64	Fluoride	Air	µg	1.33E+02	x	4.82E+01	7.78E+01	6.55E+00
65	Formaldehyde	Air	g	2.02E+00	1.84E+00	5.34E-03	1.68E-01	7.16E-04
66	Furan	Air	µg	6.07E+01	3.74E+00	1.37E+00	5.55E+01	1.22E-01
67	Heat, waste	Air	kWh	2.87E+03	2.23E+03	7.64E+01	5.57E+02	7.48E+00
68	Hexane	Air	g	1.96E+00	1.32E+00	1.87E-01	4.35E-01	1.66E-02
69	Hydrazine, methyl-	Air	ng	1.27E+02	x	4.60E+01	7.42E+01	6.25E+00
70	Hydrocarbons, unspecified	Air	mg	2.57E+01	x	9.35E+00	1.51E+01	1.27E+00
71	Hydrogen chloride	Air	g	3.09E+01	1.88E+01	1.18E+00	1.08E+01	1.09E-01
72	Hydrogen fluoride	Air	g	6.91E+00	4.81E+00	1.32E-01	1.95E+00	1.28E-02
73	Hydrogen sulfide	Air	g	2.99E+00	1.76E+00	4.28E-05	1.24E+00	2.29E-05
74	Indeno(1,2,3-cd)pyrene	Air	ng	9.42E+01	x	3.43E+01	5.53E+01	4.66E+00
75	Iron	Air	g	1.69E+00	1.55E+00	1.02E-03	1.31E-01	1.19E-04
76	Isophorone	Air	ng	4.32E+02	x	1.57E+02	2.53E+02	2.13E+01
77	Isoprene	Air	g	3.93E+00	1.73E-07	1.43E+00	2.31E+00	1.94E-01
78	Kerosene	Air	mg	2.13E+00	x	7.76E-01	1.25E+00	1.05E-01
79	Lead	Air	mg	1.39E+02	1.02E+02	1.79E+00	3.54E+01	9.34E-02
80	Magnesium	Air	mg	7.97E+02	6.25E+02	6.98E+00	1.64E+02	9.32E-01
81	Manganese	Air	mg	2.87E+02	2.75E+02	5.44E-01	1.05E+01	7.28E-02
82	Mercaptans, unspecified	Air	µg	1.51E+02	x	5.50E+01	8.87E+01	7.47E+00
83	Mercury	Air	mg	1.89E+01	1.09E+01	2.99E-01	7.63E+00	1.55E-02
84	Metals, unspecified	Air	pg	4.45E+02	x	1.62E+02	2.61E+02	2.20E+01

No.	Substance	Compartment	Unit	Total	Resource Extraction and Manufacturing	Transport to Consumer	Use	End-of-Life
85	Methacrylic acid, methyl ester	Air	ng	1.49E+01	x	5.42E+00	8.73E+00	7.36E-01
86	Methane, biogenic	Air	g	1.24E+02	1.10E+02	8.16E-03	1.36E+01	8.79E-04
87	Methane, bromo-, Halon 1001	Air	ng	1.20E+02	6.15E-04	4.33E+01	7.10E+01	5.89E+00
88	Methane, dichlorodifluoro-, CFC-12	Air	mg	3.06E+01	1.26E-02	2.81E-03	3.06E+01	3.81E-04
89	Methane, fossil	Air	oz	6.22E+01	4.60E+01	5.53E-01	1.56E+01	6.19E-02
90	Methane, monochloro-, R-40	Air	mg	4.10E+02	8.66E-03	3.57E-02	4.10E+02	4.07E-03
91	Methane, tetrachloro-, CFC-10	Air	mg	5.37E+00	5.42E-02	1.46E-03	5.31E+00	1.65E-04
92	Methyl ethyl ketone	Air	mg	2.26E+01	6.61E-03	7.23E-04	2.26E+01	4.68E-05
93	Naphthalene	Air	µg	2.16E+02	x	9.83E+01	1.04E+02	1.34E+01
94	Nickel	Air	mg	5.90E+02	3.77E+02	1.42E+02	7.05E+01	1.20E+00
95	Nitrogen oxides	Air	oz	8.05E+01	3.98E+01	2.58E+01	1.13E+01	3.51E+00
96	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	g	3.35E+02	1.86E+02	6.10E+01	7.87E+01	9.67E+00
97	Organic acids	Air	µg	1.64E+01	x	5.95E+00	9.60E+00	8.09E-01
98	Organic substances, unspecified	Air	mg	2.08E+02	x	3.49E+00	2.04E+02	4.74E-01
99	PAH, polycyclic aromatic hydrocarbons	Air	mg	7.17E+01	4.41E+01	1.24E+01	1.36E+01	1.66E+00
100	Particulates, < 2.5 um	Air	g	1.71E+02	1.41E+02	9.34E+00	1.82E+01	2.03E+00
101	Particulates, > 10 um	Air	g	3.38E+02	2.56E+02	1.31E+01	6.88E+01	1.92E-01
102	Particulates, > 2.5 um, and < 10um	Air	g	1.17E+02	7.40E+01	2.04E+01	2.11E+01	1.49E+00
103	Particulates, unspecified	Air	g	1.32E+01	x	7.46E+00	4.76E+00	1.01E+00
104	Phenanthrene	Air	µg	4.17E+00	x	1.52E+00	2.45E+00	2.06E-01
105	Phenol	Air	g	5.76E+00	5.76E+00	1.30E-06	1.14E-03	1.47E-07
106	Phenols, unspecified	Air	µg	4.86E+02	x	2.78E+02	1.70E+02	3.78E+01
107	Phthalate, dioctyl-	Air	ng	5.43E+01	x	1.98E+01	3.19E+01	2.69E+00
108	Potassium	Air	g	3.12E+01	3.08E+01	1.51E-03	3.86E-01	1.72E-04

