Dovetail Partners Consuming Responsibly Report No. 11

Environmental Assessment of House Cladding Products

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September 16, 2019

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Environmental Assessment of House Cladding Products

Executive Summary

Homeowners have a wide array of exterior cladding options. Among the alternatives are brick, stucco, vinyl, polypropylene, aluminum, fiber-cement, engineered wood, and solid wood siding products of various species. This report examines the relative environmental impacts of these various cladding options considering a number of categories of impact. Impact estimates are based on full life cycle assessments beginning with raw material extraction, through product manufacture, use, and end of life disposal.

Over a 60-year time frame or less, the house cladding products linked to the greatest overall environmental impacts are polypropylene siding and those products that are cement-based. These products also generate the greatest climate change impact potential. Vinyl, solid wood, and engineered wood siding products have lower overall environmental impacts, including climate impacts. Over longer time horizons than 60 years the relative impacts of cement-based products would be lower, reducing considerably the impact differences between these and vinyl, and wood cladding.

An Array of Cladding Alternatives

Whether building new or considering re-siding of an existing structure, homeowners have a wide array of commercially available exterior cladding options (Table 1). Determinants of which product is chosen typically include price, appearance, maintenance requirements, impact resistance, and long-term performance. Environmental impact is seldom considered, although differences in impacts to the environment of various cladding alternatives are in some cases quite large.

Table 1
Selected Residential Building Cladding Options

- brick and mortar
- stucco (3 coat system)
- vinyl
- insulated vinyl
- Insulated vinyl with recycled content)
- aluminum
- fiber-cement
- fiber-cement with recycled content
- engineered wood
- western red cedar and other solid wood products of various species

This report compares a wide range of environmental impacts linked to production and use of residential cladding products as listed in Table 1. Western red cedar is the only solid wood product examined in detail. Precise specifications of each product evaluated for comparison in this report can be found in Appendix A. Product comparisons are based on life cycle assessment, specifics for which are detailed in Appendix C.

Environmental Impact Comparisons

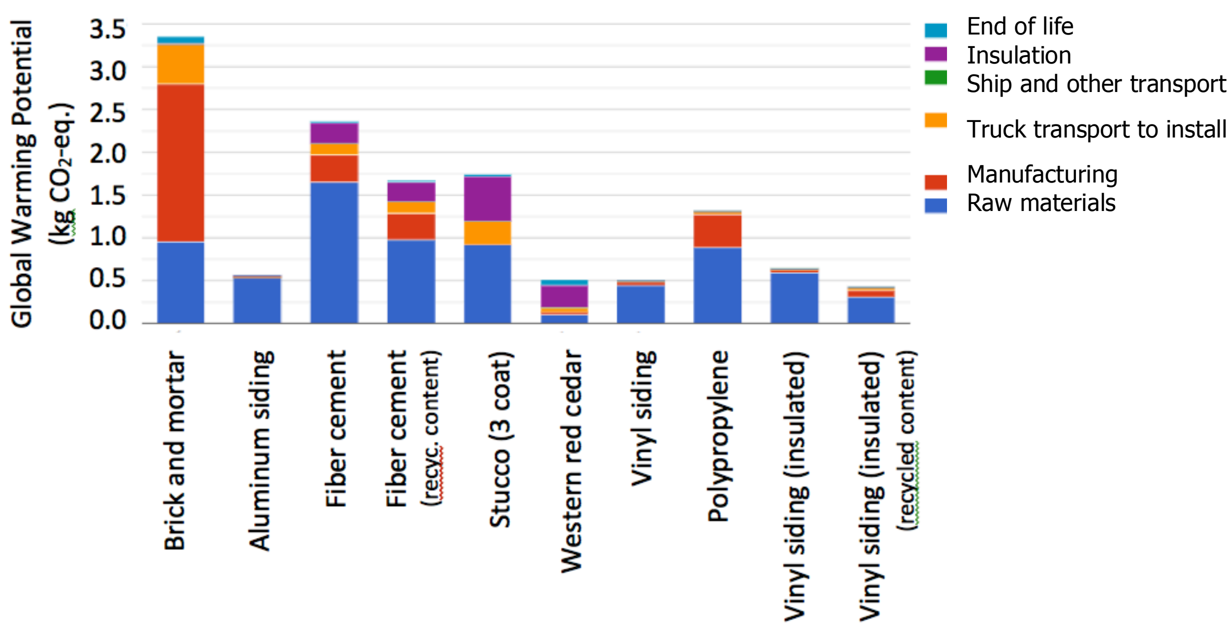
The primary source of information on which this report is based is the National Institute of Standards and Technology (NIST) and its Building for Energy and Environmental Sustainability (BEES 2.0) program. Several additional published assessments performed by various research organizations have also informed this report. See Appendix B for more information regarding the BEES program and additional sources of information used in preparing this report.

