

WOOD-PLASTIC COMPOSITE LUMBER  
VS. WOOD DECKING  
*A COMPARISON OF PERFORMANCE CHARACTERISTICS AND  
ENVIRONMENTAL ATTRIBUTES*

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## Wood-Plastic Composite Lumber vs. Wood Decking

### *A Comparison of Performance Characteristics and Environmental Attributes*

#### Introduction

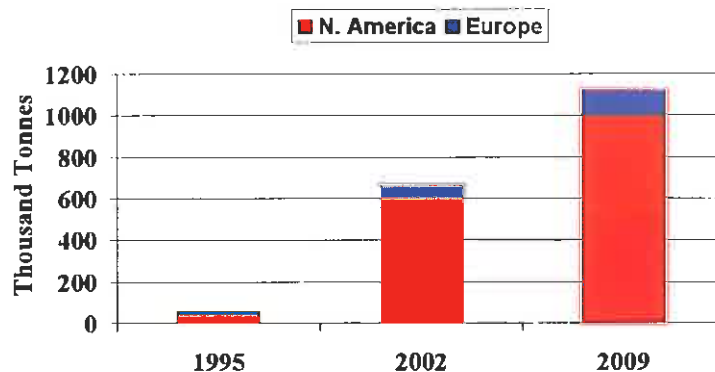
Plastic “lumber” products began appearing in U.S. markets in the late 1980s. Its development was stimulated both by the rising volume of largely un-recycled plastic waste for which uses were needed as well as by increasing consumer interest in more durable, lower maintenance outdoor products such as decking and fencing.

The major selling points for composite lumber are that it is free of potentially hazardous chemicals, and made largely from long-lasting, low-maintenance, recycled materials. It is, thus, often promoted as an environmentally preferable or “green” alternative to other decking materials. In this paper we examine the performance of wood-plastic composite (WPC) decking and its environmental properties. We also highlight a recently completed life cycle analysis (LCA) and comparison of WPC decking and western red cedar decking. The recent third-party LCA study considered a number of environmental performance measures.

#### Background

Early plastic lumber products lacked adequate structural stiffness, often resulting in sagging park benches and picnic tables. The next generation of products featured fiber reinforcement using wood, agricultural fibers, fiberglass, and other materials. The addition of fiber reinforcement markedly improved overall strength and stiffness, and rapid growth in wood and natural fiber polymer composites consumption followed (Figure 1). Recent trends in the United States suggest continued market growth for plastic and wood-plastic composite lumber (Figure 2); whether the prolonged recession will negatively impact projected 2013 consumption remains to be seen.

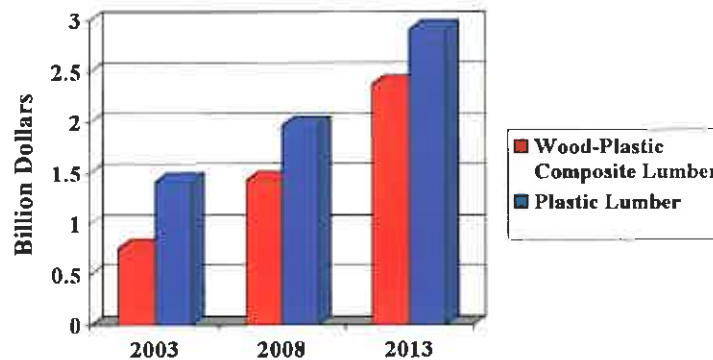
Figure 1  
Growth in North American and European Consumption  
of Wood-Plastic Composite and Plastic Lumber



Source: Data for 1995 and 2002 from PrincipiaPartners; values for 2009 from NovaInstitut (December 2009).

