Life Cycle Assessment of Acrylic Infused Engineered Hardwood Flooring

Prepared for:
Nydree Flooring LLC

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1 General aspects

This report presents the findings of the Life Cycle Assessment (LCA) conducted by SCS Global Services (SCS) of Acrylic Infused Engineered Hardwood flooring products manufactured for Nydree Flooring LLC (Nydree). The products include acrylic infused hardwood flooring manufactured at the Nydree production facility in Karthaus, Pennsylvania. The products are comprised of plywood, virgin and reclaimed hardwood veneer, acrylics and various additives and adhesives. This study includes the cradle-to-grave life cycle assessment of the flooring products, for use in various interior commercial and residential applications.

The primary intended application of this LCA is to support the development of an Environmental Product Declaration (EPD), conformant to ISO 14025[1], ISO 14044[2], ISO 21930[3], and the Product Category Rule[4] [5]. The LCA report will also be used to develop product carbon footprints following ISO 14067[6], to serve as the basis of a product carbon neutral claim.

The LCA study scope, methodology, data sources, assumptions, and limitations, used to calculate final indicator results developed for the EPD are described in this report. The following life cycle stages are included: raw material extraction and processing; transport to manufacturer; product manufacturing and packaging; product distribution, use and maintenance; and product disposal.

This report is provided to aid in understanding the potential life cycle impacts for the Nydree Flooring products for the category indicators specified by the PCR. The intended audience for this technical LCA report includes Nydree, the EPD verifier, and other LCA practitioners or technical audiences with which Nydree choses to share the report. This report has been critically reviewed by an external LCA practitioner independent of the project for conformance to ISO 14044 and the PCR and verification of the product carbon footprints. A reasonable level of assurance has been agreed upon for the project.

The results presented herein are NOT to be used as the sole basis for a comparative assertion to be disclosed to the public.

[1] ISO 14025:2006 Environmental labels and declarations – Type III environmental declarations – Principles and procedures
[2] ISO 14044: 2006/AMD 1:2017/ AMD 2:2020 Environmental Management – Life cycle assessment – Requirements and Guidelines.
[3] ISO 21930:2017 Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services.
[4] PCR Guidance for Building-Related Products and Services Part A: Life Cycle Assessment Calculation Rules and Report Requirements. Version 3.2. UL Environment. December 2018.
[5] PCR Guidance for Building-Related Products and Services Part B: Flooring EPD Requirements. Version 2.0. September 2018.
[6] ISO 14067:2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification

2 Goal of the study

The goals of the study include three primary objectives:

1. To assess the potential environmental impacts, using category indicators specified by the PCR, for the flooring products over their entire life cycle – raw material extraction and processing, manufacture of flooring, product use and maintenance, and disposal.
2. To serve as the basis of preparing an Environmental Product Declaration (EPD), conformant to the UL PCR Guidance for Building-Related Products and Services Part A and Part B: Flooring EPD Requirements (the PCR), ISO 14025, ISO 14044, and ISO 21930.
3. To support the development of a Product Carbon Footprint of the Nydree products, over the cradle-to-grave product life cycle, conformant to ISO 14067[7]. This report documents the carbon footprint analysis and is intended to serve as supporting documentation for the critical review of the carbon footprint for public communication and to support a carbon neutral certification.

Life Cycle Impact Assessment (LCIA) results are reported using the indicators prescribed by the Product Category Rule (the PCR) including both the CML-IA[9] and TRACI 2.1[10] characterization methodologies. It should be noted that the PCR does not require reporting of all environmentally relevant impacts, such as impacts to ecosystems, key species habitats, or water resources.

The LCA study scope, methodology, data sources, assumptions, and limitations, used to calculate final indicator results developed for the EPDs are described in this report. The following life cycle stages are included: raw material extraction and processing; transport to manufacturer; product manufacturing and packaging; product distribution, use and maintenance; and product disposal.

The Nydree Flooring products are used in various interior commercial and residential applications.

[7] ISO 14067:2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification
[9] CML 4.1 baseline, from Institute of Environmental Sciences Faculty of Science University of Leiden, Netherlands.
[10] Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI). Dr. Bare, J., https://www.epa.gov/chemical-research/tool-reduction-and-assessment-chemicals-and-other-environmental-impacts-traci .

3 Scope of the study

3.1 Function, functional unit and reference flows

The Acrylic Infused Hardwood flooring products assessed provide the primary function of floor covering. According to ISO 14044, the functional unit is "the quantified performance of a product system, for use as a reference unit." The functional unit used in the study, as specified in the PCR, is 1 m^2 of flooring maintained for 75 years. The products are used in various commercial applications including retail, healthcare, education, and hospitality.

Although the manufacturer noted that the lifetime of their products may exceed that of the building lifetime when properly maintained and with periodic refinishing, a conservative estimate of 30 years was assumed for the Reference Service Life (RSL) of the flooring products to represent the lifetime for the life cycle modeling. The product lifetime estimates are based on product use for the specified application; installation, maintenance and cleaning as recommended in product guidance documents.

Table 1 summarizes the reference flow, Reference Service Life for flooring products assessed and the total number of product replacements and life cycles required during the 75-year time horizon for the assessment. Two (2) product thicknesses are considered – 7/16" and 9/16". Additionally, the 7/16" product is modeled with an iron film backing strip to facilitate an alternative method of installation. Product installation, maintenance and cleaning procedures are summarized in Section 4.2. A sample product image is presented in Figure 1, below.

Table 1. Reference flow and Reference Service Life (RSL) for the flooring products included in the assessment.

Product	7/16" Acrylic Infused Hardwood Flooring	7/16" Acrylic Infused Hardwood Flooring with iron film backing	9/16" Acrylic Infused Hardwood Flooring
Product Thickness (mm)	11.1 (7/16")	11.1 (7/16")	14.3 (9/16")
Reference flow (kg/m^2)	9.67	11.25	10.32
Mass conversion factor	9.67	11.25	10.32
Reference Service Life – RSL (years)	30	30	30
# of Product replacements (Replacement cycle)	1.5	1.5	1.5

Figure 1. Representative product image for the installed flooring products included in the LCA scope.

3.2 System description

General description of the system

The Nydree Flooring products (UNSPSC Code 30161702/CSI Code 09 64 00) are manufactured at the production facility in Karthaus, PA. The primary materials include plywood, virgin and recycled hardwood veneer, acrylics and adhesives. The products are distributed to consumer markets in North America and assessed over the 75-year ESL of the building, as noted above.

Table 2 summarizes the product characteristics for the flooring products included in the assessment. The products are available in the form of planks.

Table 2. Product specifications for the Nydree Flooring Acrylic Infused Engineered Hardwood Flooring products.

Characteristic	Unit	7/16" Flooring	7/16" Flooring with iron film backing	9/16" Flooring
Thickness	mm	11.1 (7/16")	11.1 (7/16")	14.3 (9/16")
Width	mm	133.4 (5 ¼")	133.4 (5 ¼")	133.4 (5 ¼")
Product Weight	g/m^2	9,670	11,250	10,320

The products are installed following the manufacturer's recommended methods and maintained with regular and periodic cleaning. The manufacturer provided estimates of the service lifetime for their products, as summarized above in Table 1.

The product system studied in this LCA includes the cradle-to-grave impacts of the flooring products. The system was modeled based on information provided by the manufacturer and completed Data Request Forms. Product packaging, including end-of-life disposal, is also included in the model.

In addition to the product installation, maintenance of the flooring products was modeled over the products' lifetime based on information provided by the manufacturer. Product cleaning methods and recommended frequency of cleaning are summarized below (Section 4.2).

Geographical coverage

The flooring products are manufactured at the Nydree Flooring manufacturing facility in Karthaus, PA. The products are distributed in North America and modeled based on data provided by the manufacturer. Electricity use at the manufacturing facility was modeled using inventory datasets modified to reflect the eGRID energy mix for the RFCE eGRID EPA NERC subregion Disposal processes are modeled based on regional statistics as specified by the PCR. Environmental impact category indicators are reported based on the CML-IA characterization factors, as well as the U.S. EPA TRACI 2.1 characterization methodology.

Time coverage

Manufacturer-supplied data (primary data) are based on production for calendar year 2022.

3.3 System boundaries

Initial inclusion and exclusion rules for unit processes and flows

The product system under study includes the production of all the components shown in Table 5 (Section 4.2), as well as transportation to point of use, installation, use and maintenance, and end-of-life (see Figure 2). The system boundaries include all unit processes contributing measurably to category indicator results for those category indicators specified in the PCR.

All inputs and outputs relevant to the production of products were included in the LCA calculations. According to the PCR, processes contributing greater than 1% of the total environmental impact indicator for each impact must be included in the inventory. With the exception of the processes noted below, all known materials and processes were included in the life cycle inventory.

The specification of the system boundary for the product system aligns with the following two LCA modeling principles:

1. The “modularity principle”: Processes influencing the construction product’s environmental performance during its life cycle are assigned to the information module of the life cycle stage where they occur; all environmental aspects and potential impacts are declared in the life cycle stage where they can be attributed; and

2. The “polluter pays principle”: Processes relevant to waste processing are assigned to the product system that generates the waste until the system boundary between product systems is reached.

Consistent with PCR requirements, processes excluded from the system boundary include the following:

- Construction activities, capital equipment, and infrastructure
- Maintenance and operation of capital equipment
- Personnel travel and resource use

The deletion of these processes is permitted since it is not expected to significantly change the overall conclusions of the study.

The life cycle stages included in the study, according to the module definitions of the PCR, are shown in Table 3. A flow diagram of the product system, including system boundaries, is provided in Figure 2.

Table 3. The modules and unit processes included in the scope for the flooring products.

Module	Module Description	Unit Processes Included in Scope
A1	Extraction and processing of raw materials; any reuse of products or materials from previous product systems; processing of secondary materials; generation of electricity from primary energy resources; energy, or other, recovery processes from secondary fuels	Extraction and processing of raw materials for the product and packaging components.
A2	Transport (to the manufacturer)	Transport of component materials to the manufacturing facility
A3	Manufacturing, including ancillary material production	Manufacturing of the flooring products and packaging (incl. upstream unit processes*)
A4	Transport (to the building site)	Transport of product (including packaging) to the building site
A5	Construction-installation process	The product is installed using the manufacturer's recommended, or similar, adhesives with negligible impacts. Only impacts from packaging disposal are included in this phase.
B1	Product use	Use of the flooring in a commercial building setting. There are no associated emissions or impacts from the use of the product
B2	Product maintenance	Maintenance of products over the 75-year ESL, including periodic cleaning.
B3	Product repair	The product is not expected to require repair over its lifetime
B4	Product replacement	The materials and energy required for replacement of the product over the 75-year ESL of the assessment are included in this phase
B5	Product refurbishment	The product is not expected to require refurbishment over its lifetime
B6	Operational energy use by technical building systems	There is no operational energy use associated with the use of the product
B7	Operational water uses by technical building systems	There is no operational water use associated with the use of the product
C1	Deconstruction, demolition	Demolition of the product is accomplished using hand tools with no associated emissions and negligible impacts
C2	Transport (to waste processing)	Transport of the product to waste treatment at end-of-life
C3	Waste processing for reuse, recovery and/or recycling	The products are disposed of via landfilling which requires no waste processing
C4	Disposal	Disposal of the product
D	Reuse-recovery-recycling potential	Module Not Declared

**This includes unit processes involved in the generation of electricity, and production of material input (e.g., adhesives and pigments).*