The environmental impact indicators associated with each of nine cladding products included in BEES are presented in graphical form in Figures 1 and 2[1]. All comparisons indicated in Figures 1 and 2 assume a 60-year building life. The effect is to assume a 60-year life for all cladding materials, although some cladding products have estimated lives well beyond 60 years. This is discussed further following the Figures.

Figure 1

Global Warming Potential Linked to Cladding Products as Reported by BEES 2.0

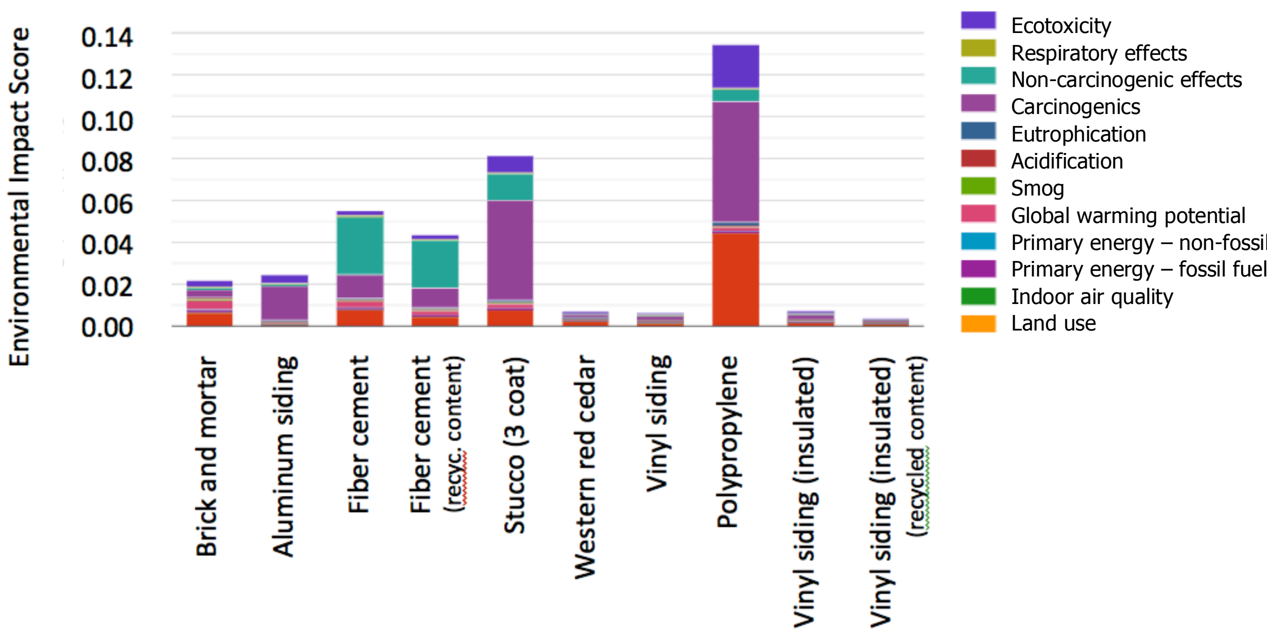
(Lower values indicate lower environmental impact)



[1] Engineered wood siding is not evaluated within the BEES environmental impact calculator, and therefore is not included in any of these figures or tables. An assessment of this type of product is contained in a recent report (Puettmann et al. 2016), and this information has been used to compare engineered wood siding to other cladding products compared using BEES 2.0 (Table 3).