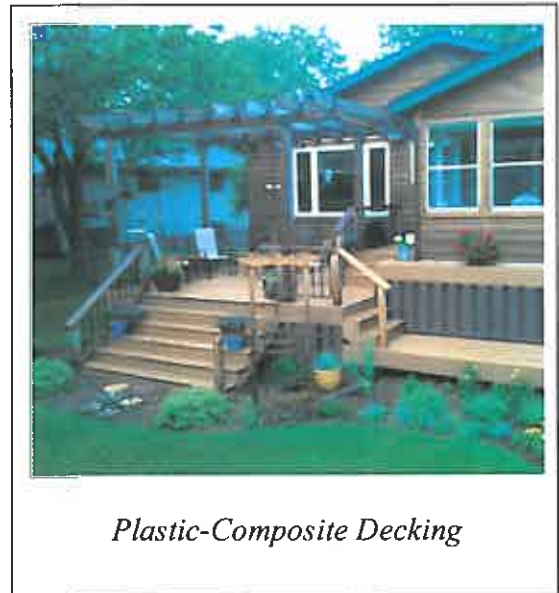
Wood-plastic composite (WPC) lumber is made primarily from high-density polyethylene (HDPE), recovered from the waste stream mainly in the form of used milk containers or recovered plastic bags, and from wood wastes (often planer shavings) that have been ground to a fine powder. A 50:50 mixture of plastic and wood is common. A few WPC products make use of low-density polyethylene, polypropylene, or polystyrene plastics and various materials other than wood, including agricultural fibers and fiberglass. While use of a high percentage of recovered plastic is common (100 percent is not unusual), some brands contain markedly less recycled plastic content and little to no post-consumer plastic content.

Figure 2  
Growth in U.S. Consumption of Wood-Plastic Composite and Plastic Lumber



Source: Freedonia Group, Inc. (2010)

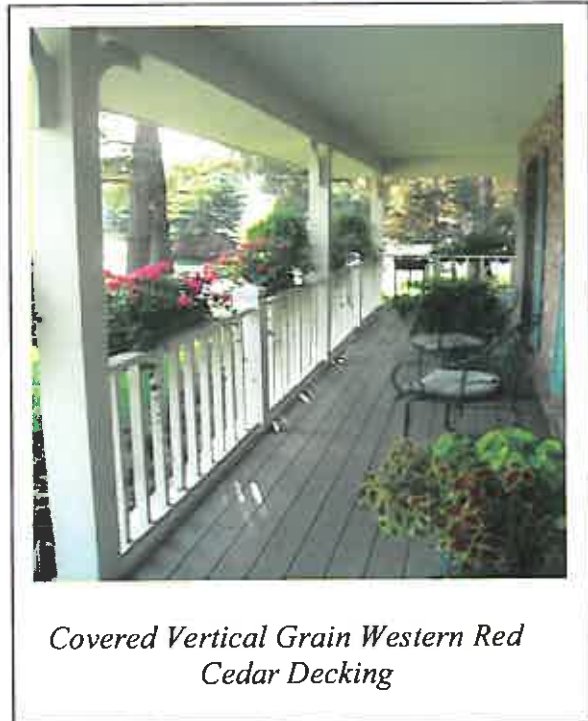
In addition to decking and fencing, plastic composite materials are being used today in making a wide variety of products including automotive parts, pallets, playground equipment, picnic tables, park benches and chairs, landscape timbers, railroad ties, and docks. Auto interiors and decking for outdoor applications represent the largest market for wood-plastic composites in both Europe and North America. Growth is most rapid, in both regions, in the decking segment. Plastic composite decking currently accounts for 10 percent of the residential decking market in North America and 6 percent in Europe. In the U.S., use of plastic composite materials for residential decking is projected to reach 23 and 32 percent of the total decking market by 2011 and 2016, respectively (Wood 2007). Solid wood remains the primary decking material globally.



## Durability and Maintenance

Comparing the most common decking material, solid lumber, with WPC decking – a material without a long-term track record of use – requires a bit of a leap of faith. On the one hand, the qualities of lumber are well known:

- ◆ Naturally durable species such as western red cedar or redwood, for instance, are known to last 20-25 years and more in a deck surface application, and even longer if periodically stained. Use of vertical grain lumber often provides even longer life. Deck boards, and especially sapwood zones that may be in them, eventually deteriorate, requiring replacement.
- ◆ Both naturally durable and treated wood decking will last for very long time periods, with minimum maintenance, when a deck is covered.
- ◆ All woods may check, split, cup, crook, twist, and warp, and weather over time to a grayish color.
- ◆ Treated wood exhibits long-term durability in a deck surface application, lasting as long, or longer, than naturally durable, untreated woods. Most such decks require periodic staining.