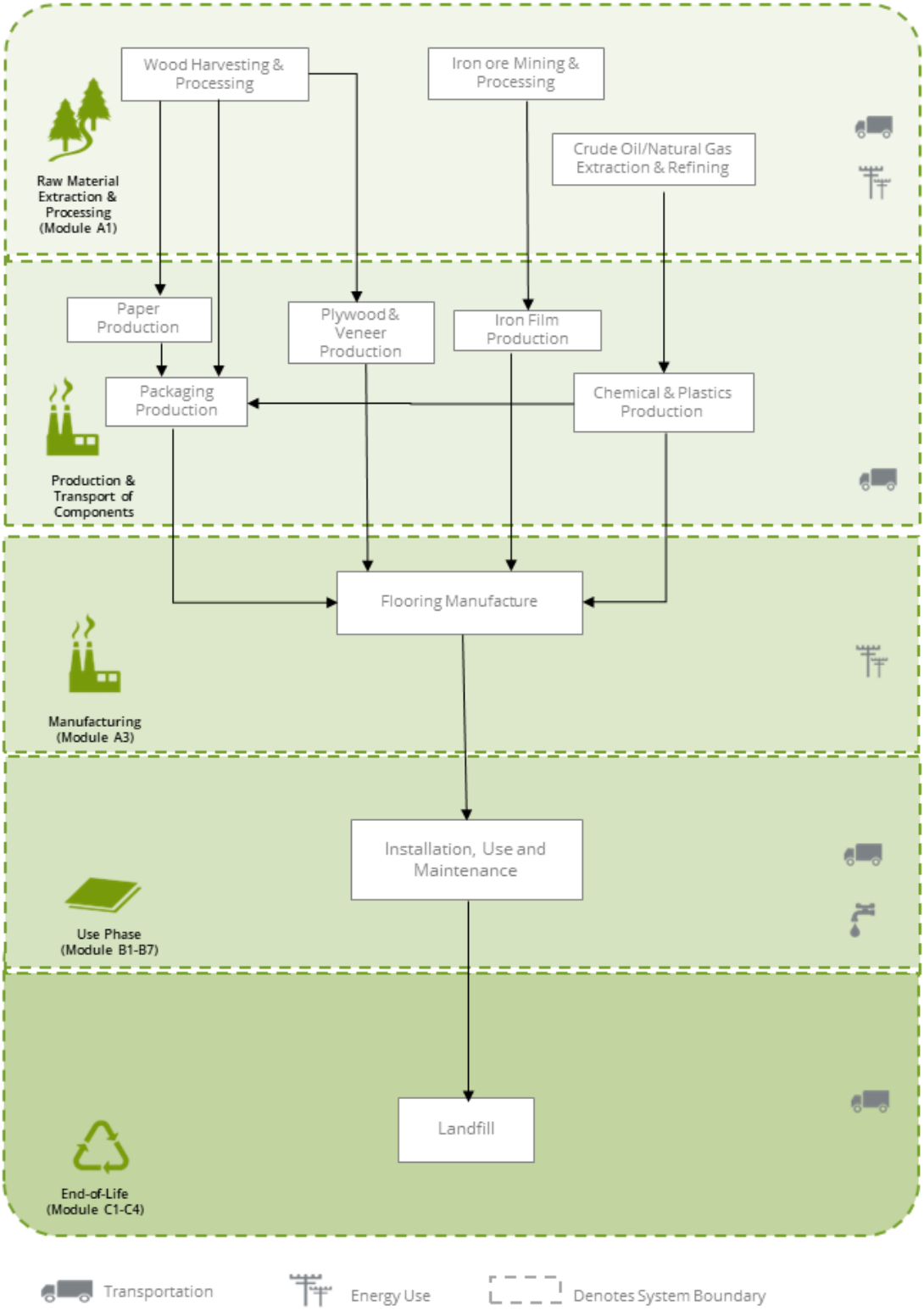

Figure 2. Flow diagram and system boundaries for the life cycle of the flooring products.

Allocation procedures

This study follows the allocation guidelines of ISO 14044 and sought to minimize the use of allocation wherever possible. The PCR requires primary data for allocation based on mass or other physical relationships (e.g., volume or energy content). Alternatively, economic allocation may be applied. The secondary databases used for the product system (discussed below) apply allocation based primarily on physical relationships.

Electricity use at the manufacturing facility was allocated to the products based on the product area as a fraction of the total facility production (i.e., area-based allocation). Area-based allocation was deemed most appropriate for the flooring products as total facility production was available as total square meters of product produced. Impacts from electricity use at the manufacturing facility was modeled using ecoinvent inventory datasets for the regional electricity grid.

The Nydree Flooring product system includes some recycled materials, which were allocated using the recycled content allocation method (also known as the 100-0 cut off method). Using the recycled content allocation approach, system inputs with recycled content do not receive any burden from the previous life cycle other than reprocessing of the waste material. At end of life, materials which are recycled leave the system boundaries with no additional burden.

Impacts from transportation, including product distribution to point of sale, were allocated based on the mass of material and distance transported.

3.4 Equivalence of compared systems

The results presented are not intended for use in comparative assertions.

3.5 Initial data quality requirements

One of the primary goals of the study is to produce an LCA and EPD for the flooring products; as such, the overarching data quality requirements are to enable a reliable assessment of the indicator results for all reported impact categories, with data quality sufficient as to identify the key unit processes, differentiated by overall contribution to final results. No data gaps were allowed which were expected to significantly affect the outcome of the indicator results.

A data quality assessment is provided in Section 4 of this report, according to the requirements of the PCR, and considers all of the following data quality requirments as noted in ISO 14044 Section 4.2.3.6.

- Time-related coverage of the data (age, minimum collection period);
- Geographical coverage;
- Technological coverage (specific technologies or technology mixes that should be used);

- Precision (measure of the variability of the data values for each data expressed);
- Completeness: Percentage of flow that is measured or estimated;
- Representativeness: Qualitative assessment of the degree to which the data set reflects the true population of interest;
- Consistency: Qualitative assessment of whether the study methodology is applied uniformly to the various components of the analysis;
- Reproducibility: qualitative assessment of the extent to which information about the methodology and data values would allow an independent practitioner to reproduce the results reported in the study;
- Sources of the data; and
- Uncertainty of the information (e.g., data, models and assumptions).

3.6 General assumptions

The assessment relied on a number of assumptions related to material composition, processing, and use and maintenance. The major assumptions used in the assessment are described below.

- Electricity use at the manufacturing facility was allocated to the products based on the product area as a fraction of the total production.
- The Nydree Flooring production facility is located in the RFCE eGRID EPA NERC subregion. An Ecoinvent inventory dataset was modified to reflect the eGRID energy mix for RFCE to estimate resource use and emissions from electricity use at the manufacturing facility.
- Inventory data for some material components were unavailable and modeled using proxy datasets from the Ecoinvent LCI databases.
- The Reference Service Life (RSL) of the products was modeled based on information provided by the manufacturer assuming the products are installed and maintained as recommended and used for the specific application noted.
- Downstream transport was modeled based on information provided by the manufacturer representing product distribution to North America.
- The maintenance phase of the product life cycle was modeled based on information provided by the manufacturer including recommended installation and cleaning methods, as well as cleaning frequency.
- For the product end-of-life, landfill disposal of product is assumed, following PCR guidance. Recycling rates for the packaging materials are based on regional statistics as specified in the PCR.
- For final disposal of the packaging material and flooring products at end-of-life, all materials are assumed to be transported 161 km by diesel truck to either a landfill or material

reclamation facility (for recycling). Datasets representing disposal in a landfill and waste incineration are from Ecoinvent.

3.7 Data types and sources

The life cycle inventory (LCI) of each unit process comprises material and energy inputs, emissions, and wastes. Primary data, as well as datasets from commercial LCI database are used to model each unit process within the product system and include data quantifying the elementary and technology flows necessary to calculate environmental impacts in the LCIA phase. These include the following general types of data:

- Inputs from nature: biotic and abiotic resources;
- Inputs from the technosphere: ancillary materials, services such as waste management and transport, energy inputs, etc.; and,
- Outputs to nature: emission to air, water and soil.

To the extent available, primary data are used for foreground processes (e.g., product manufacturing), while background processes are modeled using secondary data sourced from the Ecoinvent LCI database.

3.8 Sensitivity analysis for refining the system boundaries

Sensitivity analyses are conducted to evaluate the impact of various modeling assumptions on indicator results. For the present study, the impacts due to assumptions regarding the product maintenance are investigated in a sensitivity analysis. The results of the analysis are presented and discussed in Section 5.3.

3.9 Life cycle impact assessment

Mandatory elements

The LCA conforms to ISO 14040/44 and the UL Product Category Rule for Flooring Products. Impact category indicators are estimated using both CML-IA and TRACI 2.1 characterization factors. The impact indicators considered for the assessment include:

- Potential for Global Warming
- Acidification Potential
- Eutrophication Potential
- Photochemical Ozone (Smog) Creation Potential
- Ozone Depletion Potential

- Fossil Fuel Depletion Potential[11]
- Abiotic Resource Depletion Potential (fossil fuels)[10]

Note that for global warming calculations, the CML characterization factors are based on IPCC 2013, while TRACI 2.1 global warming calculations are based on IPCC 2007. Note also that neither characterization method includes biogenic carbon uptake or biomass CO_2 emissions. Based on the component materials of the product and production processes, there are no impacts associated with land-use change, nor are environmental impacts associated with carbonation relevant for the product system. The impact category indicators included in the assessment are described below.

Category Indicator	Units	Impact Category and Environmental Mechanism
Global Warming Potential (GWP)	kg CO_2 eq.	Anthropogenic emissions of greenhouse gases and short-lived climate forcers have led to increased radiative forcing, which has in turn increased the global mean temperature by above 0.99°C since pre-industrial times. All IPCC scenarios project an increase to 1.5°C in the near term, occurring between 2021 to 2040. The projection for the SSP2-4.5 scenario estimates an increase of 2.0°C occurring between 2043-2062, with 3°C occurring between 2061-2080[12]. As global mean temperatures continue to climb, global climate change will result. Some of the predicted impacts include reductions in food and food supplies, water supplies, and sea level rise.[13]
Ozone Layer Depletion (ODP)	kg CFC-11 eq.	Emissions of ozone depleting substances such as chlorofluorocarbons contribute to a thinning of the stratospheric ozone layer. This can lead to increased cases of skin cancer, and effects on crops, other plants, marine life, and human-built materials. All chlorinated and brominated compounds stable enough to reach the stratosphere can have an effect. CFCs, halons and HCFCs are the major causes of ozone depletion. Damage to the ozone layer reduces its ability to prevent ultraviolet (UV) light entering the earth's atmosphere, increasing the amount of carcinogenic UVB light reaching the earth's surface. Due to the international ban on ozone depleting chemicals, the stratospheric ozone layer has begun to recover; U.S. EPA projects that the ozone layer will recover within about 50 years.
Photochemical Oxidant Creation Potential (POCP) Smog Formation Potential (SFP)	kg C_2H_4 eq. – CML kg O_3 eq. - TRACI	Photochemical ozone, also called "ground level ozone", is formed by the reaction of volatile organic compounds and nitrogen oxides in the presence of heat and sunlight. If ozone concentrations reach above certain critical thresholds, health effects in humans can result, including bronchitis, asthma, and emphysema. The impact category depends largely on the amounts of carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxide (NO), ammonium and NMVOC (non-methane volatile organic compounds).

[11] TRACI 2.1 only
[12] Technical Summary. IPCC AR6 WGI. Box TS.1
https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_TS.pdf
[13] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press
https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf

Category Indicator	Units	Impact Category and Environmental Mechanism
Acidification (AP)	kg SO_2 eq.	Acidification is the increasing concentration of hydrogen ion (H^+) within the local environmental and occurs as a result of adding acids such as nitric acid and sulfuric acids into the environment. Acid precursor emissions transport in the atmosphere and deposit as acids. These acids may deposit in soils which are sensitive, or insensitive, to the increased acid burden; sensitivity can depend on a number of factors. In acid-sensitive soils, the deposition can decrease the soil pH (acidification) and increase the mobility of heavy metals in the environment, such as aluminum. This acidification can affect the pH of local soils and freshwater bodies, by increasing local hydrogen ion concentrations, causing endpoints such as tree die-offs and dead lakes. Emissions of sulfur dioxide and nitrogen oxides from the combustion of fossil fuels have been the greatest contributor to acid rain.
Eutrophication (EP)	kg PO_4^{3-} eq. – CML kg N eq. - TRACI	Eutrophication is the build-up of a concentration of chemical nutrients in an ecosystem which leads to abnormal productivity. In some regions, emissions of excess nutrients (including phosphorus and nitrogen) into water can lead to increased algal blooms. These blooms can reach such a severity that waterways become choked, with no other plant life able to establish itself. If algal blooms are intense enough, the decaying algae consumes dissolved oxygen in the water column starving other organisms of needed oxygen. Whereas phosphorous is mainly responsible for eutrophication in freshwater systems, nitrogen is mainly responsible for eutrophication in ocean water bodies. Emissions of ammonia, nitrates, nitrogen oxides and phosphorous to air or water all have an impact on eutrophication.
Fossil Fuel Depletion (FFD)	MJ surplus	This impact category reflects the relative abundance and depletion of feedstock reserves resulting from the net consumption of fossil energy resources used for electric power generation, operations and transport, and for incorporation into materials such as plastics. This indicator considers the amount of resources used for the function under study, the availability of economically recoverable reserves, the degree to which such resources may be replenished, the relative efficiency of power generation systems and fuel systems, and whether the resource is available for reuse at end of life (e.g., recycling). All fossil fuel resources which are consumed in a non-renewable fashion are included.
Abiotic Depletion, fossil fuels (ADPF)	MJ	This impact category refers to the consumption of fossil fuels. The value of the abiotic resource consumption of a substance (e.g., lignite or coal) is a measure of the scarcity of a substance and depends on the amount of resources and the extraction rate. It is calculated as the amount of resources that are depleted and measured in equivalent MJ of fossil fuels.

