Generic Linoleum Flooring

Product Selection and Description

Linoleum is a resilient, organic-based floor covering consisting of a backing covered with a thick wearing surface. For the BEES system, 2.5 mm (0.098 in) sheet linoleum manufactured in Europe, with a jute backing and a polyurethane-acrylic finish coat, is studied. An acrylate copolymer adhesive is included for installation.

Flow Diagram

The flow diagram below presents the major elements of the production of this product as it is currently modeled for BEES.

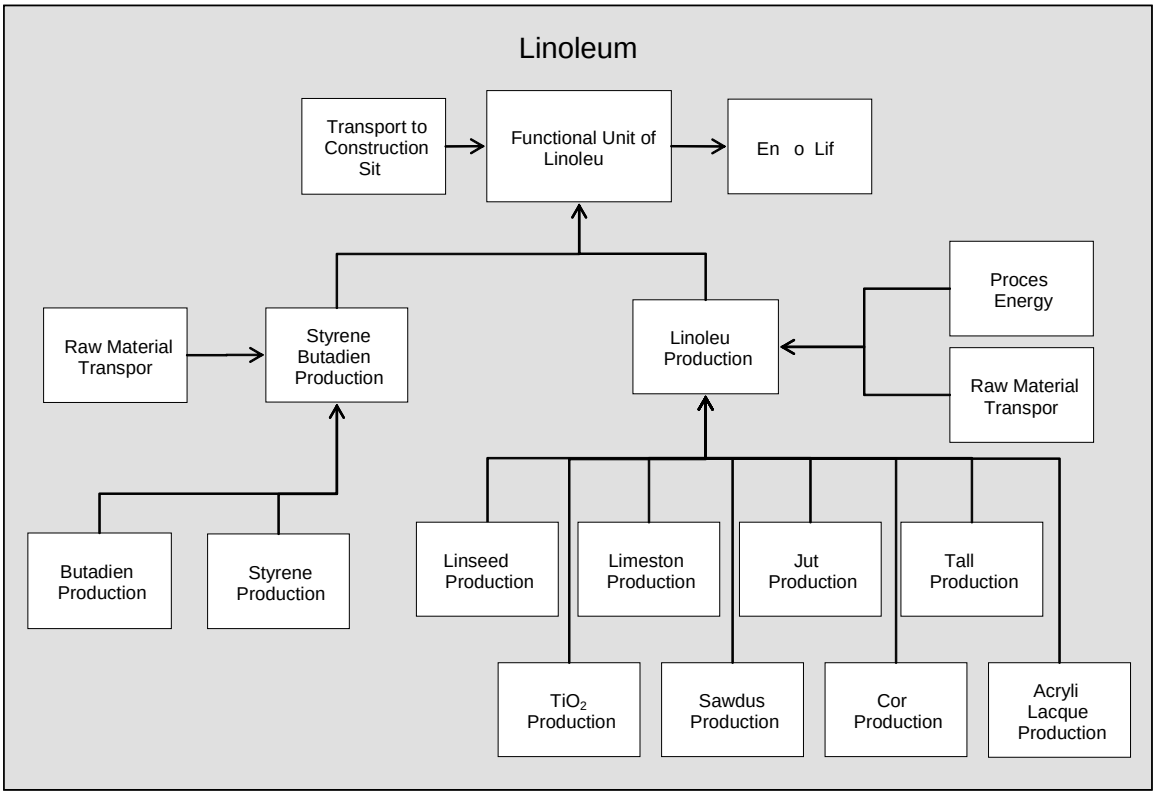

Figure 1: Linoleum Flooring System Boundaries

Raw Materials

The following Table lists the constituents of linoleum and their proportions. The data comes from a European study on the life cycle of flooring materials.[1] One square meter of 2.5 mm (0.098 in) linoleum weighs approximately 2.9 kg (6.4 lb).

[1] Asa, J., et al.(Sweden: Chalmers University of Technology, 1995).

Table 1: Linoleum Constituents

Constituent	*Mass Fraction*	*g/m^2 (oz/ft^2)*
Linseed oil	23.3 %	670 (2.2)
Pine rosin/tall oil	7.8 %	224 (0.7)
Limestone	17.7 %	509 (1.7)
Wood flour	30.5 %	877 (2.9)
Cork flour	5.0 %	144 (0.5)
TiO_2 (pigment)	4.4 %	127 (0.4)
Jute (backing)	10.9 %	313 (1.0)
Acrylic lacquer	0.35 %	10 (0.03)
Total	**100 %**	**2 874 (9.4)**

The cultivation of linseed is based on a modified version of wheat production from the U.S. LCI Database (for lack of other available data), and inputs are presented below.

Table 2: Inputs to Linseed Agriculture

Input	*Kg/ha (lb/acre)*
Nitrogen Fertilizer	31 (28)
Phosphorus Fertilizer	20 (17)
Potassium Fertilizer	25 (22)
Pesticides (active compounds, with 20 % lost to the atmosphere)	0.7 (0.7)

To harvest the linseed, it is assumed that a diesel tractor is used, requiring approximately 0.61 MJ of diesel fuel per kg (263 Btu/lb) of linseed harvested. The yield of linseed is 1 038 kg per hectare (420 lb/acre). Energy requirements for linseed oil production include fuel oil and steam, and are allocated on an economic basis between linseed oil (87 %) and linseed cake (13 %). Allocation is necessary because linseed cake is a co-product of linseed oil production, so its production impacts should not be included in the BEES model for linoleum flooring. The emissions associated with linseed oil production are allocated on the same economic basis. The production of the fertilizers and pesticides is based on elements of the SimaPro and EcoInvent databases.