The qualities of WPC decking, on the other hand, are largely defined at this point by manufacturer's claims and those of various NGOs and other organizations. The EPA is quoted by Fox News as reporting that WPC products last indefinitely (Cant 2009). The EPA's GreenScapes website<sup>1</sup>, in fact, appears to wholeheartedly endorse plastic lumber over traditional materials for a wide variety of applications. But is sweeping endorsement justified? Is everything that is being said, in fact, true? A bit of investigation into WPC performance to date suggests that caution may be in order when considering such products. For instance, various sources document a number of problems that have been encountered with plastic composite decks and a recent study offers new information to help evaluate environmental impacts.

Before examining problems that have been encountered with WPC products it is worth noting that such products are relatively new, and that ongoing R&D is focused on addressing current problems. Morrell et al. (2010) and Breslin (2010) describe additives and processing modifications that have already helped to reduce performance problems. Shut (2005) also discusses efforts to improve product performance. Continued effort can be expected to improve the performance of these products going forward.

<sup>1</sup> <http://www.epa.gov/wastes/conservc/trr/greenscapes/>

Documented WPC problems include:

- ◆ *Mold and mildew development.* The same types of mold and mildew that affect solid wood can also develop within WPCs (Ibach 2010). Numerous sources report that mold and mildew in WPCs can lead to unsightly blotchy appearance of surfaces and through the product thickness.
- ◆ *Biodeterioration.* Morrell et al. (2010) cites over a dozen studies reported between 2000 and 2009 that “clearly illustrate that the wood in many WPCs remains susceptible to degradation.” Ibach et al. (2003) documented decay (degradation resulting from fungal activity) in WPC lumber and noted in a more recent article (Ibach 2010) that fungal degradation remains a problem.
- ◆ *Moisture cycling.* Morrell et al. (2010) found that moisture uptake and loss, and accompanying swelling and shrinking, has been observed in WPCs, a problem that can result in cracking and surface degradation. Several manufacturers advertise products that utilize fiberglass rather than wood or other natural fiber, or that are made of a high percentage of polyethylene and additives to address potential moisture issues, such as might occur when plastic composites are used in marine environments, (Power 2004).
- ◆ *UV degradation.* Just as with wood, exposure to ultraviolet light can adversely affect surface quality and reduce stiffness. Winandy et al. (2004) reported that UV exposure can change the structure of WPCs during their service life.
- ◆ *Fading.* Stark et al. (2003) documented marked fading of WPC decking at 1000 hours of sunlight exposure (within a single summer season), with continued fading through 3000 hours. This research group also found a marked reduction in WPC stiffness associated with sunlight exposure.
- ◆ *Discoloration.* Several WPC decking manufacturers/distributors recommend protection of decks through the use of grill mats and immediate cleaning of greases and oils in order to avoid staining and discoloration, indicating that this is a potential problem in at least some product lines.<sup>2</sup>

The preceding list reveals that many of the same problems that characterize solid wood decking also occur in WPC decking.

### **Environmental Impacts of Decking Production and Use**

While there have been detractors (Platt et al. 2005), plastic lumber is often promoted as a green product based on the fact that it is typically manufactured from recycled plastic and also because of perceived longevity and relative freedom from maintenance. Up until recently, however, there has been no systematic analysis of the environmental impacts of WPC lumber production and use. A new report from FPInnovations (Mahalle and O’Connor 2009) details the results of a life cycle assessment of western red cedar vs. WPC decking. The study was commissioned by the Western Red Cedar Association, but performed independently by FPInnovations-Forintek Division. It is the only known LCA conducted to date on solid wood vs. WPC decking.

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<sup>2</sup> These problems and more are also discussed by Shut (2005).