For the Nydree Flooring products, greenhouse gas indicators are calculated as the product of the 100-year GWP, based on IPCC AR6, and the mass of greenhouse emission, summed over all contributing greenhouse gases and for all sources and sinks within the life cycle system boundary for the assessed products. Results are reported in units of kg CO_2 eq. across the cradle-to-grave life cycle.

The primary greenhouse gasses included in the inventory, as well as the corresponding GWPs, are summarized in Table 4. The 100-year GWPs used in the assessment are from the IPCC Sixth Assessment Report (AR6) as implemented in the OpenLCA v1.11[14] software and databases.

Table 4. Greenhouse gases and GWPs for the global warming potential indicators.

GHG	100-yr Global Warming Potential (AR6)	Unit
Caron dioxide (CO_2)	1.0	kg CO_2e/kg CO_2
Methane (CH_4)	29.8	kg CO_2e/kg CH_4
Nitrous oxide (N_2O)	273	kg CO_2e/kg N_2O
Sulfur hexafluoride (SF_6)	25,200	kg CO_2e/kg SF_6
Perfluorocarbons (PFCs)	Various	kg CO_2e/kg PFC
hydrofluorocarbons (HFCs)	Various	kg CO_2e/kg HFC

The PCR requires that several additional parameters be reported in the EPD, including resource use, waste categories and output flows, and other environmental information. Many of these additional parameters seek to classify resources and materials with respect to their use as raw materials for the product. While the LCA model tracks the input of these elementary flows, the model does not explicitly track whether those energy flows are used to generate energy (e.g., natural gas-based electricity) or used in a product (e.g., fossil-based plastics). In such cases, and when the parameters cannot be estimated by other means (e.g., from primary material content and/or resource use data), these parameters are reported herein, and in the EPD, as "*Indicator not assessed (INA).*"

Elementary flows were reviewed for resources which are considered renewable on a human time scale. Elementary flows related to land occupation were not included. In addition, water consumption was not included since this flow is reported separately. As the flooring products do not contain significant amounts of bio-based materials, biogenic carbon emissions and removals are not declared.

In light of the above discussion, the additional parameters were assessed using the following methods:

- *Use of renewable primary energy excluding renewable primary energy resources used as raw materials (RPR_E).* This parameter is estimated as the total consumption of renewable primary energy renewable resources minus the primary energy resources used as raw materials.
- *Use of renewable primary energy resources used as raw materials (RPR_M).* The primary energy resources used as raw materials in the product system includes the virgin hardwood veneer lumber. The parameter is estimated and reported using a lower heating value of 19.8 MJ/kg of oven dry wood.

[14] OpenLCA v1.11. https://www.openlca.org/greendelta/

- *Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials ($NRPR_E$).* No classification scheme is available in OpenLCA for energy resources used as raw materials. *Indicator not assessed.*
- *Use of non-renewable primary energy resources used as raw materials ($NRPR_M$).* No classification scheme is available in openLCA for energy resources used as raw materials. *Indicator not assessed.*
- *Use of secondary material (SM).* The product system includes reclaimed materials used as components of the products and this is reported as use of secondary materials in the product system.
- *Use of renewable and non-renewable secondary fuels (RSF/NRSF).* The main consumption of any secondary fuel in the product system is the combustion of municipal solid waste, used to generate electricity in some regions. This parameter is assumed negligible for the current assessment.
- *Net use of fresh water (FW).* Net use of fresh water (consumption) is included in the Ecoinvent datasets used for the modeling and are reported for all modules. Water consumption includes evaporation, transpiration, product integration and discharge into a different drainage basin or the sea.
- *Hazardous waste disposed (HWD).* All flows of hazardous waste included in the full LCI and other data sources were aggregated into a single result for total hazardous waste disposal.
- *Non-hazardous waste disposed (NHWD).* This includes all wastes produced across all life cycle stages included in the study scope. Flows of non-hazardous waste included in the full LCI were also aggregated into a single result for total non-hazardous waste disposal.
- *Radioactive wastes disposed (HLRW/ILLRW).* All flows of radioactive wastes included in the full LCI and other data sources were classified and reported as low-level and high-level radioactive.
- *Components for re-use (CRU).* There are no components of the product which can be reused, or recycled, at the end of the reference service lifetime and this parameter is reported as zero.
- *Materials for recycling (MR).* The flooring products are not typically recycled. It is assumed for the current assessment that no components of the product are recycled at end-of-life. This parameter, as reported, includes only recycled materials of the product packaging at end-of-life based on the recycling rates for packaging as specified by the PCR.
- *Materials for energy recovery (MER). T*he production of materials for energy recovery crossing the system boundaries is negligible.
- *Recovered energy (RE).* The recovered energy crossing the system boundaries is negligible.
- *Exported energy (EE).* The exported energy crossing the system boundaries is negligible.

All results are calculated with the OpenLCA model using primary and secondary inventory data as described below.

The interpretation phase conforms to ISO 14044 with further guidance from the ILCD General Guide for Life Cycle Assessment.[15] The interpretation included the use of evaluation and sensitivity checks to steer the iterative process during the assessment, and a final evaluation including completeness, sensitivity, and consistency checks, at the end of the study.

Value Choices and Optional Elements

The study avoids the use of value choices in the assessment, as described in ISO 14044, such as normalization, weighting or grouping of indicator results. The study also includes a data quality assessment, considered optional under ISO 14044.

3.10 Calculation methods

The LCIA and inventory results were calculated based on the TRACI 2.1 and CML-IA characterization methodologies using the OpenLCA v1.11 model with primary and secondary data as described in Section 4.

3.11 Limitations of the study

As a result of the choice of study scope and LCIA methodologies used, there were several important study limitations which should be understood to ensure an appropriate interpretation of results. None of these limitations were judged to have significant relevance to final indicator results and were deemed acceptable limitations.

Limitations in the Study Scope

- Energy resource use (electricity) and emissions at the manufacturing facility were allocated to the flooring products based on the product area as a fraction of the total facility production.
- Lacking detailed supplier information, much of the upstream raw materials extraction and processing could not be modeled with actual process information. Representative data from the Ecoinvent LCI databases were utilized as appropriate.
- Specific data to estimate the disposition of the product packaging at end-of-life were unavailable. Assumptions for end-of-life are based on regional statistics regarding municipal solid waste generation and disposal as specified in the PCR.

[15] European Joint Research Commission. International Reference Life Cycle Data System handbook. *General guide for Life Cycle Assessment – Detailed Guidance.* © European Union, 2010.

Limitations in Life Cycle Impact Assessment Phase

There are several important limitations in the LCIA methodologies used, which are based upon the requirements of the PCR. These limitations are described below.

There may be additional impacts relevant to the production of the products at the manufacturing facility. Some of these omitted impact categories are listed in Table 5. This list is not exhaustive; there may be other impact categories which are not included.

Table 5. Impact categories omitted from the LCIA of the flooring products.

Impact Categories	Impact Categories
Terrestrial Biome Disturbance	Hazardous Environmental Contaminant Exposure Risks
Freshwater Biome Disturbance	$PM_{2.5}$ Exposures
Wetland Biome Disturbance	Hazardous Ambient Air Contaminant Exposure Risks
Loss of Key Species	Hazardous Food and Water Contaminant Exposure Risks
Arctic Climate Change	Risks from Radioactive Wastes
Ocean Acidification	

It should also be noted that LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

Limitations in Results for Other Parameters

The PCR allows for the results for several inventory flows related to construction products to be reported as “other parameters”. These are aggregated inventory flows, and do not characterize any potential impact; results should be interpreted considering this limitation.

3.12 Type of critical review

This LCA report has been critically reviewed by an external LCA expert not involved with the execution of this study, in conformance with ISO 14044 and ISO 14067, following ISO 14071 and ISO 14064-3[16].

[16] ISO 14064-3:2019 Greenhouse gases —Part 3:Specification with guidance for the verification and validation of greenhouse gas statements

4 Life Cycle Inventory

4.1 Data Requirements

The life cycle inventory (LCI) of each unit process comprises those material and energy inputs, emissions, wastes, and product outputs associated with the operation. Environmental flows from the LCI modeling are used to calculate environmental impacts in the Life Cycle Impact Assessment (LCIA) phase, discussed in Section 5. According to the PCR, processes contributing greater than 1% of the total environmental impact indicator for each impact must be included in the inventory. In the present study, except as noted, all known materials and processes were included in the life cycle inventory.

The study included several key data requirements:

- Functional description of the products, using the requirements of the PCR;
- Material composition of the products and packaging;
- Primary data for manufacturing operations, including energy use and waste generation;
- Representative inventory data for many unit processes, using secondary data from the Ecoinvent life cycle databases, with a prioritization for data with the highest degree of representativeness of the actual material or process;
- Transportation data for materials and estimates of product distribution.

4.2 Primary data

Primary data for the material composition of the products, manufacturing electricity use and waste generation were provided by the manufacturer via completed Data Request Forms (DRFs). The primary data used to model the product systems considered in the assessment are described below.

Product Composition

The product system studied in this LCA included the cradle-to-grave impacts of the flooring products described above and shown in Figure 1. Table 6 summarizes the material components by weight and material for the product and product packaging data. Also presented are the material components as a percent of total mass.

Table 6. Material component summary for the flooring products and packaging by mass in kg/m^2 and as a percentage of total mass. All values in the table have been rounded to three significant figures.

Material	7/16" Flooring		7/16" Flooring with iron film backing		9/16" Flooring	
	kg/m^2	Percent	kg/m^2	Percent	kg/m^2	Percent
Product						
Plywood	6.19	64%	6.19	55%	8.04	78%
Hardwood veneer	1.18	12%	1.18	10%	1.44	14%
Reclaimed veneer	1.31	14%	1.31	12%	0.00	0%
Acrylic	0.659	6.8%	0.659	5.9%	0.513	5%
Adhesive	0.151	1.6%	0.259	2.3%	0.151	1.5%
Finish	0.181	1.9%	0.181	1.6%	0.181	1.8%
Iron film	0.00	0%	1.48	13%	0.00	0%
Total Product	**9.67**	**100%**	**11.3**	**100%**	**10.3**	**100%**
Packaging						
Corrugate	0.342	58%	0.342	58%	0.381	55%
Wood	0.237	40%	0.237	40%	0.288	42%
Plastic	$1.46x10^{-2}$	2.5%	$1.46x10^{-2}$	2.5%	$1.95x10^{-2}$	2.8%
Total Packaging	**0.594**	**100%**	**0.594**	**100%**	**0.688**	**100%**

In conformance with the PCR, product materials were reviewed for the presence of any toxic or hazardous chemicals. Based on a review of the product components provided by the manufacturer, no regulated chemicals were identified in the product or product components.

Manufacturing

The products are manufactured at production facility in Karthaus, PA. The manufacturer provided primary data for their annual production, resource use and elecricity consumption and waste generation at the facility. Electricity consumption is modeled using Ecoinvent datasets for the regional electricity grid resource mix.