Figure 2
Overall Environmental Impact Scores of Cladding Products as Reported by BEES 2.0

(Lower values indicate lower environmental impact)



Global Warming Potential

Note in Figure 1 that global warming potential (GWP) estimates linked to a number of the cladding products are similar. Estimates for aluminum, western red cedar, and all of the vinyl siding products are relatively low and similar. The estimated GWP for composite wood siding (not shown) also aligns with these values. Fiber cement without recycled content and brick and mortar are associated with the greatest GWP. The difference in warming potential for a US home of average size between the lowest impact material (recycled content vinyl siding) and the highest impact material (brick and mortar) is modest – roughly equivalent to driving 21,400 miles in an average US passenger car. Spread out over a 60-year assumed life, the difference is equivalent to 355 miles of driving each year (about ¾ tank of gas annually) over that 60-year time span.

Comparison of Composite of Impact Estimators

When the full range of impact estimators is considered, the vinyl and wood-based siding products, including the engineered wood siding (not shown in Figure 2) again rank as the lowest impact cladding materials. Use of brick and aluminum results in slightly higher impacts, while impacts associated with fiber cement and stucco products are substantially greater. Polypropylene siding results in by far the greatest environmental impact because high GWP potential and carcinogenic risk.

Vinyl Cladding Products

Environmental assessment information contained in BEES, and in several published third-party verified LCA reports for vinyl siding products,[2] is much different than indicated in a 2007 Dovetail report.[3] That earlier report, prepared prior to the availability of verified vinyl LCA studies, incorrectly indicated very high impacts of vinyl products in comparison to wood-based products. The latest data, surprising to our team, shows vinyl products to, in general, have the lowest environmental impacts of all cladding materials. By far the greatest contributor to environmental impact of vinyl products is from obtaining raw materials. All of these products are petroleum derived.

One factor that is not accounted for in the BEES comparisons is periodic cleaning of vinyl, a practice that is recommended by vinyl siding manufacturers.[4] A number of vinyl siding cleaning products are commercially available, and a search of companies that provide vinyl siding services yields scores and even hundreds of hits for major cities across North America suggesting that cleaning is both common and frequent. A number of sources recommend cleaning annually. The fact that impacts linked to cleaning are not included in the results presented herein is unfortunate. Were such impacts included, the impacts linked to vinyl siding products would undoubtedly be greater.

Western Red Cedar and Other Solid Wood

Cedar commands only a minor part of the siding market today, although it has long been a popular siding material. Painting or staining at the time of installation, and at 15-year intervals thereafter was assumed in the BEES model. This is the only solid wood cladding material for which third-party verified life cycle information is available. Other wood species used for wood siding include redwood, other species of cedar, and larch (commonly used in parts of Europe). Verification of responsible management and harvesting any wood species used in siding products can be obtained by purchasing PEFC, SFI or FSC certified wood products.

Engineered Wood Siding

Information for engineered wood siding has been obtained from APA – the Engineered Wood Association[5] and from the only published LCA for this product.[6] Painting at the time of installation, and at 15-year intervals thereafter was assumed.

Fiber-cement Siding Products

The primary factors contributing to environmental impact of these products is energy consumption in manufacture (and particularly in the manufacture of Portland cement), and human health issues (both carcinogenic and non-carcinogenic) related to processing.

[2] CertainTeed Corporation (2011), Sustainable Solutions Corporation (2016)
[3] http://www.dovetailinc.org/report_pdfs/2007/dovetailvinyl1007ku.pdf
[4] CertainTeed Corporation (2019)
[5] APA (2017)
[6] Puettmann et al. (2016)

Stucco

Stucco has long been a favorite cladding material in many parts of the world. Both the three-coat system evaluated herein, and a more recent on-coat system result in high impact at the time of application due to the prevalence of cement as a coating material. The most significant factors contributing to environmental impact are energy consumption, contribution to global warming, and non-carcinogenic health concerns related to production of components. This product has a longer estimated product life (100 years) than most of the other cladding systems evaluated, so that if the time span considered (60 years in this evaluation) were extended, the relative impact of stucco relative to other cladding alternatives would be lower.