No.	Substance	Compartment	Unit	Total	Resource Extraction and Manufacturing	Transport to Consumer	Use	End-of-Life
109	Propanal	Air	µg	1.24E+02	3.52E+01	4.16E+00	7.80E+01	6.68E+00
110	Propene	Air	g	3.09E+00	2.95E+00	1.82E-02	1.19E-01	1.68E-03
111	Radioactive species, unspecified	Air	kBq	8.75E+01	x	3.19E+01	5.13E+01	4.33E+00
112	Radionuclides (Including Radon)	Air	mg	1.19E+02	x	4.34E+01	6.99E+01	5.89E+00
113	Selenium	Air	mg	4.33E+01	2.93E+01	3.07E+00	1.08E+01	1.33E-01
114	Sodium	Air	g	2.03E+00	1.95E+00	4.51E-03	7.10E-02	5.24E-04
115	Styrene	Air	µg	8.92E+02	5.71E+02	2.15E+00	3.19E+02	2.64E-01
116	Sulfur dioxide	Air	oz	1.13E+02	6.24E+01	1.73E+01	3.28E+01	2.92E-01
117	Sulfur oxides	Air	g	1.08E+02	x	7.98E+01	1.69E+01	1.08E+01
118	Sulfuric acid, dimethyl ester	Air	ng	3.57E+01	x	1.30E+01	2.10E+01	1.77E+00
119	t-Butyl methyl ether	Air	mg	2.20E+00	2.17E+00	2.13E-05	2.46E-02	2.63E-06
120	Tar	Air	ng	1.35E+02	x	4.91E+01	7.91E+01	6.67E+00
121	Toluene	Air	g	1.65E+00	1.04E+00	1.14E-01	4.85E-01	5.28E-03
122	Toluene, 2,4-dinitro-	Air	pg	2.08E+02	x	7.58E+01	1.22E+02	1.03E+01
123	Vinyl acetate	Air	ng	5.66E+00	x	2.06E+00	3.32E+00	2.80E-01
124	VOC, volatile organic compounds	Air	g	4.77E+01	x	2.74E+01	1.66E+01	3.72E+00
125	Xylene	Air	g	2.04E+00	1.58E+00	9.38E-02	3.63E-01	3.41E-03
126	Zinc	Air	mg	5.20E+02	4.64E+02	5.19E+00	5.04E+01	5.35E-01
127	2-Hexanone	Water	mg	1.37E+00	x	5.86E-01	7.04E-01	7.96E-02
128	Acetone	Water	mg	2.17E+00	3.81E-05	8.99E-01	1.15E+00	1.22E-01
129	Acidity, unspecified	Water	mg	3.17E+02	2.19E+02	3.55E-02	9.70E+01	3.82E-03
130	Acids, unspecified	Water	µg	2.52E+00	x	9.17E-01	1.48E+00	1.25E-01
131	Aluminum	Water	g	2.46E+02	1.76E+02	8.10E+00	6.06E+01	1.09E+00
132	Ammonia	Water	g	3.37E+00	x	1.68E+00	1.46E+00	2.29E-01
133	Ammonia, as N	Water	µg	1.27E+00	x	4.60E-01	7.42E-01	6.25E-02
134	Ammonium, ion	Water	g	1.01E+01	9.35E+00	1.82E-02	7.27E-01	2.98E-03
135	Antimony	Water	g	1.08E+00	7.55E-01	4.95E-03	3.21E-01	6.70E-04
136	Arsenic, ion	Water	mg	3.16E+02	1.97E+02	2.51E+01	9.00E+01	3.41E+00
137	Barium	Water	g	1.76E+02	2.88E+00	1.07E+02	5.25E+01	1.45E+01
138	Benzene	Water	g	1.34E+01	1.27E+01	1.80E-01	4.64E-01	2.31E-02
139	Benzene, 1-methyl-4-(1-methylethyl)-	Water	µg	2.10E+01	x	8.97E+00	1.08E+01	1.22E+00

No.	Substance	Compartment	Unit	Total	Resource Extraction and Manufacturing	Transport to Consumer	Use	End-of-Life
140	Benzene, ethyl-	Water	mg	7.26E+01	2.48E+01	1.85E+01	2.73E+01	2.04E+00
141	Benzene, pentamethyl-	Water	µg	1.57E+01	x	6.73E+00	8.08E+00	9.14E-01
142	Benzenes, alkylated, unspecified	Water	mg	6.66E+00	x	4.25E+00	1.84E+00	5.77E-01
143	Benzoic acid	Water	mg	2.13E+02	x	9.10E+01	1.09E+02	1.24E+01
144	Beryllium	Water	mg	2.79E+01	1.87E+01	1.42E+00	7.52E+00	1.91E-01
145	Biphenyl	Water	µg	4.31E+02	x	2.75E+02	1.19E+02	3.74E+01
146	BOD5, Biological Oxygen Demand	Water	oz	1.50E+02	7.53E+01	5.09E+01	2.31E+01	3.61E-01
147	Boron	Water	g	3.54E+00	2.16E+00	2.87E-01	1.04E+00	3.88E-02
148	Bromide	Water	g	4.49E+01	x	1.92E+01	2.31E+01	2.61E+00
149	Cadmium, ion	Water	mg	4.83E+01	1.85E+01	3.71E+00	2.56E+01	5.01E-01
150	Calcium, ion	Water	oz	1.32E+02	9.94E+01	1.06E+01	2.07E+01	1.42E+00
151	Chloride	Water	oz	9.86E+02	6.35E+02	1.22E+02	2.12E+02	1.62E+01
152	Chromium	Water	mg	2.80E+02	x	2.05E+02	4.73E+01	2.78E+01
153	Chromium VI	Water	mg	9.23E+02	5.29E+02	1.22E+00	3.93E+02	1.89E-01
154	Chromium, ion	Water	mg	2.44E+02	1.56E+02	1.66E+01	6.95E+01	2.19E+00
155	Cobalt	Water	mg	6.19E+02	2.24E+02	2.26E+00	3.92E+02	2.99E-01
156	COD, Chemical Oxygen Demand	Water	oz	3.37E+02	2.05E+02	5.15E+01	8.00E+01	4.34E-01
157	Copper, ion	Water	g	2.43E+00	1.71E+00	2.66E-02	6.84E-01	3.66E-03
158	Cyanide	Water	mg	2.73E+01	1.24E+01	7.97E-01	1.40E+01	7.09E-02
159	Decane	Water	mg	6.11E+00	x	2.62E+00	3.14E+00	3.55E-01
160	Dibenzofuran	Water	µg	3.99E+01	x	1.71E+01	2.05E+01	2.32E+00
161	Dibenzothiophene	Water	µg	3.36E+01	x	1.47E+01	1.70E+01	1.99E+00
162	DOC, Dissolved Organic Carbon	Water	oz	8.74E+01	5.22E+01	1.39E+01	2.12E+01	8.62E-02
163	Docosane	Water	µg	2.24E+02	x	9.60E+01	1.15E+02	1.30E+01
164	Dodecane	Water	mg	1.16E+01	x	4.96E+00	5.96E+00	6.74E-01
165	Eicosane	Water	mg	3.19E+00	x	1.37E+00	1.64E+00	1.86E-01
166	Fluorene, 1-methyl-	Water	µg	2.39E+01	x	1.02E+01	1.23E+01	1.39E+00
167	Fluorenes, alkylated, unspecified	Water	µg	3.86E+02	x	2.46E+02	1.06E+02	3.34E+01
168	Fluoride	Water	g	1.29E+01	7.12E+00	3.26E-02	5.76E+00	3.19E-03
169	Fluorine	Water	µg	1.96E+02	x	1.21E+02	5.85E+01	1.65E+01
170	Hexadecane	Water	mg	1.27E+01	x	5.42E+00	6.51E+00	7.36E-01