Transportation and Distribution

Transportation for the LCA model is based on data provided by the manufacturer for transport from the component manufacturer (1st tier supplier) to the production facility. Transportation data for 2nd tier suppliers (material supplier to component manufacturer) are based on data embedded in the representative LCI datasets. Road transport is assumed to be by diesel truck while sea transport is by ocean freighter. There are no aircraft emissions associated with the product system.

Distribution of the flooring products to the point of sale is included in the model, based on data from the manufacturer. Weighted transport distances were estimate based on the percentage of annual product sales by region across the US. The transport parameters used to model the product system are summarized in Table 7.

Table 7. Product distribution parameters, per functional unit, from manufacturer to point of installation.

Parameter	Unit	7/16" Flooring	7/16" Flooring with iron film backing	9/16" Flooring
Fuel type	-	Diesel	Diesel	Diesel
Liters of fuel	L/100km	18.7	18.7	18.7
Vehicle type	-	Diesel truck	Diesel truck	Diesel truck
Transport distance	km	1,866	1,866	1,866
Capacity utilization	%	76	76	76
Gross density of products transported	kg/m^3	870	1,013	722
Weight of products transported	kg	10.26	11.85	11.00

Product Installation, Use and Maintenance and Replacement

Installation of the product and periodic cleaning are included in the life cycle use phase. The products are installed using hand tools following the manufacturer's recommended guidance. For the current assessment, the impacts associated with the product installation are assumed negligible. The VOC emissions associated with the installation, use and maintenance of the products are negligible.

For installation of the iron film backed flooring products, an underlayment, consisting of magnetic polymer-based sheeting, is provided with the product by the manufacturer.

Impacts associated with the disposal of packaging materials are included in the installation life cycle phase. Table 8 summarizes the relevant parameters for the product installation phase including biogenic carbon emissions and removals, and wastes associated with product packaging.

Table 8. Installation parameters for the flooring products, per 1 m^2.

Parameter	7/16" Flooring	7/16" Flooring with iron film backing	9/16" Flooring
Ancillary materials – underlayment (kg)	-	4.15	-
Net freshwater consumption (m^3)	-	-	-
Electricity consumption (kWh)	-	-	-
Product loss per functional unit (kg)	negligible	negligible	negligible
Waste materials generated by product installation (kg)	negligible	negligible	negligible
Output materials resulting from on-site waste processing (kg)	na	na	na
Direct emissions (kg)	-	-	-
Mass of packaging waste (kg)			
Corrugated	0.342	0.342	0.342
Plastic	$1.46x10^{-2}$	$1.46x10^{-2}$	$1.46x10^{-2}$
Wood	0.237	0.237	0.237
Biogenic carbon in packaging (kg CO_2)	1.06	1.06	1.06
VOC emissions	negligible	negligible	negligible

Routine maintenance required for the product includes regular sweeping and cleaning following the manufacturer's guidance.[17] The product system's use and maintenance life cycle phases were modeled based on the reference service life (RSL) of each of the products. There are no impacts associated with the use of the products, other than product maintenance. The present assessment is based on a moderate traffic level; sensitivity analyses were conducted to evaluate the impacts of different assumptions regarding product maintenance. The parameters used to model the product maintenance are summarized in Table 9 and Table 10.

Table 9. Maintenance guidance for the flooring products.

Cleaning Process	Traffic Level			Energy & Resource Use
	Light - 500 traffics or less daily	Moderate - 500-1,000 traffics daily	Heavy – 1,000-2,500 traffics daily	
Dust mop	Twice or more each week	At least once daily	Daily	None
Hardwood Floor Cleaner	Monthly	Weekly	Daily	Water; neutral cleaning agent

Table 10. Maintenance parameters for the flooring products, per 1 m^2.

Parameter	Unit	Value
Maintenance process	-	Hardwood Floor Cleaning
Maintenance cycle	Cycles/RSL	1,560
Maintenance cycle	Cycles/ESL	3,900
Net freshwater consumption	$m^3/m^2/yr$	0.0058
Hardwood Floor Cleaner	$kg/m^2/yr$	0.119
Further assumptions	-	Moderate traffic

The materials and energy required for replacement of the product over the 75-year ESL of the assessment are included in this stage. The relevant replacement parameters, as specified by the PCR, are summarized Table 11.

Table 11. Product replacement parameters for the flooring products, per 1 m^2.

Parameter	Units	7/16" Flooring	7/16" Flooring with iron film backing	9/16" Flooring
Reference service life	Years	30	30	30
Replacement cycle	-	1.5	1.5	1.5
Energy input	kWh	-	-	-
Freshwater consumption	m^3	-	-	-
Ancillary materials	kg	-	-	-
Replacement parts	kg	15.4	17.8	16.5
Direct emissions	kg	-	-	-

[17] NydreeBonaPrepRecoatRev6.pdf; NydreeUrethaneFinishMaintenanceRev12.pdf

Product Repair, Product Refurbishment and Building Operation

There are no energy or resource use nor impacts associated with product repair (B3), product refurbishment (B5) or building operation (B6-B7) over the 75-year ESL of the assessment.

Product End-of-Life

At end-of-life, the product is assumed to be disposed in a landfill per PCR requirements. Assumptions for end-of-life for the packaging are based on regional statistics regarding municipal solid waste generation and disposal, including end-of-life recycling rates of packaging and product materials. As per the PCR, 10% of the packaging materials are recycled while the remaining materials are landfilled at end-of-life.

Transportation for end-of-life scenarios was modeled assuming a distance of 161 km from the point of product use to a landfill, material recovery center, or waste incinerator as specified by the PCR. Ecoinvent datasets are used to model the impacts associated with incineration and landfilling, which does not include energy recovery from landfill gas. Disposal scenarios for the flooring products are summarized in Table 12.

Table 12. End-of-life disposal scenario parameters for the flooring products.

Parameter	7/16" Flooring	7/16" Flooring with iron film backing	9/16" Flooring
Assumptions for scenario development	100% landfill	100% landfill	100% landfill
Collection process			
Collected with mixed construction waste (kg)	9.67	11.25	10.32
Recovery	n/a	n/a	n/a
Landfill disposal (kg)	9.67	11.25	10.32
Removals of biogenic carbon (kg CO_2 eq)[1]	n/a	n/a	n/a

[1] Excluding packaging materials.

4.3 Secondary data sources

Secondary data are sourced from the Ecoinvent LCI database with a bias towards the most recent and representative data. The specific datasets used for the modeling are summarized below.

4.4 Summary of data sources

Unit processes were developed within the OpenLCA v1.11 LCI model, drawing upon data from multiple sources. Primary data were provided by the manufacturer for their facility operations in addition to supplier locations and transport modes for the product component materials. The principal source of secondary LCI data is the Ecoinvent database. Detailed descriptions of unit processes can be found in the accompanying documentation. The datasets shown in Table 13 are used in the LCA model to represent the manufacture of the flooring products.

Table 13. LCI datasets and associated databases used to model material production and processing.

Component	Dataset	Data Source	Publication Date
PRODUCT			
Hardwood			
Plywood	plywood production | plywood | Cutoff, S/RoW	EI v3.9	2022
Veneer	Veneer - US hardwood veneer - 0.6mm thick slicer technology	EI v3.9	2022
Veneer - Reclaimed	Recycled wood	SCS	2023
Acrylic			
Acrylic copolymer	polymethyl methacrylate production, sheet | polymethyl methacrylate, sheet | Cutoff, S/RoW	EI v3.9	2022
Adhesives			
Laminating adhesive	polyurethane adhesive production | polyurethane adhesive | Cutoff, S/GLO	EI v3.9	2022
Iron film			
Ferrite	market for ferrite | ferrite | Cutoff, S/GLO	EI v3.9	2022
PET	polyethylene terephthalate production, granulate, amorphous | polyethylene terephthalate, granulate, amorphous | Cutoff, S/RoW	EI v3.9	2022
Other			
Coatings	chemical production, organic | chemical, organic | Cutoff, S/GLO	EI v3.9	2022
PACKAGING			
Cardboard	containerboard production, linerboard, testliner | containerboard, linerboard | Cutoff, S/RoW	EI v3.9	2022
Plastic	packaging film production, low density polyethylene | packaging film, low density polyethylene | Cutoff, S/RoW	EI v3.9	2022
Wood	EUR-flat pallet production | EUR-flat pallet | Cutoff, S/RoW	EI v3.9	2022
INSTALLATION			
Underlayment			
Magnetic underlayment	acrylic dispersion production, with water, in 58% solution | acrylic dispersion, with water, in 58% solution state | Cutoff, S/RoW	EI v3.9	2022
	chemical production, organic | chemical, organic | Cutoff, S/GLO	EI v3.9	2022
	market for sponge iron | sponge iron | Cutoff, S/GLO	EI v3.9	2022
	polyethylene terephthalate production, granulate, amorphous | polyethylene terephthalate, granulate, amorphous | Cutoff, S/RoW	EI v3.9	2022
TRANSPORT			
Road transport	transport, freight, lorry 16-32 metric ton, EURO4 | transport, freight, lorry 16-32 metric ton, EURO4 | Cutoff, S/RoW	EI v3.9	2022
Ship transport	transport, freight, sea, container ship | transport, freight, sea, container ship | Cutoff, S/GLO	EI v3.9	2022
RESOURCES			
Grid electricity	Electricity, medium voltage, per kWh - RFCE/RFCE	eGRID 2021; EI v3.9	2022
Heat - biomass	heat production, wood chips from industry, at furnace 50kW | heat, central or small-scale, other than natural gas | Cutoff, S/RoW	EI v3.9	2022

4.5 Data Quality Assessment

The data quality assessment addresses the following parameters: time-related coverage, geographical coverage, technological coverage, precision, completeness, representativeness, consistency, reproducibility, sources of data, and uncertainty.

Data Quality Parameter	Data Quality Discussion
Time-Related Coverage: Age of data and the minimum length of time over which data is collected	The most recent available data are used, based on other considerations such as data quality and similarity to the actual operations. Typically, these data are less than 5 years old. All of the data used represented an average of at least one year's worth of data collection, and up to three years in some cases. Manufacturer-supplied data (primary data) are based on annual production 2022.
Geographical Coverage: Geographical area from which data for unit processes is collected to satisfy the goal of the study	The data used in the analysis provide the best possible representation available with current data. Electricity use for product manufacture is modeled using representative data for regional power mixes from the Ecoinvent LCI database. Surrogate data used in the assessment are representative of global or North American operations. Data representative of global operations are considered sufficiently similar to actual processes. Data representing product and packaging disposal are based on regional statistics.
Technology Coverage: Specific technology or technology mix	For the most part, data are representative of the actual technologies used for processing, transportation, and manufacturing operations. Representative datasets, specific to the type of material, are used to represent the actual processes, as appropriate.
Precision: Measure of the variability of the data values for each data expressed	Precision of results are not quantified due to a lack of data. Data collected for operations were typically averaged for one or more years and over multiple operations, which is expected to reduce the variability of results.
Completeness: Percentage of flow that is measured or estimated	The LCA model included all known mass and energy flows for production of the flooring products. In some instances, surrogate data used to represent upstream and downstream operations may be missing some data which is propagated in the model. No known processes or activities contributing to more than 1% of the total environmental impact for each indicator are excluded.
Representativeness: Qualitative assessment of the degree to which the data set reflects the true population of interest	Data used in the assessment represent typical or average processes as currently reported from multiple data sources and are therefore generally representative of the range of actual processes and technologies for production of these materials. Considerable deviation may exist among actual processes on a site-specific basis; however, such a determination would require detailed data collection throughout the supply chain back to resource extraction.
Consistency: Qualitative assessment of whether the study methodology is applied uniformly to the various components of the analysis	The consistency of the assessment is considered to be high. Data sources of similar quality and age are used; with a bias towards Ecoinvent v3.9 data where available. Different portions of the product life cycle are equally considered.
Reproducibility: Qualitative assessment of the extent to which information about the methodology and data values would allow an independent practitioner to reproduce the results reported in the study	Based on the description of data and assumptions used, this assessment would be reproducible by other practitioners. All assumptions, models, and data sources are documented.
Sources of the Data: Description of all primary and secondary data sources	Data representing energy use at manufacturing facility represent an annual average and are considered of high quality due to the length of time over which these data are collected, as compared to a snapshot that may not accurately reflect fluctuations in production. For secondary LCI data, Ecoinvent v3.9 LCI data are used.
Uncertainty of the Information: Uncertainty related to data, models, and assumptions	Uncertainty related to materials in the products and packaging is low. Actual supplier data for all upstream operations were not available and the study relied upon the use of existing representative datasets. These datasets contained relatively recent data (<10 years) but lacked geographical representativeness. Uncertainty related to the impact assessment methods used in the study are high. The impact assessment method required by the PCR includes impact potentials, which lack characterization of providing and receiving environments or tipping points.