The production of tall oil is based on European data for kraft pulping, with inventory flows allocated between kraft pulp and its coproduct, tall oil.[2] The production of limestone comes from the U.S. LCI Database. Wood flour is sawdust produced as a coproduct of wood processing, and its production is based on the U.S. LCI Database. Cork flour is a coproduct of wine cork production. Cork tree cultivation is not included, but energy requirements for the processing of the cork is included as shown in the table below.

Table 3: Electricity Inputs for Cork Flour Production

Cork Product	*MJ/kg (Btu/lb)*
Cork Bark	0.06 (26)
Ground Cork	1.62 (696)

Data for production of the pigments used in the product is modeled based on the European production of titanium dioxide, and comes from EcoInvent. Linoleum backing, jute, is mostly grown in India, Bangladesh,

[2] Fédération Européenne des Fabricants de Carton Ondulé (FEFCO), 2003. Found at: http://www.fefco.org/fileadmin/Fefco/pdfs/Technical_PDF/Corrected_database_2003.pdf.

Thailand, and China. Jute is a predominantly rain-fed and requires little fertilizer and pesticides, and cultivation is generally manual. Jute data are based on an EcoInvent dataset for rain-fed jute fiber production in India. Data for the production of acrylic lacquer materials come from EcoInvent data on an acrylic binder.

Manufacturing

Energy Requirements. Producing linoleum requires electricity and natural gas; the following Table lists the energy requirements for linoleum production.[3]

Table 4: Energy Requirements for Linoleum Manufacturing

Energy Carrier	*MJ/kg (Btu/lb)*
Electricity	2 (859.8)
Natural Gas	10 (4 299.2)

Emissions. Since most linoleum manufacturing takes place in Europe, it is assumed to be a European product in the BEES model. European linoleum manufacturing results in the following air emissions in addition to those from energy use.

Table 5: Emissions from Linoleum Manufacturing

Emission	*g/kg (oz/lb)*
Volatile Organic Compounds (VOC)	1.6 (0.025)
Solvents	0.94 (0.015)
Particulates (unspecified)	0.23 (0.004)

Transportation. Data for linoleum raw material transport from point of origin to a European manufacturing location is shown in the Table below.[4]

Table 6: Linoleum Raw Materials Transportation

Raw Material	*Km (mi)*	*Mode*
Linseed oil	4 350 (2 703)	Ocean Freighter
	1,500 (932)	Train
Pine rosin/tall oil	2 000 (1 243)	Ocean Freighter
Limestone	800 (497)	Train
Wood flour	600 (373)	Train
Cork flour	2 000 (1 243)	Ocean Freighter
TiO_2 (pigment)	500 (311)	Diesel Truck
Jute (backing)	10 000 (6 214)	Ocean Freighter
Acrylic lacquer	500 (311)	Diesel Truck

Transport of the finished product from Europe to the United States is included in the model as part of the manufacturing process.

Waste. Most process waste is recycled at the plant and the remainder is sent to a landfill for disposal. For this model, 3 % of process input materials are assumed to go to a landfill.

Transportation

Transportation of linoleum by heavy-duty truck from the U.S. distribution facility to the building site is

[3] Data is based on an average of public data and manufacturer-specific information.

[4] Asa, J., et. al., *Life-Cycle Assessment of Flooring Materials*(Sweden: Chalmers University of Technology, 1995).

modeled as a variable of the BEES system Transportation data is based on the U.S. LCI Database.

Installation

For optimal adhesion, an acrylate copolymer adhesive is applied to a subfloor or other surface at a thickness of 0.29 mm and mass of 290 g/m². Usually linoleum seams are sealed against moisture by welding with a weld rod. This minimal amount of energy is not accounted for in the model.

Installation waste is assumed to be 5 % of the installed weight. In the United States, and in BEES, this waste is assumed to be sent to a landfill for disposal. (In Europe, this waste would go into incineration, which would generate 18.3 MJ/kg (2.31 kWh/lb) energy.)

Use

Linoleum is known for its durability. Through evaluation of actual lifetime data, is has been determined that linoleum has a useful life of 30 years.[5] As with all BEES products, the life cycle environmental impacts from this replacement during the 50-year use phase are included in the life cycle inventory data. Volatile organic compound (VOC) off-gassing from the adhesive is included in the BEES modeling.

End of Life

At end of life, it is assumed that linoleum is disposed of in a landfill.

References

Life Cycle Data

National Renewable Energy Laboratory (NREL): *U.S. Life-Cycle Inventory Database*. 2005. Golden, CO. Found at: http://www.nrel.gov/lci/database.

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Industry Contacts

Jennifer Gaalswyk, Armstrong Corporation (Sept 2005 – Jan 2006)

[5] Federal Association of the Sworn Experts for Room and Equipment e.V., *Guide to the Inquiry of Time Values and Decreases in Value of Floor Coverings*(Bonn, Germany: Federal Association of the Sworn Experts for Room and Equipment e.V.)