No.	Substance	Compartment	Unit	Total	Resource Extraction and Manufacturing	Transport to Consumer	Use	End-of-Life
171	Hexanoic acid	Water	mg	4.41E+01	x	1.89E+01	2.26E+01	2.56E+00
172	Hydrocarbons, unspecified	Water	g	1.12E+01	1.04E+01	1.82E-03	8.78E-01	6.75E-05
173	Iron	Water	g	2.62E+01	x	1.55E+01	8.66E+00	2.10E+00
174	Iron, ion	Water	g	1.75E+02	1.40E+02	1.03E-01	3.55E+01	1.12E-02
175	Lead	Water	mg	8.71E+02	5.15E+02	5.41E+01	2.95E+02	7.24E+00
176	Lithium, ion	Water	g	1.08E+02	4.09E-03	4.70E+00	1.02E+02	6.37E-01
177	m-Xylene	Water	mg	6.58E+00	1.15E-04	2.72E+00	3.48E+00	3.70E-01
178	Magnesium	Water	g	2.36E+02	7.49E+01	5.87E+01	9.44E+01	7.87E+00
179	Manganese	Water	g	9.13E+00	8.36E+00	1.19E-01	6.36E-01	1.53E-02
180	Mercury	Water	mg	8.41E+00	5.34E+00	8.95E-02	2.97E+00	1.20E-02
181	Metallic ions, unspecified	Water	ng	1.18E+02	x	4.30E+01	6.93E+01	5.84E+00
182	Methane, monochloro-, R-40	Water	µg	8.44E+00	x	3.61E+00	4.34E+00	4.91E-01
183	Methyl ethyl ketone	Water	µg	1.69E+01	x	7.22E+00	8.68E+00	9.81E-01
184	Molybdenum	Water	mg	2.48E+02	1.49E+02	2.49E+00	9.65E+01	3.27E-01
185	n-Hexacosane	Water	µg	1.40E+02	x	5.99E+01	7.20E+01	8.14E+00
186	Naphthalene	Water	mg	3.82E+00	x	1.64E+00	1.96E+00	2.22E-01
187	Naphthalene, 2-methyl-	Water	mg	3.32E+00	x	1.42E+00	1.71E+00	1.93E-01
188	Naphthalenes, alkylated, unspecified	Water	µg	1.09E+02	x	6.96E+01	3.01E+01	9.45E+00
189	Nickel	Water	mg	4.84E+01	x	2.43E+01	2.08E+01	3.29E+00
190	Nitrate	Water	g	1.70E+02	1.66E+02	5.02E-02	3.67E+00	4.53E-03
191	Nitrate compounds	Water	ng	3.41E+01	x	1.24E+01	2.00E+01	1.69E+00
192	Nitric acid	Water	µg	7.66E+01	x	2.79E+01	4.49E+01	3.79E+00
193	o-Cresol	Water	mg	6.03E+00	x	2.58E+00	3.10E+00	3.51E-01
194	Octadecane	Water	mg	3.13E+00	x	1.34E+00	1.61E+00	1.82E-01
195	Oils, unspecified	Water	g	5.76E+02	7.03E+01	4.56E+02	4.70E+01	2.77E+00
196	p-Cresol	Water	mg	6.51E+00	x	2.79E+00	3.35E+00	3.78E-01
197	Phenanthrene	Water	µg	4.52E+01	x	2.49E+01	1.69E+01	3.39E+00
198	Phenanthrenes, alkylated, unspecified	Water	µg	4.53E+01	x	2.89E+01	1.25E+01	3.92E+00
199	Phenol	Water	g	5.52E+00	5.30E+00	7.87E-02	1.32E-01	8.71E-03
200	Phenol, 2,4-dimethyl-	Water	mg	5.88E+00	x	2.51E+00	3.02E+00	3.42E-01
201	Phosphate	Water	g	1.76E+01	7.79E+00	1.13E-02	9.80E+00	7.09E-03

No.	Substance	Compartment	Unit	Total	Resource Extraction and Manufacturing	Transport to Consumer	Use	End-of-Life
202	Selenium	Water	mg	7.10E+01	5.16E+01	1.23E+00	1.80E+01	1.61E-01
203	Silver	Water	mg	4.40E+02	x	1.89E+02	2.26E+02	2.56E+01
204	Sodium, ion	Water	oz	4.38E+02	3.21E+02	3.67E+01	7.49E+01	4.78E+00
205	Solved solids	Water	oz	3.47E+02	5.44E+00	1.41E+02	1.81E+02	1.92E+01
206	Strontium	Water	g	1.86E+01	4.09E+00	5.66E+00	8.16E+00	7.32E-01
207	Sulfate	Water	oz	4.51E+01	3.27E+01	3.24E-01	1.20E+01	4.02E-02
208	Sulfide	Water	mg	7.06E+01	1.58E+01	4.86E+00	4.93E+01	6.42E-01
209	Sulfur	Water	mg	9.28E+02	1.66E+02	3.05E+02	4.19E+02	3.82E+01
210	Suspended solids, unspecified	Water	oz	4.46E+01	3.06E+01	8.43E+00	4.46E+00	1.14E+00
211	Tar	Water	ng	1.93E+00	x	7.02E-01	1.13E+00	9.54E-02
212	Tetradecane	Water	mg	5.08E+00	x	2.18E+00	2.61E+00	2.96E-01
213	Thallium	Water	mg	7.36E+00	4.25E+00	1.03E+00	1.93E+00	1.42E-01
214	Tin	Water	mg	3.65E+01	x	1.97E+01	1.41E+01	2.68E+00
215	Titanium, ion	Water	g	2.15E+02	5.48E+00	9.29E-02	2.09E+02	1.22E-02
216	Toluene	Water	mg	6.13E+02	1.28E+02	1.94E+02	2.67E+02	2.40E+01
217	Vanadium	Water	mg	5.70E+00	x	2.44E+00	2.93E+00	3.31E-01
218	Xylene	Water	mg	4.04E+02	1.06E+02	1.19E+02	1.64E+02	1.42E+01
219	Yttrium	Water	mg	1.41E+00	x	6.05E-01	7.26E-01	8.22E-02
220	Zinc	Water	mg	2.90E+02	x	1.79E+02	8.66E+01	2.44E+01
221	Zinc, ion	Water	g	2.98E+00	2.08E+00	3.21E-02	8.64E-01	3.03E-03

Appendix VII: Cradle-to-gate LCI Ecosphere Flows for the Base Case Linoleum Flooring System