4.6 Life cycle inventory results

Environmental flows from the LCI modeling are used to calculate environmental impacts in the Life Cycle Impact Assessment (LCIA) phase, discussed in Section 5.

The resource use and emissions from each step of the product life cycle are summed to obtain the life cycle inventory results. The LCIA and inventory flow results were calculated using the OpenLCA model and summarized for the functional unit from cradle-to-grave. Where necessary, the lower heating value is used for energy flow calculations. Table 14 summarizes the nomenclature and reporting units for the additional inventory parameters (energy and waste flows), as specified in the PCR, while Table 15 through Table 17 present these results according to the life cycle module definitions summarized in Table 3 (Section 3.3).

Life cycle inventory results were reviewed for completeness, consistency and representativeness. Overall, with respect to those impact categories assessed, the inventory was considered consistent and generally representative of the system processes as the same types of data sources are used throughout, primarily from the manufacturer, as well as the Ecoinvent life cycle inventory database. As noted previously, all known processes and materials of the product system are included in the inventory.

Table 14. Nomenclature and reporting units for resource use and waste flows for the flooring products.

Parameter	Units
RESOURCES	
Renewable primary resources used as energy carrier (RPR_E)	MJ, LHV
Renewable primary resources used as material (RPR_M)	MJ, LHV
Non-renewable primary resources used as an energy carrier ($NRPR_E$)	MJ, LHV
Non-renewable primary resources used as material ($NRPR_M$)	MJ, LHV
Secondary materials (SM)	MJ, LHV
Renewable secondary fuels (RSF)	MJ, LHV
Non-renewable secondary fuels (NRSF)	MJ, LHV
Recovered energy (RE)	MJ, LHV
Use of net freshwater resources (FW)	m^3
WASTES	
Non-hazardous waste disposed (NHWD)	kg
Hazardous waste disposed (NWD)	kg
High-level radioactive waste (HLRW)	kg
Intermediate- and low-level radioactive waste (ILLRW)	kg
Components for re-use (CRU)	kg
Materials for recycling (MR)	kg
Materials for energy recovery (MER)	kg
Recovered energy exported from the product system (EE)	MJ

INA = Indicator not assessed | Neg. = Negligible

Table 15. Resource use and waste flows for the flooring products over a 75-yr time horizon. Results reported in MJ are calculated using lower heating values. All values are rounded to three significant digits.
(**7/16" Acrylic Infused Hardwood Flooring)**

Parameter	A1	A2	A3	A4	A5	B2	B4	C2	C4
Resources									
RPR_E (MJ)	621	0.318	75.5	0.658	$1.43x10^{-2}$	2.46	1,080	0.110	$5.70x10^{-2}$
	35%	0.018%	4.2%	0.037%	0.0008%	0.14%	61%	0.0062%	0.0032%
RPR_M (MJ)	23.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	100%	0%	0%	0%	0%	0%	0%	0%	0%
$NRPR_E$ (MJ)	INA	INA	INA	INA	INA	INA	INA	INA	INA
$NRPR_M$ (MJ)	INA	INA	INA	INA	INA	INA	INA	INA	INA
SM (kg)	1.31	0.00	0.00	0.00	0.00	0.00	1.97	0.00	0.00
	40%	0%	0%	0%	0%	0%	60%	0%	0%
RSF/NRSF (MJ)	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
RE (MJ)	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
FW (m^3)	1.08	$1.89x10^{-2}$	1.31	$3.95x10^{-2}$	$9.70x10^{-4}$	0.647	3.69	$9.96x10^{-3}$	$3.15x10^{-3}$
	16%	0.28%	19%	0.58%	0.014%	9.5%	54%	0.15%	0.046%
Wastes									
HWD (kg)	$4.16x10^{-4}$	$1.74x10^{-4}$	$5.85x10^{-4}$	$3.34x10^{-4}$	$1.24x10^{-5}$	$5.76x10^{-5}$	$2.59x10^{-3}$	$1.90x10^{-4}$	$1.32x10^{-5}$
	9.5%	4%	13%	7.7%	0.28%	1.3%	59%	4.3%	0.3%
NHWD (kg)	1.36	0.993	11.6	2.51	0.545	0.247	40.2	0.141	9.69
	2%	1.5%	17%	3.7%	0.81%	0.37%	60%	0.21%	14%
HLRW (kg)	$9.12x10^{-5}$	$1.49x10^{-6}$	$2.85x10^{-4}$	$3.09x10^{-6}$	$7.74x10^{-8}$	$9.56x10^{-6}$	$5.73x10^{-4}$	$6.06x10^{-7}$	$2.97x10^{-7}$
	9.5%	0.15%	30%	0.32%	0.008%	0.99%	59%	0.063%	0.031%
ILLRW (kg)	$3.23x10^{-4}$	$3.54x10^{-6}$	$1.44x10^{-3}$	$7.36x10^{-6}$	$1.90x10^{-7}$	$2.22x10^{-5}$	$2.66x10^{-3}$	$1.43x10^{-6}$	$7.53x10^{-7}$
	7.3%	0.08%	32%	0.17%	0.0043%	0.5%	60%	0.032%	0.017%
CRU (kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR (kg)	0.00	0.00	0.00	0.00	$5.94x10^{-2}$	0.00	$8.91x10^{-2}$	0.00	0.00
	0%	0%	0%	0%	40%	0%	60%	0%	0%
MER (kg)	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
EE (MJ)	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.

INA = Indicator not assessed | Neg. = Negligible

Table 16. Resource use and waste flows for the flooring products over a 75-yr time horizon. Results reported in MJ are calculated using lower heating values. All values are rounded to three significant digits.
(**7/16" Acrylic Infused Hardwood Flooring - with iron film backing)**

Parameter	A1	A2	A3	A4	A5	B2	B4	C2	C4
Resources									
RPR_E (MJ)	626	0.605	75.5	0.760	4.79	2.46	1,100	0.128	$8.26x10^{-2}$
	35%	0.033%	4.2%	0.042%	0.27%	0.14%	61%	0.0071%	0.0046%
RPR_M (MJ)	23.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	100%	0%	0%	0%	0%	0%	0%	0%	0%
$NRPR_E$ (MJ)	INA	INA	INA	INA	INA	INA	INA	INA	INA
$NRPR_M$ (MJ)	INA	INA	INA	INA	INA	INA	INA	INA	INA
SM (kg)	1.31	0.00	0.00	0.00	0.00	0.00	1.97	0.00	0.00
	40%	0%	0%	0%	0%	0%	60%	0%	0%
RSF/NRSF (MJ)	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
RE (MJ)	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
FW (m^3)	1.40	$3.60x10^{-2}$	1.31	$4.56x10^{-2}$	0.325	0.647	4.70	$1.16x10^{-2}$	$4.37x10^{-3}$
	17%	0.43%	15%	0.54%	3.8%	7.6%	55%	0.14%	0.052%
Wastes									
HWD (kg)	$7.70x10^{-4}$	$3.26x10^{-4}$	$5.86x10^{-4}$	$3.86x10^{-4}$	$2.82x10^{-4}$	$5.76x10^{-5}$	$3.88x10^{-3}$	$2.21x10^{-4}$	$1.65x10^{-5}$
	12%	5%	9%	5.9%	4.3%	0.88%	59%	3.4%	0.25%
NHWD (kg)	2.08	1.96	12.1	2.90	3.93	0.247	51.6	0.165	11.3
	2.4%	2.3%	14%	3.4%	4.5%	0.29%	60%	0.19%	13%
HLRW (kg)	$1.12x10^{-4}$	$2.82x10^{-6}$	$2.85x10^{-4}$	$3.57x10^{-6}$	$2.13x10^{-5}$	$9.56x10^{-6}$	$6.39x10^{-4}$	$7.06x10^{-7}$	$4.35x10^{-7}$
	10%	0.26%	27%	0.33%	2%	0.89%	59%	0.066%	0.041%
ILLRW (kg)	$3.71x10^{-4}$	$6.74x10^{-6}$	$1.44x10^{-3}$	$8.49x10^{-6}$	$4.39x10^{-5}$	$2.22x10^{-5}$	$2.80x10^{-3}$	$1.67x10^{-6}$	$1.10x10^{-6}$
	7.9%	0.14%	31%	0.18%	0.93%	0.47%	60%	0.036%	0.024%
CRU (kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR (kg)	0.00	0.00	0.00	0.00	$5.94x10^{-2}$	0.00	$8.91x10^{-2}$	0.00	0.00
	0%	0%	0%	0%	40%	0%	60%	0%	0%
MER (kg)	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
EE (MJ)	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.

INA = Indicator not assessed | Neg. = Negligible

Table 17. Resource use and waste flows for the flooring products over a 75-yr time horizon. Results reported in MJ are calculated using lower heating values. All values are rounded to three significant digits.
(**9/16" Acrylic Infused Hardwood Flooring)**

Parameter	A1	A2	A3	A4	A5	B2	B4	C2	C4
Resources									
RPR_E (MJ)	707	0.263	77.8	0.706	$1.64x10^{-2}$	2.46	1,220	0.118	$5.83x10^{-2}$
	35%	0.013%	3.9%	0.035%	0.00081%	0.12%	61%	0.0059%	0.0029%
RPR_M (MJ)	28.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	100%	0%	0%	0%	0%	0%	0%	0%	0%
$NRPR_E$ (MJ)	INA	INA	INA	INA	INA	INA	INA	INA	INA
$NRPR_M$ (MJ)	INA	INA	INA	INA	INA	INA	INA	INA	INA
SM (kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0%	0%	0%	0%	0%	0%	0%	0%	0%
RSF/NRSF (MJ)	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
RE (MJ)	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
FW (m^3)	1.22	$1.56x10^{-2}$	1.31	$4.23x10^{-2}$	$1.11x10^{-3}$	0.647	3.90	$1.06x10^{-2}$	$3.26x10^{-3}$
	17%	0.22%	18%	0.59%	0.016%	9.1%	55%	0.15%	0.046%
Wastes									
HWD (kg)	$4.91x10^{-4}$	$1.47x10^{-4}$	$5.80x10^{-4}$	$3.58x10^{-4}$	$1.44x10^{-5}$	$5.76x10^{-5}$	$2.71x10^{-3}$	$2.02x10^{-4}$	$1.39x10^{-5}$
	11%	3.2%	13%	7.8%	0.31%	1.3%	59%	4.4%	0.3%
NHWD (kg)	1.54	0.762	8.14	2.69	0.631	0.247	36.4	0.151	10.3
	2.5%	1.3%	13%	4.4%	1%	0.41%	60%	0.25%	17%
HLRW (kg)	$1.02x10^{-4}$	$1.22x10^{-6}$	$2.85x10^{-4}$	$3.31x10^{-6}$	$8.84x10^{-8}$	$9.56x10^{-6}$	$5.89x10^{-4}$	$6.47x10^{-7}$	$3.04x10^{-7}$
	10%	0.12%	29%	0.33%	0.0089%	0.97%	59%	0.065%	0.031%
ILLRW (kg)	$3.46x10^{-4}$	$2.92x10^{-6}$	$1.44x10^{-3}$	$7.89x10^{-6}$	$2.17x10^{-7}$	$2.22x10^{-5}$	$2.69x10^{-3}$	$1.53x10^{-6}$	$7.69x10^{-7}$
	7.7%	0.065%	32%	0.17%	0.0048%	0.49%	60%	0.034%	0.017%
CRU (kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR (kg)	0.00	0.00	0.00	0.00	$6.88x10^{-2}$	0.00	0.103	0.00	0.00
	0%	0%	0%	0%	40%	0%	60%	0%	0%
MER (kg)	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
EE (MJ)	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.