## *Life Cycle Assessment*

Environmental life cycle analysis (sometimes referred to as life cycle assessment), or LCA, provides a mechanism for systematically evaluating the environmental impacts linked to a product or process and can aid 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. The use of LCA is increasing because of the systematic nature of LCA and its power as an evaluative tool. LCA is also gaining recognition as environmental performance becomes more and more important in society. It is likely that LCA will soon become widely used within American industry and by those involved in crafting national and regional environmental policy.

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, and emissions to air (SO<sub>2</sub>, NO<sub>x</sub>, and increasing concentrations of atmospheric carbon dioxide). An LCI may deal with product manufacture only, or the study boundaries may be defined more broadly to include product use, maintenance, and disposal. In a subsequent stage of the LCA, factors are considered that are currently not precisely measurable, such as impacts of an industrial activity on the landscape, flora, fauna, air, or water. For a more complete discussion of LCA, see the January 2005 Dovetail report *Life Cycle Analysis: A Key to Better Environmental Decisions*.<sup>3</sup>

### *A Life Cycle Comparison of Solid Naturally Durable Lumber and WPC Decking*

#### Assessment Framework

In March 2009 FPInnovations Forintek Division released a 142-page summary of a life cycle assessment of western red cedar siding, decking, and alternative products (Mahalle and O'Connor 2009). Western red cedar decking, WPC decking made using virgin polyethylene, and WPC decking made using 100 percent recycled polyethylene were among the product options examined. The study was done in compliance with the international life cycle inventory (LCI) and life cycle impact assessment (LCIA) standards promulgated by the International Organization for Standardization (ISO) in the form of ISO standard 14040/44:2006 series.

The functional unit used in this study was 100 ft.<sup>2</sup> of installed decking for a defined service life of 25 years. Environmental impact measures examined included embodied energy (or more specifically total primary energy on a cumulative demand basis), global warming potential, acidification potential, aquatic eutrophication<sup>4</sup> potential, ozone depletion, smog formation potential, and human respiratory effects.

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<sup>3</sup> <http://www.dovetailinc.org/documents/DovetailLCA0105.pdf>

<sup>4</sup> A eutrophic body of water, commonly a lake or pond has high primary productivity due to excessive nutrients and is subject to algal blooms resulting in poor water quality. The bottom waters of such bodies are commonly deficient in oxygen. (<http://en.wikipedia.org/wiki/Eutrophic>).

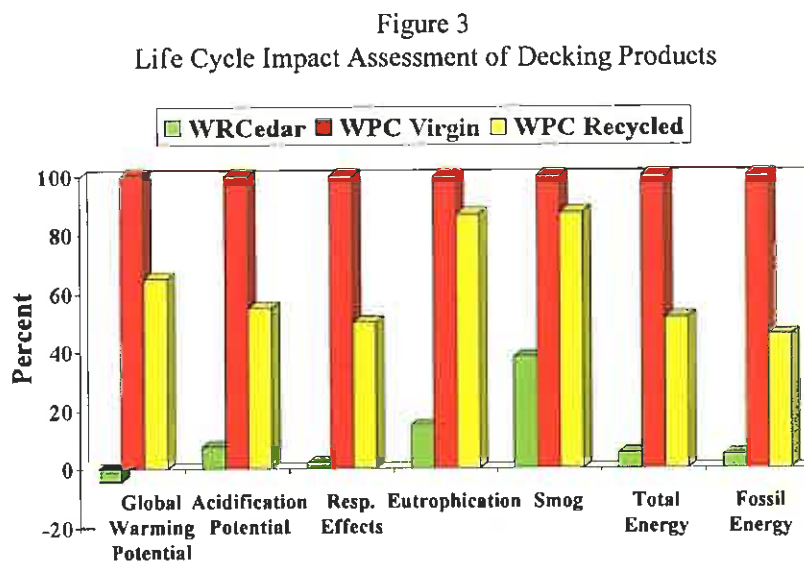
The study’s assumptions were as follows:

- ◆ Deck boards are 5/4” x 6” solid planks for both cedar and WPC.
- ◆ Decking products have a 25-year service life with no coatings or board replacements (subsequent sensitivity analyses considered the impact of replacing 20% of cedar boards and periodically staining the cedar)
- ◆ All products are disposed of in a landfill at the end of life.
- ◆ All environmental flows are attributed 100% to the decking products, although in the case of cedar some flows could fairly (and properly) be allocated to co-products such as mulch or shavings.
- ◆ All activities or building elements common to all products (such as transportation, installation and use, and end of life disposition) are considered equivalent and ignored.
- ◆ The western red cedar decking is produced in the Pacific Northwest region of the U.S. while the WPC plastic decking is produced in the eastern U.S.

Considered in the assessment for both cedar and WPC decking were resource extraction (and collection of plastic for recycling in the case of WPC), reforestation (in the case of cedar decking), resource transportation, manufacturing, transportation to site (for three hypothetical building site locations), installation, use, maintenance (excluding cleaning since annual cleaning is recommended for both cedar and WPC decks), and end-of-life disposal.

Findings

Study results that reflect basic assumptions are summarized in Figure 3. In each set of bars, the product with the highest impact in that category is the benchmark (100%). The values for other products are shown as a percentage relative to the benchmark.



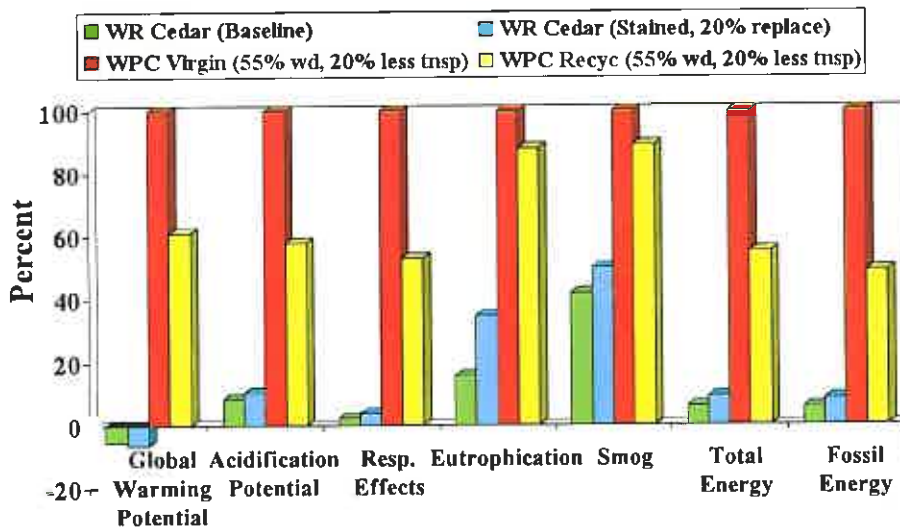
Source: Mahalle and O’Connor (2009)

For every environmental measure, wood-plastic composite decking made using virgin polyethylene corresponds to the highest values and the greatest impact (Figure 3). Also, for every measure, western red cedar decking yields the lowest values and the lowest environmental impacts, and by a wide margin. Comparing the WPC decking made with recycled plastic (yellow bars) and western red cedar decking (green bars) again shows impact measures associated with cedar decking to be far lower. With respect to global warming potential (far left bars), note that the value for cedar is negative (less than zero); this is because the quantity of carbon contained within the wood of the decking product itself is greater than the equivalent greenhouses gas emissions throughout its life cycle.

Considerable quantities of carbon are also contained within WPC lumber, but energy use in the manufacture of this product results in emissions of far greater quantities of carbon (or carbon dioxide equivalents) than are contained in the finished product. Thus, the global warming potential associated with WPC products is relatively large.