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Linoleum Manufacturing	Transport to Consumer	Use	End-of-Life
1	Coal, 26.4 MJ per kg, in ground	Raw	lb	1.25E+02	1.16E+02	2.39E-01	9.51E+00	1.43E-01
2	Coal, 29.3 MJ per kg, in ground	Raw	g	1.03E+02	1.03E+02	x	x	x
3	Coal, brown, in ground	Raw	oz	2.43E+02	2.05E+02	2.44E+00	3.57E+01	2.96E-02
4	Energy, from hydro power	Raw	kJ	3.92E+01	3.92E+01	x	x	x
5	Energy, gross calorific value, in biomass	Raw	MJ	7.77E+02	7.74E+02	4.78E-02	2.73E+00	3.00E-03
6	Energy, kinetic (in wind), converted	Raw	Wh	7.93E+02	6.67E+02	7.90E+00	1.18E+02	1.00E-01
7	Energy, potential (in hydropower reservoir), converted	Raw	MJ	2.60E+01	2.01E+01	1.74E-01	5.77E+00	7.37E-03
8	Gas, natural, 46.8 MJ per kg, in ground	Raw	kg	2.70E+00	2.70E+00	x	x	x
9	Gas, natural, in ground	Raw	yd3	2.03E+02	1.16E+02	3.91E-01	8.66E+01	1.02E-01
10	Limestone, in ground	Raw	kg	4.20E+01	4.20E+01	x	x	x
11	Oil, crude, 41 MJ per kg, in ground	Raw	mg	1.33E+01	1.33E+01	x	x	x
12	Oil, crude, 42 MJ per kg, in ground	Raw	kg	3.50E+01	3.50E+01	x	x	x
13	Uranium oxide, 332 GJ per kg, in ore	Raw	g	1.35E+00	1.24E+00	2.58E-03	1.03E-01	1.54E-03
14	Uranium, 2291 GJ per kg, in ground	Raw	mg	2.65E+00	2.65E+00	x	x	x
15	Water, cooling, unspecified natural origin/m3	Raw	gal*	7.48E+02	3.50E+02	5.73E+00	3.93E+02	3.95E-01
16	Water, unspecified natural origin/kg	Raw	kg	2.79E+01	2.79E+01	x	x	x

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Linoleum Manufacturing	Transport to Consumer	Use	End-of-Life
17	Water, unspecified natural origin/m3	Raw	dm3	8.46E+02	7.13E+02	7.07E+00	1.26E+02	3.88E-01
18	Water, well, in ground	Raw	dm3	4.13E+01	3.00E+01	3.95E-01	1.09E+01	2.60E-02
19	Wood and wood waste, 9.5 MJ per kg	Raw	kg	8.05E+00	8.05E+00	x	x	x
20	2-Chloroacetophenone	Air	ng	8.97E+01	8.30E+01	1.60E-01	6.37E+00	9.58E-02
21	Acenaphthene	Air	µg	1.39E+01	1.22E+01	2.47E-02	1.68E+00	1.60E-02
22	Acenaphthylene	Air	µg	6.02E+00	5.52E+00	1.19E-02	4.72E-01	7.10E-03
23	Acetaldehyde	Air	mg	6.25E+01	5.52E+01	2.84E-01	7.00E+00	3.82E-02
24	Acetophenone	Air	ng	1.92E+02	1.78E+02	3.43E-01	1.37E+01	2.05E-01
25	Acrolein	Air	mg	8.77E+00	7.62E+00	2.06E-02	1.12E+00	1.51E-02
26	Aldehydes, unspecified	Air	g	3.12E+00	2.51E+00	8.26E-02	4.75E-01	4.94E-02
27	Ammonia	Air	g	1.26E+02	1.24E+02	1.53E+00	5.66E-01	2.97E-02
28	Ammonium chloride	Air	mg	7.16E+01	6.59E+01	1.37E-01	5.44E+00	8.19E-02
29	Anthracene	Air	µg	5.05E+00	4.64E+00	9.96E-03	3.97E-01	5.96E-03
30	Antimony	Air	mg	1.46E+00	1.27E+00	2.25E-03	1.90E-01	5.82E-04
31	Arsenic	Air	mg	2.20E+01	1.75E+01	1.49E+00	2.96E+00	2.18E-02
32	Arsine	Air	pg	2.01E+02	1.75E+02	2.39E-03	2.63E+01	7.85E-05
33	Barium	Air	mg	2.31E+01	2.02E+01	3.86E-02	2.85E+00	1.59E-04
34	Benzene	Air	g	1.33E+00	9.99E-01	2.04E-01	1.24E-01	1.49E-03
35	Benzene, chloro-	Air	ng	2.82E+02	2.61E+02	5.03E-01	2.00E+01	3.01E-01
36	Benzene, ethyl-	Air	mg	2.15E+01	1.16E+01	5.27E+00	4.36E+00	2.87E-01
37	Benzo(a)anthracene	Air	µg	1.93E+00	1.77E+00	3.80E-03	1.51E-01	2.27E-03
38	Benzo(a)pyrene	Air	µg	4.05E+02	3.49E+02	3.26E+00	4.74E+01	5.47E+00
39	Benzo(b,j,k)fluoranthene	Air	µg	2.65E+00	2.43E+00	5.22E-03	2.08E-01	3.12E-03
40	Benzo(ghi)perylene	Air	ng	6.50E+02	5.97E+02	1.28E+00	5.10E+01	7.67E-01
41	Benzyl chloride	Air	µg	8.97E+00	8.30E+00	1.60E-02	6.37E-01	9.58E-03
42	Beryllium	Air	µg	8.03E+02	6.95E+02	1.66E+00	1.05E+02	8.74E-01
43	Biphenyl	Air	µg	4.09E+01	3.76E+01	8.07E-02	3.21E+00	4.83E-02
44	Bromoform	Air	ng	5.00E+02	4.63E+02	8.92E-01	3.55E+01	5.34E-01
45	BTEX (Benzene, Toluene, Ethylbenzene, and Xylene), unspecified ratio	Air	g	3.21E+01	1.78E+01	2.75E-02	1.43E+01	1.65E-02
46	Butadiene	Air	µg	3.12E+02	2.84E+02	9.00E-01	2.70E+01	5.38E-01
47	Cadmium	Air	mg	7.39E+00	5.94E+00	2.14E-01	1.23E+00	1.43E-02