INA = Indicator not assessed | Neg. = Negligible

5 Life Cycle Impact Assessment

5.1 General approach

LCIA Methodology

From the LCI data, impact assessment results are calculated. The choice of methods and indicators used in the assessment are based on the requirements of the PCR. It should be noted that the LCIA results presented below are relative expressions and do not predict impacts on category endpoints, exceedance of thresholds, safety margins, or risks associated with the product system. Furthermore, the environmental relevance of LCIA results are not affected by LCI functional unit calculation, system wide averaging, aggregation and allocation.

Indicator calculations

Impact category indicators are estimated using TRACI 2.1 and CML-IA characterization methods, as described above (Section 3.10). Both CML-IA and TRACI 2.1 are midpoint oriented LCIA methodologies which estimate potential environmental impacts.

It should be noted that the indicators prescribed by the PCR do not represent all categories of potential environmental and human health impact associated with the life cycle of the flooring products, and this represents a general limitation of the LCA study. Additionally, these indicators have no "environmental relevance," as defined in the ISO-14044 §4.4.2.2.2, 4.4.2.2.4, and 4.4.5, with the exception of the "Potential for Global Warming" indicator, which has low environmental relevance. That is, these "potential" results may or may not have any relationship to actual impacts occurring.

5.2 LCIA results

Category impact indicators are estimated and summarized by life cycle stage for the Nydree Flooring products using the TRACI and CML characterization methodologies below. Table 18 summarizes the nomenclature and reporting units for the impact indicator results.

Table 18. Nomenclature and reporting units for the LCA impact indicator results for the flooring products.

Impact Category	Units
CML	
Global warming potential (GWP)	kg CO_2 eq
Acidification potential (AP)	kg SO_2 eq
Eutrophication potential (EP)	kg $(PO_4)^{3-}$ eq
Photochemical oxidation creation potential (POCP)	kg C_2H_4 eq
Ozone layer depletion potential (ODP)	kg CFC-11 eq
Abiotic depletion potential (fossil fuels) (ADPF)	MJ eq
TRACI	
Global warming potential (GWP)	kg CO_2 eq
Acidification potential (AP)	kg SO_2 eq
Eutrophication potential (EP)	kg N eq
Smog formation potential (SFP)	kg O_3 eq
Ozone layer depletion potential (ODP)	kg CFC-11 eq
Fossil fuel depletion potential (FFD)	MJ, surplus

Contribution analysis

Life cycle modeling of the products was divided into distinct life cycle phases, including raw material extraction and processing, product manufacturing, delivery and installation, product use and maintenance, and disposal. A detailed examination of the potential environmental impacts provides some insight into the relative contributions from each of the product's life cycle phases.

The following life cycle phases were included in the contribution analysis:

- *Raw Materials and Processing (Sourcing/Extraction) stage (A1)* – This stage includes extraction of virgin materials and reclamation of non-virgin feedstock. This includes the extraction of all raw materials, including the transport to the manufacturing site. Resource use and emissions associated with both extraction of the raw materials and raw material processing are included.
- *Transport stage (A2)* –The impacts associated with the transport of the processed raw materials to the manufacturing facility are included in this stage.
- *Manufacturing stage (A3)* – This stage includes all the relevant manufacturing processes and flows, including the impacts from energy use and emissions at the manufacturing facility. Production of capital goods, infrastructure, manufacturing equipment, and personnel-related activities are not included. This stage also includes the production of the product packaging materials.
- *Delivery and Installation stage (A4 - A5)* – This stage includes delivery of the product to the point of installation (downstream transportation), and installation of the products. The impacts associated with packaging disposal are also included with the installation phase (*A5*) as per PCR requirements.

- *Use stage (B1)* – The use stage includes product use over the specified time period. There are no impacts associated with use of the product and the results for this phase are reported as zero.
- *Maintenance stage (B2)* – The maintenance stage includes the cleaning and maintenance of the product during the product's RSL, as well as extraction, manufacturing and transport of all sundry material for maintenance and cleaning.
- *Repair stage (B3)* – Repair of the product is not relevant during the lifetime of the product; results for this stage are reported as zero.
- *Replacement stage (B4)* – The materials and energy required for replacement of the product over the 75-year ESL of the assessment are included in this stage.
- *Refurbishment stage (B5)* – Product refurbishment is not relevant during the lifetime of the product; results for this stage are reported as zero.
- *Building operation stage (B6 – B7)* – There is no operational energy or water use associated with the use of the product and the results for these stages are zero.
- *Disposal stage (C1 - C4)* **–** The end-of-life stage includes demolition of the products (*C*1), transport of the products to waste treatment facilities (*C2*), waste processing (*C3*) and associated emissions as the product degrades in a landfill or is burned in an incinerator (*C4*). For the products, no emissions are generated during demolition while no waste processing is required for incineration or landfill disposal. Results for these stages (*C1 & C3*) are reported as zero for the product system.

The life cycle stages included in the system boundary for the flooring products are summarized below.

Product			Construction Process		Use							End-of-life				Benefits and loads beyond the system boundary
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Raw material extraction and processing	Transport to manufacturer	Manufacturing	Transport	Construction - installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction demolition	Transport	Waste processing	Disposal	Reuse, recovery and/or recycling potential
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	MND

X = Included in system boundary
MND = Module not declared

Category indicator results for the flooring products are summarized by life cycle phase in Table 19 through Table 21. Modules B1, B3, B5, B6, and B7 are not associated with any impact and are therefore declared as zero. In addition, module C1 and C3 are likewise not associated with any impact as the products are expected to be manually deconstructed. As the flooring products do not contain significant amounts of bio-based materials, biogenic carbon emissions and removals are not declared. Module D is not declared. In the interest of space and table readability, these modules are not included in the results presented below.

The CML impact indicators are displayed graphically by life cycle phase in Figure 3 for the flooring products. Results are shown for a 75-year time horizon from cradle-to-grave, excluding product replacements. The contributions to total impact indicator results are dominated by the product replacement phase of the assessment. With few exceptions, of the remaining life cycle phases, the product maintenance phase is the highest contributor followed by raw material extraction and processing, product manufacture and downstream processes.

Table 19. Life Cycle Impact Assessment results for the flooring products over a 75-yr time horizon. Results reported in MJ are calculated using lower heating values. All values are rounded to three significant digits.
(7/16" Acrylic Infused Hardwood Flooring)

Impact Category	A1	A2	A3	A4	A5	B2	B4	C2	C4
CML									
GWP (kg CO_2 eq)	23.9	2.14	16.9	3.63	0.623	3.56	76.0	2.14	1.29
	18%	1.6%	13%	2.8%	0.48%	2.7%	58%	1.6%	0.99%
AP (kg SO_2 eq)	0.130	$2.23x10^{-2}$	$4.66x10^{-2}$	$1.20x10^{-2}$	$5.99x10^{-4}$	$1.47x10^{-2}$	0.331	$8.47x10^{-3}$	$6.89x10^{-4}$
	23%	3.9%	8.2%	2.1%	0.11%	2.6%	58%	1.5%	0.12%
EP (kg $(PO_4)^{3-}$ eq)	$3.31x10^{-2}$	$3.14x10^{-3}$	$4.10x10^{-2}$	$3.04x10^{-3}$	$1.57x10^{-3}$	$3.76x10^{-3}$	0.163	$1.92x10^{-3}$	$2.52x10^{-2}$
	12%	1.1%	15%	1.1%	0.57%	1.4%	59%	0.69%	9.1%
POCP (kg C_2H_4 eq)	$1.04x10^{-2}$	$7.02x10^{-4}$	$5.58x10^{-3}$	$5.80x10^{-4}$	$1.29x10^{-4}$	$8.67x10^{-4}$	$2.71x10^{-2}$	$3.68x10^{-4}$	$2.83x10^{-4}$
	23%	1.5%	12%	1.3%	0.28%	1.9%	59%	0.8%	0.62%
ODP (kg CFC-11 eq)	$1.74x10^{-6}$	$2.78x10^{-8}$	$2.02x10^{-7}$	$4.82x10^{-8}$	$1.80x10^{-9}$	$1.78x10^{-8}$	$3.08x10^{-6}$	$2.70x10^{-8}$	$2.28x10^{-9}$
	34%	0.54%	3.9%	0.93%	0.035%	0.35%	60%	0.52%	0.044%
ADPF (MJ eq)	327	28.7	146	51.0	1.87	89.2	878	27.8	2.49
	21%	1.8%	9.4%	3.3%	0.12%	5.7%	57%	1.8%	0.16%
TRACI 2.1									
GWP (kg CO_2 eq)	23.5	2.13	15.6	3.61	0.523	3.51	72.8	2.13	1.05
	19%	1.7%	12%	2.9%	0.42%	2.8%	58%	1.7%	0.84%
AP (kg SO_2 eq)	0.138	$2.43x10^{-2}$	$5.31x10^{-2}$	$1.44x10^{-2}$	$7.66x10^{-4}$	$1.50x10^{-2}$	0.363	$1.08x10^{-2}$	$8.37x10^{-4}$
	22%	3.9%	8.6%	2.3%	0.12%	2.4%	59%	1.7%	0.13%
EP (kg N eq)	$5.54x10^{-2}$	$2.22x10^{-3}$	$9.00x10^{-2}$	$3.41x10^{-3}$	$4.01x10^{-3}$	$6.93x10^{-3}$	0.338	$1.13x10^{-3}$	$6.95x10^{-2}$
	9.7%	0.39%	16%	0.6%	0.7%	1.2%	59%	0.2%	12%
SFP (kg O_3 eq)	2.37	0.489	1.13	0.363	$2.11x10^{-2}$	0.185	7.07	0.322	$1.96x10^{-2}$
	20%	4.1%	9.4%	3%	0.18%	1.5%	59%	2.7%	0.16%
ODP (kg CFC-11 eq)	$1.86x10^{-6}$	$3.66x10^{-8}$	$2.74x10^{-7}$	$6.35x10^{-8}$	$2.40x10^{-9}$	$2.66x10^{-8}$	$3.42x10^{-6}$	$3.59x10^{-8}$	$3.08x10^{-9}$
	33%	0.64%	4.8%	1.1%	0.042%	0.47%	60%	0.63%	0.054%
FFD (MJ eq)	41.1	4.14	19.7	7.25	0.279	12.2	116	4.20	0.347
	20%	2%	9.6%	3.5%	0.14%	6%	56%	2.1%	0.17%

Table 20. Life Cycle Impact Assessment results for the flooring products over a 75-yr time horizon. Results reported in MJ are calculated using lower heating values. All values are rounded to three significant digits.
(7/16" Acrylic Infused Hardwood Flooring - with iron film backing)