Brick and Mortar

Brick is a primary cladding material in some parts of North America. The greatest contributor to environmental impact is energy consumption in the manufacturing process, including production of cement. Although a high-impact cladding option in a 60-year building life scenario, the very long estimated life (200 years) combined with low maintenance requirements mean that if the time span considered (60 years in this evaluation) were extended (for instance to 200 years), the relative impact of brick and mortar would be much lower.

Aluminum Siding

Environmental impacts of this product stem mainly from energy consumption in production of aluminum. Nonetheless, the impacts are relatively modest due to the thin profiles, and low product weight.

Polypropylene

The main environmental disadvantages of this product are high energy consumption, global warming potential, and contribution to ecotoxicity. Compared to all other cladding products examined in this report, this product has the greatest overall environmental impact.

Environmental Impact Ranking of Cladding Options

Taking into consideration global warming potential (the most important impact factor as rated by the BEES Stakeholder Panel), as well as the complete list of impact indicators into consideration, various cladding products were ranked. Those products having the lowest impact are vinyl siding and wood-based siding products, while cement-related products and polypropylene are those products leading to the greatest impacts (Table 2).

Table 2
Ranking of Cladding Options Considering a Wide Range of Impact Estimators and Assuming a 60-Year Building Life [a/]

Relative Impact	Relative Environmental Ranking	
	Global Warming Potential (Least impact to greatest impact)	Weighted Ranking of All Impact Indicators (Least impact to greatest impact)
Least	Vinyl with recycled content	Vinyl with recycled content
	Western red cedar	Vinyl
	Vinyl	Western red cedar
	Aluminum	Engineered wood
	Engineered wood	Insulated vinyl
	Insulated vinyl	Brick and mortar
	Polypropylene	Aluminum
	Fiber cement with recycled content	Fiber cement with recycled content
	Stucco	Fiber cement
	Fiber cement	Stucco
Greatest	Brick and mortar	Polypropylene

[a/] Green shading indicates little difference in environmental impact.

A Cautionary Note

The analyses and comparisons described in this report are based on an assumption that materials will be properly installed and used in environments suitable to extended product life (see Appendix A for assumed useful life of each cladding product). When installation not properly done or climate is unfavorable to a particular product type, the result can be premature deterioration of the cladding material or other components of exterior walls. This, in turn, can cause a sharp increase in environmental impact. For instance, stucco is generally found to have a long product life. However, stucco is a porous material and must be installed with a proper drainage plane behind it if the structural framing of the underlying wall is wood or steel; the wetter the climate, the more attention must be paid to this issue. Failure to install properly can lead to major deterioration of wall components and substantial adverse environmental impacts within a relatively short time frame. Vinyl, on the other hand, does not perform well over the long term in extreme heat, being prone under those circumstances to cracking and buckling, and need for replacement after only a few years. Again, the environmental impacts of replacement are large.

Recommended Actions

When buying new or considering a cladding replacement, take the time to investigate pros and cons of available options, including relative environmental impact. Specifically:

- Do a bit of research before buying to determine the best performing cladding products for the region in which you live.
- Consider environmental impacts of best performing alternatives in decision-making.
- Seek builders/installers known for quality installation practices.

Summary

A number of house cladding options are available to North American consumers. While environmental impacts of various options are seldom taken into account in product selection, information regarding specific impact measures through the life cycles of products is now readily available. This information reveals differences in impacts linked to various types of cladding options. Over an assumed building life of 60 years or less environmental performance of vinyl and wood-based products is generally better than that of available alternatives. However, should a longer building life be assumed, the relative ranking of brick and mortar cladding would improve with each decade of additional assumed life, up to 200 years. Aluminum and stucco cladding rankings would similarly improve with an assumed building life of 80 and 100 years, respectively.