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Linoleum Manufacturing	Transport to Consumer	Use	End-of-Life
48	Carbon dioxide, biogenic	Air	oz	6.58E+02	6.43E+02	3.60E-01	1.49E+01	1.13E-01
49	Carbon dioxide, fossil	Air	kg	5.18E+02	4.31E+02	1.98E+01	6.20E+01	4.93E+00
50	Carbon disulfide	Air	mg	1.36E+02	1.18E+02	1.29E-01	1.75E+01	7.88E-03
51	Carbon monoxide, biogenic	Air	g	4.95E+00	4.72E+00	8.75E-04	2.34E-01	7.94E-05
52	Carbon monoxide, fossil	Air	g	5.82E+02	2.70E+02	6.40E+01	2.24E+02	2.43E+01
53	Chloride	Air	µg	1.89E+00	1.74E+00	3.68E-03	1.47E-01	2.21E-03
54	Chloroform	Air	µg	3.26E+02	1.89E+02	5.38E-02	1.37E+02	2.85E-01
55	Chromium	Air	mg	5.31E+01	4.55E+01	6.67E-01	6.88E+00	2.67E-02
56	Chromium VI	Air	mg	3.17E+00	2.72E+00	6.28E-03	4.40E-01	2.52E-03
57	Chrysene	Air	µg	2.41E+00	2.21E+00	4.74E-03	1.89E-01	2.84E-03
58	Cobalt	Air	mg	9.96E+00	7.80E+00	1.66E-01	1.96E+00	3.29E-02
59	Copper	Air	mg	3.39E+01	2.45E+01	1.66E+00	7.41E+00	3.26E-01
60	Cumene	Air	mg	8.43E+02	8.41E+02	1.56E-01	1.84E+00	1.49E-02
61	Cyanide	Air	mg	8.83E+00	5.28E+00	2.05E-02	3.52E+00	7.30E-03
62	Dinitrogen monoxide	Air	g	7.45E+01	7.34E+01	4.77E-01	5.42E-01	1.21E-01
63	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	Air	ng	5.46E+01	3.95E+01	3.91E+00	1.11E+01	1.12E-01
64	Ethane	Air	g	3.50E+00	2.72E+00	8.06E-02	6.89E-01	4.28E-03
65	Ethane, 1,1,1-trichloro-, HCFC-140	Air	µg	6.33E+01	3.49E+01	1.92E-01	2.81E+01	1.71E-01
66	Ethane, 1,2-dibromo-	Air	ng	1.54E+01	1.42E+01	2.74E-02	1.09E+00	1.64E-02
67	Ethane, 1,2-dichloro-	Air	mg	2.03E+00	1.80E+00	9.37E-03	2.13E-01	9.98E-04
68	Ethane, chloro-	Air	ng	5.38E+02	4.98E+02	9.60E-01	3.82E+01	5.75E-01
69	Ethanol	Air	mg	2.25E+01	1.57E+01	2.43E-01	6.56E+00	1.32E-02
70	Ethene, tetrachloro-	Air	mg	1.22E+00	1.07E+00	2.49E-03	1.46E-01	1.61E-03
71	Ethene, trichloro-	Air	µg	2.04E+01	2.04E+01	x	x	x
72	Fluoranthene	Air	µg	1.71E+01	1.57E+01	3.37E-02	1.34E+00	2.02E-02
73	Fluorene	Air	µg	2.19E+01	2.01E+01	4.32E-02	1.72E+00	2.58E-02
74	Fluoride	Air	mg	1.85E+02	1.84E+02	4.07E-03	1.62E-01	2.44E-03
75	Formaldehyde	Air	g	3.52E+01	3.51E+01	1.08E-03	4.69E-02	2.66E-04
76	Furan	Air	µg	1.16E+02	1.14E+02	8.30E-01	1.43E+00	4.53E-02
77	Heat, waste	Air	kWh	4.71E+02	3.07E+02	4.63E+01	1.15E+02	2.78E+00
78	Hexane	Air	mg	4.62E+02	2.30E+02	1.13E+02	1.13E+02	6.17E+00
79	Hydrazine, methyl-	Air	µg	2.18E+00	2.02E+00	3.89E-03	1.55E-01	2.33E-03

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Linoleum Manufacturing	Transport to Consumer	Use	End-of-Life
80	Hydrocarbons, unspecified	Air	g	2.89E+00	2.86E+00	7.89E-04	3.14E-02	4.72E-04
81	Hydrogen chloride	Air	g	3.58E+01	3.04E+01	2.92E-01	5.07E+00	4.07E-02
82	Hydrogen fluoride	Air	g	4.46E+00	3.87E+00	3.15E-02	5.50E-01	4.75E-03
83	Hydrogen sulfide	Air	mg	4.37E+02	3.73E+02	3.95E-01	6.32E+01	8.51E-03
84	Indeno(1,2,3-cd)pyrene	Air	µg	1.47E+00	1.35E+00	2.89E-03	1.15E-01	1.73E-03
85	Iron	Air	mg	1.52E+02	5.41E+01	3.09E+00	9.48E+01	4.41E-02
86	Isophorone	Air	µg	7.43E+00	6.88E+00	1.33E-02	5.28E-01	7.94E-03
87	Isoprene	Air	g	6.19E+01	5.69E+01	1.21E-01	4.81E+00	7.23E-02
88	Kerosene	Air	mg	3.48E+01	3.20E+01	6.55E-02	2.61E+00	3.92E-02
89	Lead	Air	mg	4.67E+01	3.83E+01	9.12E-01	7.46E+00	3.48E-02
90	Magnesium	Air	mg	4.26E+02	3.11E+02	7.81E-01	1.14E+02	3.47E-01
91	Manganese	Air	mg	7.21E+01	6.88E+01	1.12E-01	3.16E+00	2.71E-02
92	Mercaptans, unspecified	Air	mg	2.68E+00	2.48E+00	4.64E-03	1.85E-01	2.78E-03
93	Mercury	Air	mg	8.57E+00	7.69E+00	1.49E-01	7.18E-01	5.77E-03
94	Metals, unspecified	Air	mg	1.17E+01	1.17E+01	1.37E-08	5.44E-07	8.18E-09
95	Methacrylic acid, methyl ester	Air	ng	2.56E+02	2.37E+02	4.57E-01	1.82E+01	2.74E-01
96	Methane, biogenic	Air	g	1.19E+02	1.19E+02	5.93E-03	3.58E-01	3.27E-04
97	Methane, dichloro-, HCC-30	Air	mg	9.91E+00	8.47E+00	4.39E-02	1.37E+00	2.71E-02
98	Methane, dichlorodifluoro-, CFC-12	Air	µg	8.44E+00	5.95E+00	2.52E-01	2.09E+00	1.42E-01
99	Methane, fossil	Air	g	5.08E+02	2.90E+02	6.85E+00	2.10E+02	6.52E-01
100	Methanol	Air	g	1.26E+01	6.12E-01	7.36E-04	1.20E+01	5.51E-05
101	Methyl ethyl ketone	Air	mg	3.10E+01	2.69E+01	3.77E-04	4.05E+00	1.74E-05
102	N-Nitrodimethylamine	Air	µg	4.59E+00	4.59E+00	x	x	x
103	Naphthalene	Air	mg	1.11E+01	1.08E+01	8.30E-03	2.17E-01	4.97E-03
104	Nickel	Air	mg	2.00E+02	9.49E+01	8.26E+01	2.21E+01	4.46E-01
105	Nitrogen oxides	Air	oz	1.17E+02	1.02E+02	8.93E+00	4.75E+00	1.31E+00
106	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	g	5.25E+02	4.44E+02	1.75E+01	5.97E+01	3.60E+00
107	Organic acids	Air	µg	2.63E+02	2.42E+02	5.02E-01	2.00E+01	3.01E-01
108	Organic substances, unspecified	Air	g	5.24E+00	4.82E+00	2.95E-04	4.24E-01	1.76E-04
109	PAH, polycyclic aromatic hydrocarbons	Air	mg	2.06E+01	1.01E+01	7.44E+00	2.50E+00	6.18E-01