Impact Category	A1	A2	A3	A4	A5	B2	B4	C2	C4
CML									
GWP (kg CO_2 eq)	30.7	3.93	17.3	4.20	10.7	3.56	107	2.50	2.29
	17%	2.2%	9.5%	2.3%	5.9%	2%	59%	1.4%	1.3%
AP (kg SO_2 eq)	0.155	$3.65x10^{-2}$	$4.66x10^{-2}$	$1.39x10^{-2}$	$3.40x10^{-2}$	$1.47x10^{-2}$	0.446	$9.87x10^{-3}$	$9.05x10^{-4}$
	21%	4.8%	6.2%	1.8%	4.5%	1.9%	59%	1.3%	0.12%
EP (kg $(PO_4)^{3-}$ eq)	$4.03x10^{-2}$	$5.38x10^{-3}$	$4.23x10^{-2}$	$3.51x10^{-3}$	$2.14x10^{-2}$	$3.76x10^{-3}$	0.217	$2.23x10^{-3}$	$2.93x10^{-2}$
	11%	1.5%	12%	0.96%	5.9%	1%	59%	0.61%	8%
POCP (kg C_2H_4 eq)	$1.23x10^{-2}$	$1.19x10^{-3}$	$5.65x10^{-3}$	$6.69x10^{-4}$	$2.55x10^{-3}$	$8.67x10^{-4}$	$3.49x10^{-2}$	$4.28x10^{-4}$	$4.99x10^{-4}$
	21%	2%	9.6%	1.1%	4.3%	1.5%	59%	0.73%	0.84%
ODP (kg CFC-11 eq)	$2.07x10^{-5}$	$5.12x10^{-8}$	$2.02x10^{-7}$	$5.56x10^{-8}$	$8.42x10^{-6}$	$1.78x10^{-8}$	$4.41x10^{-5}$	$3.15x10^{-8}$	$2.76x10^{-9}$
	28%	0.07%	0.28%	0.076%	11%	0.024%	60%	0.043%	0.0038%
ADPF (MJ eq)	468	53.1	146	58.9	136	89.2	1,350	32.4	3.01
	20%	2.3%	6.3%	2.5%	5.8%	3.8%	58%	1.4%	0.13%
TRACI 2.1									
GWP (kg CO_2 eq)	30.2	3.90	15.9	4.16	10.5	3.51	103	2.48	1.86
	17%	2.2%	9%	2.4%	6%	2%	59%	1.4%	1.1%
AP (kg SO_2 eq)	0.164	$4.00x10^{-2}$	$5.32x10^{-2}$	$1.66x10^{-2}$	$3.50x10^{-2}$	$1.50x10^{-2}$	0.484	$1.25x10^{-2}$	$1.11x10^{-3}$
	20%	4.9%	6.5%	2%	4.3%	1.8%	59%	1.5%	0.14%
EP (kg N eq)	$6.90x10^{-2}$	$4.02x10^{-3}$	$9.36x10^{-2}$	$3.94x10^{-3}$	$4.88x10^{-2}$	$6.93x10^{-3}$	0.452	$1.31x10^{-3}$	$8.03x10^{-2}$
	9.1%	0.53%	12%	0.52%	6.4%	0.91%	59%	0.17%	11%
SFP (kg O_3 eq)	2.72	0.819	1.13	0.419	0.465	0.185	8.93	0.374	$2.38x10^{-2}$
	18%	5.4%	7.5%	2.8%	3.1%	1.2%	59%	2.5%	0.16%
ODP (kg CFC-11 eq)	$2.72x10^{-5}$	$6.74x10^{-8}$	$2.75x10^{-7}$	$7.33x10^{-8}$	$1.13x10^{-5}$	$2.66x10^{-8}$	$5.85x10^{-5}$	$4.18x10^{-8}$	$3.74x10^{-9}$
	28%	0.069%	0.28%	0.075%	12%	0.027%	60%	0.043%	0.0038%
FFD (MJ eq)	60.5	7.64	19.8	8.37	13.3	12.2	172	4.89	0.411
	20%	2.6%	6.6%	2.8%	4.5%	4.1%	58%	1.6%	0.14%

Table 21. Life Cycle Impact Assessment results for the flooring products over a 75-yr time horizon. Results reported in MJ are calculated using lower heating values. All values are rounded to three significant digits.
(9/16" Acrylic Infused Hardwood Flooring)

Impact Category	A1	A2	A3	A4	A5	B2	B4	C2	C4
CML									
GWP (kg CO_2 eq)	23.1	1.87	14.8	3.90	0.701	3.56	71.9	2.29	1.26
	19%	1.5%	12%	3.2%	0.57%	2.9%	58%	1.9%	1%
AP (kg SO_2 eq)	0.128	$2.26x10^{-2}$	$4.64x10^{-2}$	$1.29x10^{-2}$	$6.92x10^{-4}$	$1.47x10^{-2}$	0.331	$9.04x10^{-3}$	$7.20x10^{-4}$
	23%	4%	8.2%	2.3%	0.12%	2.6%	58%	1.6%	0.13%
EP (kg $(PO_4)^{3-}$ eq)	$3.63x10^{-2}$	$3.03x10^{-3}$	$3.23x10^{-2}$	$3.26x10^{-3}$	$1.83x10^{-3}$	$3.76x10^{-3}$	0.159	$2.04x10^{-3}$	$2.69x10^{-2}$
	14%	1.1%	12%	1.2%	0.68%	1.4%	59%	0.76%	10%
POCP (kg C_2H_4 eq)	$1.09x10^{-2}$	$6.89x10^{-4}$	$5.14x10^{-3}$	$6.22x10^{-4}$	$1.45x10^{-4}$	$8.67x10^{-4}$	$2.73x10^{-2}$	$3.92x10^{-4}$	$2.77x10^{-4}$
	24%	1.5%	11%	1.3%	0.31%	1.9%	59%	0.85%	0.6%
ODP (kg CFC-11 eq)	$1.76x10^{-6}$	$2.41x10^{-8}$	$2.02x10^{-7}$	$5.16x10^{-8}$	$2.09x10^{-9}$	$1.78x10^{-8}$	$3.11x10^{-6}$	$2.88x10^{-8}$	$2.42x10^{-9}$
	34%	0.46%	3.9%	0.99%	0.04%	0.34%	60%	0.55%	0.047%
ADPF (MJ eq)	313	24.7	146	54.7	2.17	89.2	860	29.7	2.65
	21%	1.6%	9.6%	3.6%	0.14%	5.9%	56%	2%	0.17%
TRACI 2.1									
GWP (kg CO_2 eq)	22.8	1.85	13.9	3.87	0.590	3.51	69.4	2.27	1.03
	19%	1.6%	12%	3.2%	0.49%	2.9%	58%	1.9%	0.86%
AP (kg SO_2 eq)	0.139	$2.45x10^{-2}$	$5.28x10^{-2}$	$1.54x10^{-2}$	$8.85x10^{-4}$	$1.50x10^{-2}$	0.368	$1.15x10^{-2}$	$8.73x10^{-4}$
	22%	3.9%	8.4%	2.5%	0.14%	2.4%	59%	1.8%	0.14%
EP (kg N eq)	$6.02x10^{-2}$	$1.98x10^{-3}$	$6.70x10^{-2}$	$3.66x10^{-3}$	$4.66x10^{-3}$	$6.93x10^{-3}$	0.319	$1.20x10^{-3}$	$7.43x10^{-2}$
	11%	0.37%	12%	0.68%	0.86%	1.3%	59%	0.22%	14%
SFP (kg O_3 eq)	2.58	0.484	1.13	0.389	$2.44x10^{-2}$	0.185	7.45	0.343	$2.07x10^{-2}$
	20%	3.8%	8.9%	3.1%	0.19%	1.5%	59%	2.7%	0.16%
ODP (kg CFC-11 eq)	$1.89x10^{-6}$	$3.17x10^{-8}$	$2.74x10^{-7}$	$6.81x10^{-8}$	$2.78x10^{-9}$	$2.66x10^{-8}$	$3.46x10^{-6}$	$3.83x10^{-8}$	$3.26x10^{-9}$
	33%	0.55%	4.7%	1.2%	0.048%	0.46%	60%	0.66%	0.056%
FFD (MJ eq)	37.5	3.58	19.7	7.77	0.323	12.2	111	4.48	0.369
	19%	1.8%	10%	4%	0.16%	6.2%	56%	2.3%	0.19%

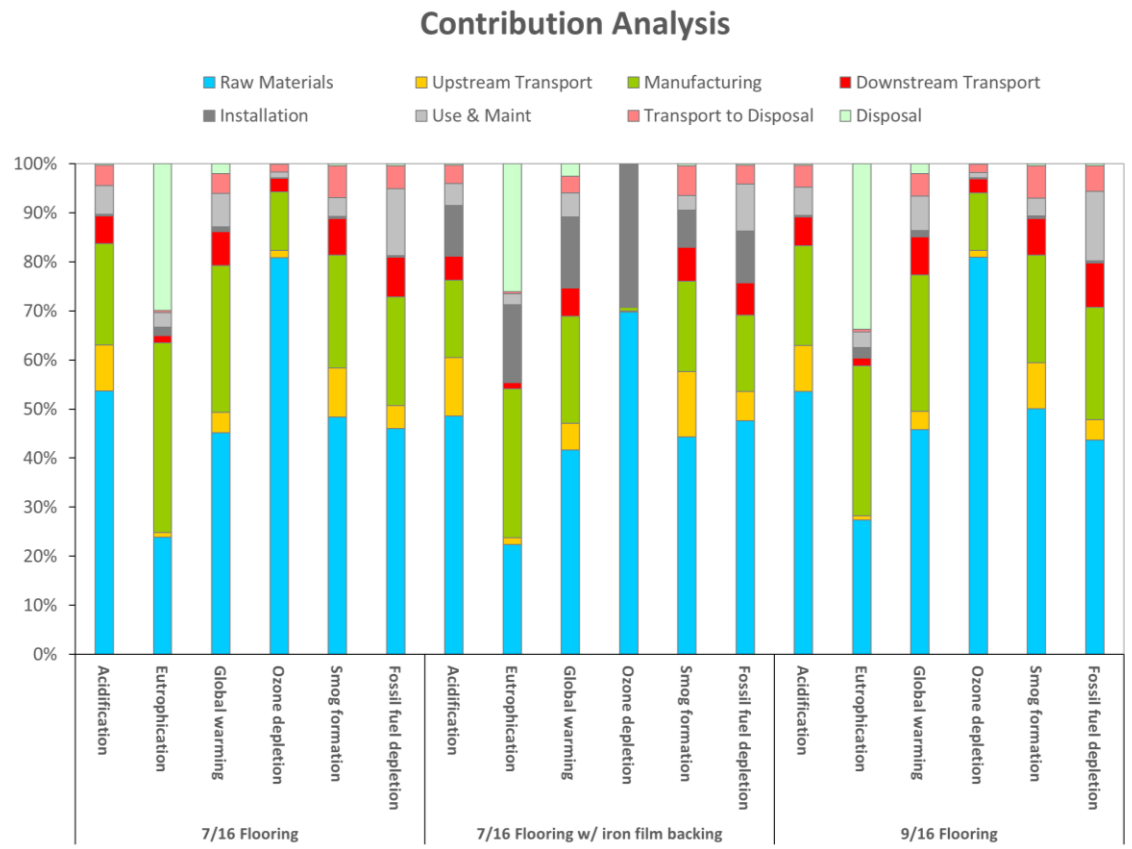

Figure 3. Contribution analysis for the Nydree Flooring products – TRACI 2.1 Method (excluding product replacements).

Global Warming Potential Results

Global Warming Potential results for the Nydree Flooring products are presented below. Results are presented for cradle-to-grave, cradle-to-gate and gate-to-gate in units of kg CO_2e per declared unit.

Table 22. Global warming potential results for the Nydree products per square meter of flooring.

Product	GWP 100 (AR6) kg CO_2e/m^2		
	Cradle-to-Gate	Gate-to-Gate	Cradle-to-Grave
7/16" Flooring	43.0	16.8	130
7/16" Flooring with iron film backing	52.0	17.1	183
9/16" Flooring	39.9	14.8	124

Greenhouse gas emissions for the compounded resin are summarized by category in Table 23, including emissions and removals of biogenic CO_2, emissions from land use/land use change (LULC) and net fossil CO_2 emissions.

Table 23. Greenhouse gas emissions for the Nydree products per square meter of flooring.

Source	Unit	7/16" Flooring	7/16" Flooring with iron film backing	9/16" Flooring
Biogenic Emissions	kg CO_2e	18.8	21.8	14.0
Biogenic Removals	kg CO_2e	-157	-158	-177
Net Fossil CO_2	kg CO_2e	111	161	110
LULC	kg CO_2e	0.149	0.179	0.168

Biogenic Carbon Emissions and Removals

The acrylic infused hardwood flooring products include biogenic material, thus biogenic carbon emissions and removals are reported in line with the PCR and ISO 21930 standard. Per ISO 21930, biogenic carbon entering the product system is accounted as removal and presented as negative carbon emission. Biogenic carbon leaving the product system as a product, co-products or combustion emission are accounted as positive emissions. Biogenic carbon emissions and removals for flooring products analyzed are presented Table 25 through Table 27.

Emissions and removals reported are listed below:

- Biogenic carbon removed through hardwood lumber input to the product system is reported in module A1,
- Biogenic carbon associated with the packaging materials and product wastes are reported in module A3,
- Combustion of biomass fuel in the boiler that is used in the manufacturing process are reported in module A3,
- Biogenic carbon associated with the disposal of packaging waste materials during installation is reported in module A5,
- Biogenic carbon leaving the product system through disposal are reported as emissions in module C4.

Table 24. Indicators describing biogenic carbon emissions and removals.