To test the impact of changes in key assumptions a sensitivity analysis was performed. In the base case it was assumed that western red cedar decking was not stained and that no deck boards would be replaced over the life of the deck. In the sensitivity analysis periodic staining was assumed, as was replacement of 20% of the deck boards over the 25-year life of the deck. With respect to WPC decking, the sensitivity analysis investigated the impacts of increasing the proportion of wood from 50% to 55% (and thereby reducing the proportion of plastic), and of reducing transportation distances by 20%. Periodic staining and deck board replacement in cedar decks increases the environmental impacts, while increasing the proportion of wood in WPC decking and reducing transportation distances decreases the impacts. The results of the analysis are shown in Figure 4.

Figure 4  
Life Cycle Impact Assessment of Decking Products – Sensitivity Analysis



Source: Mahalle and O'Connor (2009)

Comparing the worst case scenario evaluated for cedar decking (blue bars in figure 4) with the best case scenario evaluated for WPC decking (yellow bars) again shows large differences in environmental impact measures, with lower impacts consistently associated with cedar decking.



But what if plastic decking lasts a very long time? Though not explicitly examined in the FP Innovations study, the effect of extraordinary product life can be seen through re-examination of Figure 3. Note that even if WPC lumber were to have a service life double or even triple that of solid lumber, the environmental performance measures would nonetheless decidedly favor solid lumber. The same result, through less dramatic, can be seen in Figure 4.

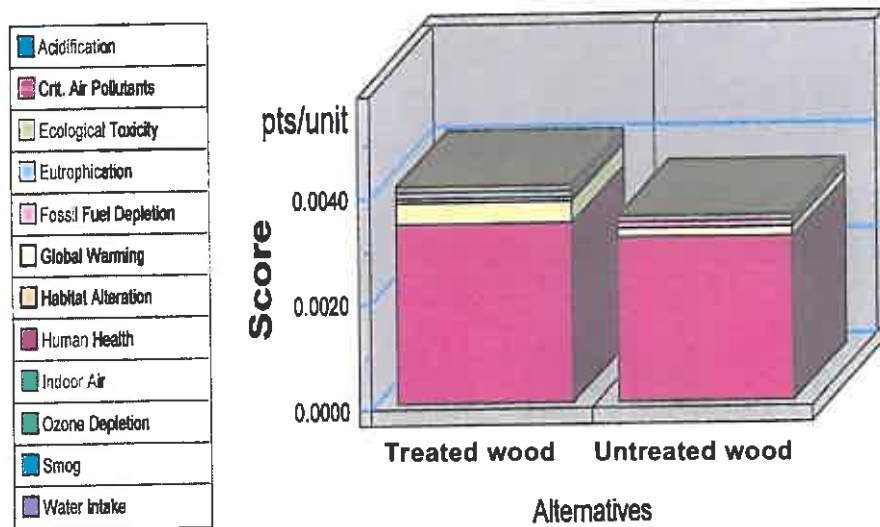
*Comparisons of Treated Solid Wood and WPC Lumber*

Comprehensive life cycle comparisons of treated solid wood and WPC lumber products have not yet been conducted. However, an indication of how treated solid wood lumber might compare to WPC lumber with regard to environmental measures can be obtained by studying life cycle comparisons of treated and untreated lumber, and then considering findings in light of the comparison of naturally durable lumber and WPC lumber discussed previously.

For instance, a life cycle comparison of treated and untreated lumber is included in the Building for Environmental and Economic Sustainability (BEES) program of the Building and Fire Research Laboratory of the National Institute for Standards and Technology (National Institute for Standards and Technology 2007). This analysis shows higher impacts for treated wood<sup>5</sup> than those associated with untreated wood in every environmental performance category. However, the weighted environmental performance score across all categories shows impacts only marginally higher than for untreated wood (Figure 5). As a result, a comparison of solid treated wood with WPC composite lumber can be expected to show similar results to the comparison of naturally durable, untreated solid wood to WPC lumber. An important difference relates to the presence of added chemicals in treated wood that are not present in either untreated wood or most WPC lumber products.

Figure 5

A Comparison of Environmental Impacts of Treated and Untreated Lumber Framing Using the BEES 4.0 Model



Note: Lower values indicate lower impact.