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Linoleum Manufacturing	Transport to Consumer	Use	End-of-Life
110	Particulates, < 10 um	Air	g	1.54E+02	1.54E+02	x	x	x
111	Particulates, < 2.5 um	Air	g	2.45E+01	1.43E+01	5.54E+00	3.88E+00	7.54E-01
112	Particulates, > 10 um	Air	g	4.86E+01	2.89E+01	7.62E+00	1.21E+01	7.13E-02
113	Particulates, >2.5 um, and <10um	Air	g	7.52E+01	5.90E+01	6.84E+00	8.82E+00	5.54E-01
114	Particulates, unspecified	Air	g	1.65E+02	1.54E+02	6.29E-01	9.93E+00	3.77E-01
115	Phenanthrene	Air	µg	6.50E+01	5.97E+01	1.28E-01	5.10E+00	7.67E-02
116	Phenol	Air	mg	7.84E+02	7.84E+02	7.56E-05	1.26E-01	5.48E-05
117	Phenols, unspecified	Air	mg	1.85E+00	1.46E+00	2.35E-02	3.55E-01	1.41E-02
118	Phthalate, dioctyl-	Air	ng	9.35E+02	8.66E+02	1.67E+00	6.65E+01	9.99E-01
119	Potassium	Air	g	4.95E+00	4.89E+00	1.41E-03	6.54E-02	6.41E-05
120	Propanal	Air	µg	6.56E+01	7.53E+00	2.47E+00	5.31E+01	2.48E+00
121	Propene	Air	mg	3.97E+02	3.51E+02	1.07E+01	3.49E+01	6.25E-01
122	Pyrene	Air	µg	7.94E+00	7.29E+00	1.57E-02	6.23E-01	9.37E-03
123	Radioactive species, unspecified	Air	kBq	1.61E+03	1.50E+03	2.69E+00	1.07E+02	1.61E+00
124	Radionuclides (Including Radon)	Air	g	1.92E+00	1.77E+00	3.66E-03	1.46E-01	2.19E-03
125	Selenium	Air	mg	4.05E+01	3.41E+01	1.41E+00	4.99E+00	4.94E-02
126	Sodium	Air	mg	2.36E+02	2.02E+02	2.88E+00	3.09E+01	1.95E-01
127	Styrene	Air	µg	1.92E+02	1.49E+02	3.05E-01	4.26E+01	9.84E-02
128	Sulfur dioxide	Air	oz	1.31E+02	8.28E+01	6.85E+00	4.10E+01	1.09E-01
129	Sulfur oxides	Air	g	4.15E+02	3.69E+02	6.74E+00	3.53E+01	4.03E+00
130	Sulfuric acid	Air	µg	3.62E+01	3.15E+01	4.31E-04	4.74E+00	1.41E-05
131	Sulfuric acid, dimethyl ester	Air	ng	6.15E+02	5.69E+02	1.10E+00	4.37E+01	6.57E-01
132	t-Butyl methyl ether	Air	µg	4.42E+02	4.40E+02	9.00E-03	1.60E+00	9.78E-04
133	Tar	Air	µg	2.12E+00	1.95E+00	4.14E-03	1.65E-01	2.48E-03
134	Toluene	Air	mg	4.70E+02	2.42E+02	1.09E+02	1.17E+02	1.97E+00
135	Toluene, 2,4-dinitro-	Air	ng	3.59E+00	3.32E+00	6.40E-03	2.55E-01	3.83E-03
136	Tungsten	Air	ng	9.24E+02	x	9.24E+02	x	x
137	Vinyl acetate	Air	ng	9.74E+01	9.02E+01	1.74E-01	6.92E+00	1.04E-01
138	VOC, volatile organic compounds	Air	g	1.66E+02	1.23E+02	2.31E+00	3.92E+01	1.38E+00
139	2-Hexanone	Water	mg	3.13E+00	1.59E+00	4.95E-02	1.47E+00	2.96E-02
140	Acetone	Water	mg	4.85E+00	2.46E+00	7.58E-02	2.27E+00	4.54E-02

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Linoleum Manufacturing	Transport to Consumer	Use	End-of-Life
141	Acidity, unspecified	Water	mg	8.62E+00	1.94E+00	8.31E-03	6.67E+00	1.42E-03
142	Acids, unspecified	Water	mg	1.03E+02	1.03E+02	7.74E-05	3.08E-03	4.63E-05
143	Aluminum	Water	g	7.79E+01	5.83E+01	8.96E-01	1.83E+01	4.07E-01
144	Ammonia	Water	g	6.63E+00	3.35E+00	1.42E-01	3.05E+00	8.50E-02
145	Ammonia, as N	Water	µg	1.99E+01	1.83E+01	3.89E-02	1.55E+00	2.33E-02
146	Ammonium, ion	Water	g	1.10E+00	1.02E+00	1.00E-02	7.02E-02	1.11E-03
147	Arsenic, ion	Water	mg	1.87E+02	1.16E+02	2.44E+00	6.72E+01	1.27E+00
148	Barium	Water	g	2.02E+02	8.38E+01	9.19E+00	1.04E+02	5.38E+00
149	Benzene	Water	g	2.26E+00	1.82E+00	3.02E-02	3.98E-01	8.58E-03
150	Benzene, 1-methyl-4-(1-methylethyl)-	Water	µg	4.79E+01	2.43E+01	7.57E-01	2.25E+01	4.53E-01
151	Benzene, ethyl-	Water	mg	6.55E+01	3.15E+01	6.79E+00	2.64E+01	7.57E-01
152	Benzene, pentamethyl-	Water	µg	3.60E+01	1.82E+01	5.68E-01	1.68E+01	3.40E-01
153	Benzenes, alkylated, unspecified	Water	mg	7.34E+00	2.94E+00	3.59E-01	3.83E+00	2.15E-01
154	Benzoic acid	Water	mg	4.87E+02	2.46E+02	7.69E+00	2.28E+02	4.60E+00
155	Beryllium	Water	mg	9.94E+00	5.91E+00	1.47E-01	3.81E+00	7.12E-02
156	Biphenyl	Water	µg	4.76E+02	1.90E+02	2.32E+01	2.48E+02	1.39E+01
157	BOD5, Biological Oxygen Demand	Water	oz	1.22E+02	1.15E+02	1.97E+00	4.66E+00	1.34E-01
158	Boron	Water	g	2.27E+00	1.42E+00	2.88E-02	8.13E-01	1.44E-02
159	Bromide	Water	g	1.03E+02	5.21E+01	1.62E+00	4.82E+01	9.72E-01
160	Cadmium, ion	Water	mg	7.07E+01	6.20E+01	3.73E-01	8.16E+00	1.86E-01
161	Calcium, ion	Water	oz	6.10E+01	3.29E+01	1.15E+00	2.64E+01	5.30E-01
162	Chloride	Water	oz	6.52E+02	3.38E+02	1.41E+01	2.94E+02	6.03E+00
163	Chromate	Water	µg	4.67E+02	4.67E+02	x	x	x
164	Chromium	Water	mg	4.21E+02	2.95E+02	1.73E+01	9.88E+01	1.03E+01
165	Chromium VI	Water	mg	3.65E+02	1.52E+02	2.53E-01	2.12E+02	7.03E-02
166	COD, Chemical Oxygen Demand	Water	oz	1.59E+02	1.50E+02	2.02E+00	6.07E+00	1.61E-01
167	Copper, ion	Water	mg	3.71E+02	2.92E+02	3.25E+00	7.52E+01	1.36E+00
168	Cyanide	Water	mg	1.27E+01	1.05E+01	4.80E-01	1.74E+00	2.64E-02
169	Decane	Water	mg	1.40E+01	7.08E+00	2.21E-01	6.55E+00	1.32E-01
170	Dibenzofuran	Water	µg	9.12E+01	4.62E+01	1.44E+00	4.27E+01	8.62E-01
171	Dibenzothiophene	Water	µg	7.54E+01	3.80E+01	1.24E+00	3.54E+01	7.42E-01