Sources of Information

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Appendix A – Detailed Specifications for Each of the Cladding Products Assessed in the Report [a/]

Cladding material	Product description	Principal raw materials	Est. service life
Brick and mortar	The brick unit evaluated is 92 mm x 57 mm x 194 mm (3⅝ in. × 2¼ in. × 7⅝ in.), translating to nominal dimensions of the brick including the mortar joint of 102 mm × 68 mm × 203 mm (4 in. × 2☐ in. × 8 in.). Bricks are cored prior to being fired, which removes about 25 % to 30 % of the clay or shale material. The cored and fired brick unit weighs 1.7 kg (3.7 lb) and is assumed to be installed with Type N mortar, which has a density of 1840 kg/m^3 (115 lb/ft^3) and a maximum air content of 20 %. The brick wall is assumed to be 80 % brick and 20 % mortar by surface area.	Clay (99.2%), bottom ash (0.8%)	200 yr.
Aluminum siding	The aluminum siding panels evaluated are 20 cm (8 in) wide and 22 gauge or 0.064 cm (0.025 in) thick. The siding is fastened using aluminum fasteners every 41 cm to 61 cm (16 in to 24 in).	Aluminum allow sheet (99%), PVC topcoat (1%). Recycled content 67%.	80 yr.
Fiber cement, no recycled content (CertainTeed Weatherboard [b/])	Product evaluated is lap siding of 21.96 cm (8.25 in) wide and 0.79 cm (0.31 in) thick, installed with 3.18 cm (1.25 in) of overlap. Density is 13.07 kg/m^2 (2.68 lb/ft^2). Installed with galvanized nail fasteners placed 41 cm (16 in) on center. Product is painted (two coats) following installation and assumed to be repainted every 15 years.	Portland cement (34-39%), kaolin clay (2-7%), silica (48-53%), cellulose (6-10%), primer (0.2%).	60 yr.
Fiber cement, with recycled content (CertainTeed Weatherboard [b/])	Product is same as product described above, but with fly ash content which reduces both the quantity of Portland cement and silica needed. Density is 12.45 kg/m^2 (2.55 lb/ft^2).	Portland cement (30-37%), fly ash (30-50%), silica (14-34%), cellulose (6-10%), primer (0.2%).	60 yr.
Stucco	Stucco is typically a mixture of sand, cement, and lime applied to masonry or framed walls. Cladding evaluated is traditional three-coat stucco is made up of two base coats and a finish coat of Portland cement and/or masonry cement. Painting at time of installation and every 15 years thereafter.	One part Portland cement to 1.125 parts lime and 3.25 parts sand.	100 yr.
Western red cedar siding	The product evaluated is beveled cedar siding with planks 1.27 cm (0.5 in) thick and 15.2 cm (6 in) wide and a 2.54 cm (1 in) overlap. Installation is with galvanized nails 41 cm (16 in) on center. Finished at time of installation, with one coat of primer and two coats of paint. Paint is reapplied every fifteen years.	Western red cedar lumber (100%)	60 yr.
Vinyl siding	Product evaluated is 0.102 cm (0.040 in) thick, 23 cm (9 in) wide horizontal vinyl siding installed with galvanized nail fasteners. Nails placed 41 cm (16 in) on center. Mass 19.3 kg (42.4 lb) per 9.29 m^2 (100 ft^2).	PVC resin (74%), acrylonitrile styrene acrylate (6%), calcium carbonate (10%), titanium dioxide (1.6%), impact modifier (2.0%), lubricant (1.8%), other additives (4.6%).	60 yr.