<sup>5</sup> The wood in this analysis was treated with ACQ (alkaline copper quaternary), a copper-based preservative, the most popular replacement preservative for CCA. This contains 66.7 % copper oxide and 33.3 % didecyldimethyl ammonium chloride.

## Raw Material Availability Issues

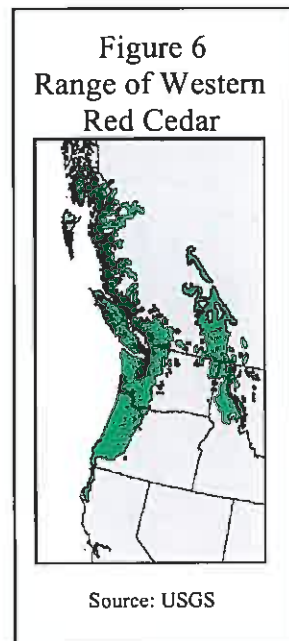
### *Waste Plastic*

In 2008, 30+ million tons of plastic materials were contained within the nation's municipal solid waste (MSW). Of this, 7.1 percent was recovered for recycling. Of the approximately 6 million tons of HDPE in the form of white translucent bottles in MSW, 29.3 percent was recovered for reuse (USEPA 2010), with some of this going into production of WPC lumber.

Raw material availability is not likely to inhibit production of plastic composite products within the near term given the vast quantities of waste plastic available, the considerable potential of increased recovery for recycling, and the possibility of using types of plastics other than HDPE in plastic composite products. Over the longer term, a rise in energy prices that would make burning of plastics (as well as the wood used in WPC) for power a more competitive economic proposition could change the raw material picture.

### *Lumber Used in Making Treated Wood Products and Wood Used in WPC*

Supplies of lumber commonly used for production of treated wood products are abundant. Wood in the form of shavings or sawdust that is used along with recycled plastic in making WPC is likewise abundant. In the most recent assessment of U.S. forest land (USDA-Forest Service, RPA Assessment 2010) net growth was estimated to exceed removals by 72%; for softwood species often used in decks and other treated wood products, the ratio of net growth to removals is about 1.55 (i.e., wood volumes added to forests annually exceed volumes removed annually by over 50%, meaning that the inventory of wood contained within the nation's forests is increasing steadily).



### *Naturally Durable Wood*

Western red cedar, the naturally durable wood highlighted in this report, grows over a relatively limited range of the U.S. and Canada (Figure 6). As explained by Shaw (2009), there are two main clusters of Western redcedar. One arcs along the coast from northwestern California up to southeastern Alaska along the Cascades and Coast Range; the other is centered in the Rocky Mountains from Idaho and Montana north into British Columbia. Canada has the greatest volume of Western redcedar, about 824 million m<sup>3</sup> compared to 228 million m<sup>3</sup> in the United States. Thus, supplies are large yet limited. Assuming a harvest of about 0.5% of volume per year would yield approximately 1.4 billion board feet annually.

While sufficient volumes of western red cedar are not available to supply anything close to the entire North American decking market (4-5 billion board feet annually in recent peak years), cedar can be expected to provide an ongoing alternative to other decking products.

Wood species other than western red cedar are also often used untreated in decking applications. These include other types of cedar, redwood, and Douglas fir. Together, these are sustainably available in very large volumes, with environmental impacts of production similar to those of western red cedar.

## The Bottom Line

Wood plastic composites provide an exciting alternative to solid wood for many applications. These products are relatively new, under constant development, and are likely to improve over time.

WPC products, on the other hand, have many of the same limitations as wood in exterior uses, a reality that requires a dose of caution for anyone considering their use. Moreover, a robust life cycle assessment indicates that WPCs have substantially higher environmental impacts in comparison to a naturally durable solid wood product such as western red cedar. While WPCs may be made completely, or nearly so, from recycled content, the overall environmental impact of WPC products is nonetheless large as compared to impacts linked to traditional solid-wood decking products.

For anyone seeking to build an environmentally responsible structure, a thorough investigation of environmental attributes of alternatives is always recommended. Single attributes – such as recycled content – while important, do not tell the whole story and need to be considered holistically.

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