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Linoleum Manufacturing	Transport to Consumer	Use	End-of-Life
172	DOC, Dissolved Organic Carbon	Water	g	3.80E+02	3.34E+02	1.65E+01	2.91E+01	9.09E-01
173	Docosane	Water	µg	5.13E+02	2.60E+02	8.11E+00	2.41E+02	4.85E+00
174	Dodecane	Water	mg	2.65E+01	1.34E+01	4.19E-01	1.24E+01	2.51E-01
175	Eicosane	Water	mg	7.31E+00	3.70E+00	1.15E-01	3.42E+00	6.91E-02
176	Fluorene, 1-methyl-	Water	µg	5.46E+01	2.76E+01	8.62E-01	2.56E+01	5.16E-01
177	Fluorenes, alkylated, unspecified	Water	µg	4.26E+02	1.70E+02	2.08E+01	2.22E+02	1.24E+01
178	Fluoride	Water	g	4.95E+02	4.95E+02	2.04E-02	4.77E-01	1.19E-03
179	Fluorine	Water	µg	2.38E+02	9.96E+01	1.03E+01	1.22E+02	6.14E+00
180	Hexadecane	Water	mg	2.90E+01	1.47E+01	4.57E-01	1.36E+01	2.74E-01
181	Hexanoic acid	Water	mg	1.01E+02	5.10E+01	1.59E+00	4.72E+01	9.53E-01
182	Hydrocarbons, unspecified	Water	mg	6.36E+02	1.20E+02	1.10E+00	5.15E+02	2.51E-02
183	Iron	Water	g	3.75E+01	1.74E+01	1.31E+00	1.81E+01	7.82E-01
184	Iron, ion	Water	g	3.61E+01	3.20E+01	2.70E-01	3.79E+00	4.18E-03
185	Lead	Water	mg	3.92E+02	2.35E+02	6.09E+00	1.48E+02	2.69E+00
186	Lithium, ion	Water	g	4.49E+02	2.49E+02	3.88E-01	1.99E+02	2.37E-01
187	m-Xylene	Water	mg	1.47E+01	7.44E+00	2.30E-01	6.87E+00	1.38E-01
188	Magnesium	Water	g	3.37E+02	1.82E+02	6.20E+00	1.46E+02	2.93E+00
189	Manganese	Water	g	1.89E+00	1.54E+00	2.23E-02	3.21E-01	5.68E-03
190	Mercury	Water	mg	4.97E+00	4.70E+00	1.24E-02	2.50E-01	4.46E-03
191	Metallic ions, unspecified	Water	mg	8.22E+02	8.22E+02	3.63E-06	1.45E-04	2.17E-06
192	Methane, monochloro-, R-40	Water	µg	1.93E+01	9.78E+00	3.05E-01	9.05E+00	1.83E-01
193	Methyl ethyl ketone	Water	µg	3.86E+01	1.96E+01	6.10E-01	1.81E+01	3.65E-01
194	Molybdenum	Water	mg	8.56E+01	4.33E+01	4.42E-01	4.17E+01	1.22E-01
195	n-Hexacosane	Water	µg	3.20E+02	1.62E+02	5.06E+00	1.50E+02	3.03E+00
196	Naphthalene	Water	mg	8.72E+00	4.41E+00	1.38E-01	4.08E+00	8.26E-02
197	Naphthalene, 2-methyl-	Water	mg	7.60E+00	3.85E+00	1.20E-01	3.56E+00	7.18E-02
198	Naphthalenes, alkylated, unspecified	Water	µg	1.20E+02	4.81E+01	5.87E+00	6.28E+01	3.52E+00
199	Nickel	Water	mg	9.09E+01	4.41E+01	2.05E+00	4.35E+01	1.23E+00
200	Nickel, ion	Water	mg	4.27E+02	3.70E+02	9.23E-01	5.56E+01	5.58E-02
201	Nitrate	Water	g	4.05E+02	4.05E+02	2.87E-02	1.99E-01	1.69E-03
202	Nitric acid	Water	mg	1.21E+00	1.11E+00	2.35E-03	9.37E-02	1.41E-03
203	o-Cresol	Water	mg	1.38E+01	6.99E+00	2.18E-01	6.47E+00	1.30E-01