Insulated vinyl siding	Insulated vinyl siding evaluated is 22.4 kg (49.3 lb) per 9.29 m^2 (100 ft^2) installed with galvanized nail fasteners placed 41 cm (16 in) on center. Product has an EPS foam-contoured backing made by expanding compressed EPS beads into foam board which is then laminated onto the siding.	Vinyl siding (86%), foam backing (12.5 %) lamination glue (1.5%).	60 yr.
Insulated vinyl siding with recycled content CertainTeed Cedarboard Recycled Content	This product is the same as that described above, with the exception that about 74% of the PVC resin is recycled, with material recovered both post-industrial (vinyl siding and window manufacturers), and post construction (construction waste, end of life siding and construction tear-down). T	Vinyl siding with recycled content 78.8 – 96.3 % (74.3% of PVC recycled), foam backing (10.4 – 12.8 %), lamination glue (0.8 – 1.0 %).	60 yr.
Polypropylene siding	The product evaluated is 0.216 cm (0.085 in) thick, 17.8 cm (7 in) wide horizontal polypropylene siding installed with galvanized nail fasteners placed 41 cm (16 in) on center. The product mass is 32.3 kg (71.3 lb) per 9.29 m^2 (100 ft^2).	Polypropylene (85%), calcium carbonate (12%), pigments (3%).	60 yr.
Engineered wood siding	This product is typically available as lap siding in 9.5-11.1 mm (0.375-0.4375 in) thicknesses (sometimes thicker), and nominal widths of 15.2-30.5 cm (6-12 in) and in lengths up to 4.9m (16) ft, intended for installation with common or galvanized nails placed 41 cm (16 in) on center, or as great as 61cm (24 in) on center for thicker products. The product mass is 68 kg (149.9 lb) per 9.29 m^2 (100 ft^2) for 9.5 mm (0.375 inch) thick siding and 79.3 kg (174.8 lb) for 11.1 mm (0.4375 in) siding.	Wood fiber (94.8%), Phenol-formaldehyde resin (1.7%), paraffin/wax emulsion (1.5%), zinc borate (0.8 %), alum (0.6%), compregnite (0.5%), release agent (0.1%).	60 yr.

a/ Abbreviations included in this table include in. (inches), ft. (feet), $ft.^2$ (square feet), $ft.^3$ (cubic feet), mm (millimeters), cm. (centimeters), m (meters), m^2 (square meters), m^3 (cubic meters), lb. (pounds), kg (kilograms)

b/ https://www.certainteed.com/siding/

Appendix B – BEES 2.0 and its Use in this Report

The primary source of information on which this report is based is the National Institute of Standards and Technology (NIST) and its Building for Energy and Environmental Sustainability (BEES 2.0) program. Several additional published assessments performed by various research organizations have also informed this report.

BEES makes use of published life cycle assessments (LCAs)[7] conducted by various organizations which have conducted third-party verified assessments in accordance with a set of internationally recognized rules for data collection and analysis. Environmental impacts resulting from raw material extraction or collection, product production, transportation, installation, use, and ultimate disposal are assessed. Not included in assessment is periodic cleaning or maintenance, other than painting. A wide range of environmental impact categories are examined.

BEES is the most comprehensive source of LCA-based information about building materials in North America. There are currently seventeen cladding products in the system, of which nine are distinctly different products. The BEES program is accessible online[8] and free to download and use.

Examination of Cladding Options

Using BEES 2.0 yields information regarding thirteen environmental attributes, including:

- Global warming potential
- Primary energy
- Human health criteria air
- Human health cancer
- Water consumption
- Ecological toxicity
- Eutrophication
- Land use
- Human health non-cancer
- Smog formation
- Acidification
- Indoor air quality
- Ozone depletion

Product comparisons as presented in this report are based on assessments using the LCA assessment Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI 2.1), enhanced by addition of impact indicators for land use, water consumption, and indoor air quality. Overall environmental impact was determined using a system that weights the above attributes according to the degree or seriousness of environmental impact. Within BEES, information is provided regarding weighting factors developed by a BEES Stakeholder Panel (2006) (Table B-1).

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7 See Appendix for more information about life cycle assessment.
8 BEES 2.0 online can be accessed via: (https://ws680.nist.gov/Bees2)

Table B-1
Weighting of Relative Importance of Impact Factors

Impact Factor	**Weighting (%)**
Ozone depletion	2
Water use	8
Land use	6
Indoor air quality	3
Primary energy demand – non renewable	8
Primary energy demand – renewable	2
Global warming potential	29
Smog	4
Acidification	3
Eutrophication	6
Carcinogenics	8
Non-carcinogenics	5
Respiratory effects	9
Ecotoxicity	7
Total	100