Parameter	Parameter	Unit
Biogenic Carbon Removal from Product	BCRP	kg CO_2
Biogenic Carbon Emission from Product	BCEP	kg CO_2
Biogenic Carbon Removal from Packaging	BCRK	kg CO_2
Biogenic Carbon Emission from Packaging	BCEK	kg CO_2
Biogenic Carbon Emission from Combustion of Waste Used in Production	BCEW	kg CO_2

Table 25. Biogenic carbon emissions and removals for the ***7/16" Flooring*** product.

Parameter	Unit	A1	A2	A3	A4	A5	B2	B4	C2	C4
BCRP	kg CO_2	-29.6	N/A	0.00	N/A	0.00	N/A	-44.4	N/A	0.00
BCEP	kg CO_2	0.00	N/A	14.8	N/A	0.00	N/A	44.4	N/A	14.8
BCRK	kg CO_2	0.00	N/A	-0.749	N/A	0.00	N/A	-1.12	N/A	0.00
BCEK	kg CO_2	0.00	N/A	0.00	N/A	0.749	N/A	1.12	N/A	0.00
BCEW	kg CO_2	0.00	N/A	11.3	N/A	0.00	N/A	16.9	N/A	0.00

Table 26. Biogenic carbon emissions and removals for the ***7/16" Flooring w/ iron film backing*** product.

Parameter	Unit	A1	A2	A3	A4	A5	B2	B4	C2	C4
BCRP	kg CO_2	-29.6	N/A	0.00	N/A	0.00	N/A	-44.4	N/A	0.00
BCEP	kg CO_2	0.00	N/A	14.8	N/A	0.00	N/A	44.4	N/A	14.8
BCRK	kg CO_2	0.00	N/A	-0.749	N/A	0.00	N/A	-1.12	N/A	0.00
BCEK	kg CO_2	0.00	N/A	0.00	N/A	0.749	N/A	1.12	N/A	0.00
BCEW	kg CO_2	0.00	N/A	11.3	N/A	0.00	N/A	16.9	N/A	0.00

Table 27. Biogenic carbon emissions and removals for the ***9/16" Flooring*** product.

Parameter	Unit	A1	A2	A3	A4	A5	B2	B4	C2	C4
BCRP	kg CO_2	-24.8	N/A	0.00	N/A	0.00	N/A	-37.1	N/A	0.00
BCEP	kg CO_2	0.00	N/A	8.87	N/A	0.00	N/A	37.1	N/A	15.9
BCRK	kg CO_2	0.00	N/A	-0.877	N/A	0.00	N/A	-1.32	N/A	0.00
BCEK	kg CO_2	0.00	N/A	0.00	N/A	0.877	N/A	1.32	N/A	0.00
BCEW	kg CO_2	0.00	N/A	11.3	N/A	0.00	N/A	16.9	N/A	0.00

Sensitivity analysis

Sensitivity analyses were conducted to evaluate the impact of various modeling assumptions on indicator results. The sensitivity analysis conducted as part of the study is described below. All sensitivity results are presented per square meter over the cradle-to-grave life cycle for a 75-yr time horizon.

As noted above, the flooring products were modeled assuming resource allocation based on the area of the products. To evaluate the effect of the allocation assumptions on the estimated impact indicators, the product systems were modeled assuming economic resource allocation based on the product sales price and annual sales for the facility.

The results of the sensitivity analysis modeling are presented in Table 28. Results are shown for the products modeled assuming economic allocation, as well as the percent change from the reference product system. Only minor decreases (<~4%) are estimated for all products and indicators when modeled with cost-based allocation.

Table 28. Life Cycle Impact Assessment results for the flooring products assuming cost-based resource allocation. Results are shown per square meter of flooring over a 75-year building lifetime. Percent change from reference product system is also shown.

Impact Category	Units	7/16" Flooring	7/16" Flooring with iron film backing	9/16" Flooring
CML-IA				
Global warming potential	kg CO_2 eq	128 (-2.0%)	176 (-3.4%)	123 (-0.6%)
Acidification potential	kg SO_2 eq	0.555 (-1.8%)	0.733 (-3.3%)	0.563 (-0.6%)
Eutrophication potential	kg $(PO_4)^{3-}$ eq	0.272 (-1.4%)	0.355 (-2.6%)	0.267 (-0.4%)
Photochemical oxidation creation potential	kg C_2H_4 eq	$4.50x10^{-2}$ (-2.1%)	$5.66x10^{-2}$ (-4.1%)	$4.60x10^{-2}$ (-0.7%)
Ozone layer depletion potential	kg CFC-11 eq	$5.10x10^{-6}$ (-0.9%)	$7.35x10^{-5}$ (-0.2%)	$5.19x10^{-6}$ (-0.3%)
Abiotic depletion potential (fossil fuels)	MJ eq	1,520 (-2.1%)	2,260 (-3.4%)	1,510 (-0.7%)
TRACI				
Global warming potential	kg CO_2 eq	122 (-2.0%)	170 (-3.5%)	118 (-0.6%)
Acidification potential	kg SO_2 eq	0.608 (-1.9%)	0.793 (-3.5%)	0.625 (-0.6%)
Eutrophication potential	kg N eq	0.565 (-1.1%)	0.745 (-2.0%)	0.537 (-0.3%)
Smog formation potential	kg O_3 eq	11.7 (-2.1%)	14.4 (-4.1%)	12.5 (-0.6%)
Ozone layer depletion potential	kg CFC-11 eq	$5.66x10^{-6}$ (-1.1%)	$9.73x10^{-5}$ (-0.2%)	$5.78x10^{-6}$ (-0.3%)
Fossil fuel depletion potential	MJ, surplus	200 (-2.1%)	289 (-3.6%)	195 (-0.7%)

6 Interpretation

6.1 Preliminary interpretation

Life cycle stage contribution

Results were summarized by life cycle phase for a cradle-to-grave assessment of the Nydree Flooring product system. The contributions to total impact indicator results are dominated by the product replacement phase of the assessment. With few exceptions, impact contributions are dominated by the product maintenance phase followed by raw material extraction and processing, product manufacturing and downstream processes.

6.2 Evaluation

Completeness check

Life cycle inventory results were reviewed for completeness, consistency and representativeness. Overall, the inventory was considered consistent and generally representative of the product system, with respect to the impact categories assessed. The primary source of data used during the assessment was from the manufacturer, with the remaining derived from the Ecoinvent life cycle inventory database.

Consistency check

Throughout all stages of the assessment under SCS' control, methodological choices and practices were consistent with ISO 14044 and the PCR. Overall, the inventory was considered consistent with respect to the processes and impact categories assessed.

Sensitivity check

A sensitivity analysis was conducted to investigate the impacts on estimated indicator results due to assumptions regarding the resource allocation approach used in the assessment. The results indicate minimal decreases are estimated when the product system is modeled assuming cost-based resource allocation.

6.3 Conclusions, limitations and recommendations

General conclusions

A Life Cycle Impact Assessment of the Nydree Flooring products was conducted to support the development of an Environmental Product Declaration (EPD) conformant to ISO 14044, ISO 14025, ISO 21930 and the UL Product Category Rule (PCR) for Flooring. Results are reported using the

indicators prescribed by the PCRs based on the TRACI and CML characterization methodologies. Impact category indicator results for the product systems considered are presented in Section 5.

Impact category indicator results are summarized by life cycle phase including raw material extraction and processing; transport to manufacturer; product manufacturing and packaging; product distribution, use and maintenance; and product disposal. Results were evaluated using sensitivity and process contribution analyses.

Excluding product replacements, the contributions to indicator results are dominated by the product maintenance and the raw material extraction and processing phases. Incorporation of primary data for upstream material components and processing is recommended to improve the overall quality of the assessment.

Limitations

The assessment relied on a number of assumptions and limitations, the most relevant of which are discussed in this report. Most of the upstream raw materials extraction and processing could not be modeled with actual process information. Representative data from Ecoinvent life cycle inventory databases were utilized as appropriate. These datasets were modified to represent the flooring product system, where necessary.

It is noted that the LCIA results presented in this report are relative expressions and do not predict impacts on category endpoints, exceedance of thresholds, safety margins, or risks associated with the product system. Impact indicators rely on the use of generic models and potential impacts, and therefore are not able to measure actual environmental impacts. Additionally, the indicators prescribed by the PCR do not represent all categories of potential environmental and human health impacts associated with the life cycle of the assessed products, and this represents a general limitation of the LCA study.

Recommendations

The contribution analysis suggests improvements in the assessment may be realized through collection and incorporation of additional primary data for the extraction and processing of product components.

APPENDIX A: ISO 14044 Critical Review Report

Industrial Ecology Consultants

September 23, 2023

Keith Killpack
Manager, LCA Services | SCS Global Services
2000 Powell St., Ste. 600 | Emeryville, CA 94608

Verification Report: Nydree Flooring Acrylic Infused Hardwood Flooring

The LCA Practitioner, SCS Global Services, commissioned Industrial Ecology Consultants to perform an external independent verification of the **Life Cycle Assessment of Acrylic Infused Engineered Hardwood Flooring.** SCS Global Services completed the Life Cycle Assessment (LCA) study and respective Environment Product Declaration (EPD) on behalf of the commissioning organization, **Nydree Flooring LLC.**

The review of the study was performed to demonstrate conformance with the following standards, general program instructions, and product category rules:

- International Organization for Standardization. (2000). *Environmental labels and declarations -- General principles* (ISO 14020:2000).
- International Organization for Standardization. (2006). *Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures* (ISO 14025:2010).
- International Organization for Standardization. (2006). *Environmental management -- Life cycle assessment – Principles and framework* (ISO 14040:2006 / Amd 1:2020).
- International Organization for Standardization. (2006). *Environmental management -- Life cycle assessment -- Requirements and guidelines* (ISO 14044:2006 / Amd 1:2017 / Amd 2:2020).
- International Organization for Standardization. (2014). *Environmental management -- Life cycle assessment -- Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006.* (ISO/TS 14071:2014).
- International Organization for Standardization. (2017). *Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services*. (ISO 21930:2017).
- SCS Global Services (2021). *Program Operator Manual: Type III Environmental Declaration Program*, v11-0, November.
- UL Environment (2018). *PCR for Building-Related Products and Services - Part A: Calculation Rules for the LCA and Requirements*, UL 10010 v.3.2.
- UL Environment (2018). *PCR for Building-Related Products and Services - Part B: Flooring EPD Requirements*, UL 10010-7 v.2.0

The independent third-party verification was conducted by an external expert per ISO 14044:2006 Section 6.2: Critical review by internal or external expert:

Thomas P. Gloria, Ph.D.

Industrial Ecology Consultants

Founder, Chief Sustainability Engineer
Industrial Ecology Consultants

REVIEW SCOPE

The intent of this review was to provide an independent third-party external verification of a completed LCA study report and respective EPD. The EPD generated from this LCA study included the **Nydree** flooring product:

- Acrylic Infused Hardwood Flooring

REVIEW PROCESS

The review involved the verification of the SCS Global Services standard review matrices based on the requirements set forth by the applicable ISO standards, the UL Environment Part A and Part B PCRs, and SCS Global Services General Program Instructions (GPIs). The LCA report and review of the EPD covered identified requirements specified by the PCR, GPIs, and applicable ISO standards.

The LCA study report was reviewed by an independent ***external*** reviewer and deemed to conform to the applicable ISO standards, PCRs, and General Program Instructions. This review did not include an assessment of the Life Cycle Inventory (LCI) model, however, it did include a detailed analysis of the individual datasets used to complete the study.

VERIFICATION STATEMENT

Based on the independent verification objectives, the **Life Cycle Assessment of Acrylic Infused Engineered Hardwood Flooring *Prepared for: Nydree Flooring LLC* September 20, 2023, by SCS Global Services,** and the respective EPD listed above were verified to be ***in conformance*** with the applicable ISO standards, the UL Environment Part A and Part B PCRs, and SCS Global Services General Program Instructions. The plausibility, quality, and accuracy of the LCA-based data and supporting information are confirmed.

As the External Independent Third-Party Reviewer, I confirm that I have sufficient knowledge and experience of flooring products, the relevant PCR, and ISO standards, and the geographical areas intended to generate EPDs to carry out this verification.

Sincerely,

Thomas P. Gloria, Ph.D.
Founder, Chief Sustainability Engineer
Industrial Ecology Consultants