No.	Substance	Compartment	Unit	Total	Raw Material Extraction and Linoleum Manufacturing	Transport to Consumer	Use	End-of-Life
204	Octadecane	Water	mg	7.16E+00	3.62E+00	1.13E-01	3.35E+00	6.76E-02
205	Oils, unspecified	Water	g	6.70E+01	3.15E+01	1.74E+01	1.70E+01	1.03E+00
206	Organic substances, unspecified	Water	mg	4.48E+02	4.48E+02	x	x	x
207	p-Cresol	Water	mg	1.49E+01	7.54E+00	2.35E-01	6.98E+00	1.41E-01
208	Phenanthrene	Water	µg	7.20E+01	3.33E+01	2.11E+00	3.53E+01	1.26E+00
209	Phenanthrenes, alkylated, unspecified	Water	µg	4.99E+01	2.00E+01	2.44E+00	2.61E+01	1.46E+00
210	Phenol	Water	mg	7.10E+02	6.13E+02	2.78E+01	6.69E+01	3.24E+00
211	Phenol, 2,4-dimethyl-	Water	mg	1.34E+01	6.80E+00	2.12E-01	6.30E+00	1.27E-01
212	Phosphate	Water	g	3.85E+02	3.85E+02	5.13E-03	4.23E-01	2.64E-03
213	Selenium	Water	mg	2.19E+01	1.72E+01	1.98E-01	4.47E+00	5.99E-02
214	Silver	Water	g	1.01E+00	5.09E-01	1.59E-02	4.71E-01	9.53E-03
215	Sodium, ion	Water	oz	1.91E+02	9.96E+01	5.43E+00	8.37E+01	1.78E+00
216	Solved solids	Water	oz	7.69E+02	3.93E+02	1.19E+01	3.57E+02	7.13E+00
217	Strontium	Water	g	2.84E+01	1.44E+01	8.74E-01	1.28E+01	2.72E-01
218	Sulfate	Water	oz	4.78E+01	4.60E+01	8.86E-02	1.70E+00	1.50E-02
219	Sulfide	Water	mg	5.77E+00	2.25E+00	6.44E-01	2.64E+00	2.39E-01
220	Sulfur	Water	g	3.13E+00	2.43E+00	6.04E-02	6.31E-01	1.42E-02
221	Sulfuric acid	Water	mg	5.57E+01	5.57E+01	x	x	x
222	Suspended solids, unspecified	Water	g	4.93E+02	2.25E+02	2.04E+01	2.36E+02	1.21E+01
223	Tar	Water	ng	3.04E+01	2.79E+01	5.93E-02	2.36E+00	3.55E-02
224	Tetradecane	Water	mg	1.16E+01	5.89E+00	1.84E-01	5.45E+00	1.10E-01
225	Thallium	Water	mg	3.04E+00	1.57E+00	9.03E-02	1.32E+00	5.30E-02
226	Tin	Water	mg	6.05E+01	2.83E+01	1.66E+00	2.95E+01	9.95E-01
227	Titanium, ion	Water	g	2.27E+02	2.27E+02	1.38E-02	5.66E-01	4.52E-03
228	Toluene	Water	mg	8.72E+02	4.33E+02	4.32E+01	3.87E+02	8.93E+00
229	Vanadium	Water	mg	1.30E+01	6.60E+00	2.06E-01	6.10E+00	1.23E-01
230	Xylene	Water	mg	4.83E+02	2.38E+02	3.24E+01	2.07E+02	5.27E+00
231	Yttrium	Water	mg	3.23E+00	1.64E+00	5.11E-02	1.51E+00	3.06E-02
232	Zinc	Water	mg	3.69E+02	1.64E+02	1.51E+01	1.81E+02	9.06E+00
233	Zinc, ion	Water	mg	6.69E+02	5.26E+02	2.02E+01	1.22E+02	1.13E+00

Appendix VIII: Critical Review Report

Critical Review of the Life Cycle Assessment Study: A comparative Life Cycle Assessment of Canadian Hardwood Flooring with Alternative Flooring Types

As part of the framework for this LCA study, a critical review process was undertaken according to Clause 7.3.3 of ISO 14040 (2006) and Clause 6.3 of ISO 14044 (2006) standards. The critical review is intended to ensure consistency between this LCA study and the principles and requirements of the ISO 14040/44 International Standards on Life Cycle Assessment.A review of this study was performed by the following reviewers:

- Melissa Hamilton and Lise Lauren from Earthshift, LLC.
- Dr. Lindita Bushi – LCA Consultant, Toronto, Canada.

The review process entailed the following steps:

1. Review and comment on initial study results (Draft Report issued December 10, 2010), and
2. Review and comment on the final report issued April 29, 2011.

At each step the review process considered whether the following study elements were met::

1. The methods used to carry out the LCA are consistent with the ISO 14040 series of international LCA standards;
2. The methods used to carry out the study are scientifically and technically valid;
3. The data used are appropriate and reasonable in relation to the goal of the study;
4. The interpretations reflect the limitations identified and the goal of the study;
5. The study report is transparent.

The final remarks made by the reviewers on the final study results and supporting report are stated below.

Melissa Hamilton and Lise Lauren from Earthshift, LLC

In general, this is a good study with good attention to detail, and the report is transparent and consistent. The methods used are consistent with ISO 14044 other than the study actually not being reviewed by a panel. The reviewers however, caution that the TRACI impact assessment method used in the study is not well documented method and the results may not be repeatable outside SimaPro.

Dr. Lindita Bushi

The critical reviewer is satisfied that almost all comments have been taken into account. The critical reviewer has found this LCA study transparent and adhering to the requirements of the ISO 14040 series of standards, and has few reservations. As with any LCA study there is always room for improvement and the critical reviewer has made the following final comments and recommendations concerning any future iterations of this study:

Cradle-to gate LCI profiles for alternative flooring products

ISO 14044:2006, Clause 4.2.3.7, and ISO/TR 14049: 2000 Clause 4.2 claim:
"*When comparing product systems, special attention has to be made to confirm that the comparison is based on the same functional unit and equivalent methodological considerations, such as performance, system boundaries, data quality, allocation procedures, decision rules on evaluating inputs and outputs.*"

In this study primary data was collected for the reference product - Eastern Canadian hardwood flooring - and the data quality is expected to be high. As stated in the final report, BEES software and its manual are the principal sources of secondary LCI data used to develop cradle-to-gate inventories of alternative flooring types selected for comparative assertion. Data quality differences between reference and alternative flooring products exist in light of:

1. The "not-complete/simplified" LCI modeling applied for other flooring product systems. *e.g. BEES modeling accounts for only two input raw materials for the production of generic ceramic tile flooring products.*
2. The exclusion of certain processes for other flooring product systems. *e.g. ancillary materials, amount of energy used during internal handling of materials, packaging material, and transportation of raw materials for cork flooring.*

These LCI modeling simplifications and exclusions provide a **conservative** comparison of Eastern Canadian hardwood to any single alternative flooring product, but comparisons across alternative flooring products may be misleading. For example, if primary data was collected for ceramic tile flooring manufacturing, its performance relative to other alternative flooring products could change.

It is recommended that future iterations of this study should benchmark the BEES data with other available LCI profiles provided in available LCA papers/publications or gather first-hand data for best LCI modeling of other alternative flooring products.

Floor maintenance stage for the service life of flooring products

In-depth analyses should be conducted in the future to properly estimate the impact of the floor maintenance stage. In cases where North American statistical data are not available for this stage, European data can be adjusted and used to fill in the data gaps.