Weighting factors as assigned by BEES Stakeholder Panel

LCA comparisons for all but one of the products examined in this report were obtained from BEES 2.0. The exception is engineered wood siding, one of the most commonly used siding products on the market today. Because this product has not yet been included in the BEES system, it was necessary to search elsewhere for published information. The search turned up only one published LCA,[9] an assessment which encompasses only cradle to gate operations (i.e. raw material extraction, shipment of raw materials to manufacturing plant, manufacturing, and loading for transport). In addition, assessment was done for a more limited range of impact indicators than in the BEES model, and a different functional unit was used. The more limited scope of product life studied coupled engineered with the abbreviated number of impact indicators reported required additional steps to obtain comparable values to those reported for other products within BEES. Consequently, results of the engineered wood LCA were recalculated to the same functional unit used in BEES (1.0 ft^2 of wall coverage), and comparisons were made of those impact indicators in common with BEES results. Subsequent steps, included within the BEES reported assessments, but not included in the engineered site wood LCA – transport to building site, installation, periodic painting (if required), and disposal at end of life – were assumed equivalent to western red cedar. Comparisons were then used to obtain an imprecise estimate of how environmental impacts of engineered compare to other cladding products.

[9] Puettmann et al. (2016)

Appendix C – Life Cycle Assessment Basics

LCA provides a mechanism for systematically evaluating the environmental impacts linked to a product or process and in guiding process or product improvement efforts. LCA-based information also provides insights into the environmental impacts of raw material and product choices, and maintenance and end-of-product-life strategies. Because of the systematic nature of LCA and its power as an evaluative tool, the use of LCA is increasing as environmental performance becomes more and more important in society.

An LCA typically begins with a careful accounting of all the measurable raw material inputs (including energy), product and co-product outputs, and emissions to air, water, and land. This part of an LCA is called a Life Cycle Inventory (LCI).

Examination of energy use is particularly revealing, since a number of serious environmental problems are related to consumption of energy including acid deposition, oil spills, air pollution (SO_2, NO_x), and increasing concentrations of atmospheric carbon dioxide (responsible for much of global warming potential).

An LCI may deal with product manufacture only, or the study boundaries may be defined more broadly to involve all stages in production, use, and disposal including raw material extraction, transportation, primary processing, conversion to finished products, incorporation into finished products, maintenance and repair, and disposal (as is the case in the evaluations presented in this report).

In a subsequent stage of the LCA (the Life Cycle Impact Assessment), factors are considered that are currently not precisely measurable, such as impacts of an industrial activity on the landscape, flora, fauna, air, water, and human health.

The best available research is used in evaluating life cycle data in the context of findings regarding relative impact, and this information is used in assigning values to various impact indicators. See the box below (following page) for explanation of some of the commonly reported impact estimators.

Definition of Selected Impact Indicators

Acidification – Commonly associated with atmospheric pollution linked to emissions of sulfur and nitrogen compounds such as ammonia. Such emissions can reduce the pH (increase the acidity) of rainfall such that the natural neutralizing capacity of soils is exceeded. This can in turn stunt the growth of, and eventually kill, forest trees as well as aquatic organisms including fish in lakes and streams.

Eco-toxicity – This impact measure encompasses a number of acute and chronic toxicity effects on different species in soil and water which are linked to releases of various chemical substances to air, water, and soil, and their biodegradability and potential bioaccumulation.

Eutrophication – A condition described by excessive richness of nutrients in a lake or other body of water, frequently due to runoff from the land, which causes a dense growth of plant life and death of animal life from lack of oxygen.

Ozone depletion – The concentration of the reactive oxygen compound ozone O_3 is significantly higher in the stratosphere than in other parts of the atmosphere, and serves to increase the amount of ultraviolet radiation that reaches the earth's surface. Reduction in atmospheric ozone is strongly linked to increased skin cancer and retinal damage.

Smog potential – Under certain climatic conditions, air emissions from industry and transportation can be trapped at ground level where, in the presence of sunlight, they produce photochemical smog. It is a product of interactions of volatile organic compounds (VOCs) and nitrogen oxides (NO_x).

Human health risks – Impact indicators focused on both cancer and non-cancer human health risks can be determined from an LCA. These indicators cover a number of different effects including acute toxicity, irritation/corrosive effects, allergenic effects, irreversible damage/organ damage, genotoxicity, carcinogenic effects, toxicity to reproductive system/teratogenic effects, and neurotoxicity. Calculations of risk are based on accumulated knowledge, obtained through medical research of impacts of exposure to various chemical compounds.