Terminology

Typical environmental impacts of interest:

Material usage: amount of material used, expressed in terms of mass and/or volume.

Embodied energy: amount of energy associated with extracting, processing, manufacturing, transporting, and assembly of building materials.

Global Warming Potential (GWP): a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale which compares the gas in question to the same mass of carbon dioxide (the GWP of which is by convention equal to 1). A GWP is calculated over a specific time interval which must be stated whenever a GWP is quoted.

Air pollution: sulphur dioxide, nitrous oxides, methane, particulates, and volatile organic compounds.

Solid waste generation: solid waste generated during manufacturing and construction.

Water consumption: quantity of water use associated with a material process.

Water pollution: the effluent deposited into water bodies.

Wood Specification: Life Cycle Assessment

The best way to determine the full environmental impacts of a building product or design is through life cycle assessment (LCA). LCA analyzes the total environmental impacts of all materials and energy flows, either as input or output, over the life of a product from raw material to end-of-life disposal or to rebirth as a new product. For buildings and building products this includes resource extraction, manufacturing, on-site construction, occupancy, and eventual demolition and disposal or reuse. LCA-based Environmental Product Declarations (EPDs) also provide information about environmental impacts during the manufacture and life of a product. All of the major green building rating systems and model codes in North America recognize and encourage use of LCA and/or EPDs in building design and materials selection.

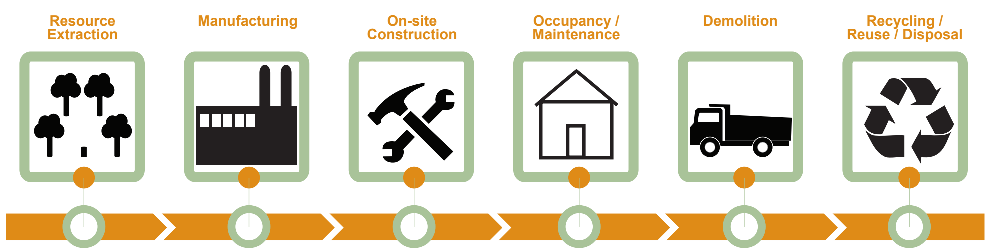
Why Life Cycle Assessment Adds Value

- Sustainable design is complex and integrated. One way to understand the complex interaction of factors involved in new construction, renovation, and retrofits is through life cycle assessment. LCA provides information about ongoing environmental impacts of building operation as well as upstream environmental burdens of the building materials and products.
- Life cycle assessment provides measurable outputs that can help clients make meaningful decisions that not only affect their real estate portfolio but also inform their climate change mitigation strategies and their corporate marketing and recruitment efforts.
- Commercial building clients are looking more closely at the environmental impacts of their operations and investments. Spurred by regulation and market forces, many corporations are committing to reporting their quality assurance and environmental initiatives and to tracking their improvements.
- Application of LCA to building design and use of LCA and/or EPDs in materials selection can gain credits in pursuit of green building certification.
- The life cycle assessment process is defined under ISO 14040/14044 (Environmental Management—Life Cycle Assessment—Principles and Framework / Environmental Management—Life Cycle Assessment—Requirements and Guidelines) which is part of the internationally recognized series of standards that address environmental management and is familiar to most businesses.

An Environmental Product Declaration (EPD) is a standardized report of environmental impacts linked to a product or service. More explicitly, an EPD is a standardized, third-party verified, and LCA-based label that communicates the environmental performance of a product and that is applicable worldwide.

An EPD includes information about both product attributes and production impacts and provides consistent and comparable information to industrial customers and end-use consumers regarding environmental impacts. The nature of EPDs also allows summation of environmental impacts along a product's supply chain – a powerful feature that greatly enhances the utility of LCA-based information

Incorporating life cycle assessment positions a business as an industry leader and provides it with a competitive advantage, particularly in markets where LCA is recognized. Taking a proactive position also reduces costs associated with future regulatory compliance.



Life Cycle of Building Products

Wood Specification: Life Cycle Assessment

Wood: A Carbon-neutral Building Material

- Manufacturing of wood products requires less total energy, and in particular less non-renewable (fossil) energy, than the manufacturing of most alternative materials.
- The drying process accounts for most of the energy used in the manufacture of wood products. Wood processing residues (such as sawdust) are commonly used to fuel the drying, avoiding depletion of fossil fuels.
- When sustainable forestry is practiced trees, and the carbon they contain, are replenished as they are harvested. Carbon is obtained from atmospheric CO2 via photosynthesis, becoming part of wood as a tree grows in height and diameter.
- Timber-based building products continue to store carbon absorbed during the tree's growing cycle for as long as they are in use. The capacity of trees to absorb and store carbon can be factored against the carbon emissions incurred during drying, processing, and transporting wood products. The result is a very low carbon building material.

How to Include Life Cycle Assessment in Design

Early green building rating initiatives in North America all were built upon lists of specific prescribed measures for reducing energy consumption and various environmental impacts. Such measures remain in place today within many green building rating systems. Arranged within categories such as Energy, Water, Indoor Air Quality, Materials and Resources, and Site, prescriptive lists of recommended or required measures for addressing specific concerns outline the path toward environmentally better buildings. Each measure typically addresses a single concern or attribute such as recycled, recycled content, rapidly renewable, and local. Recommendations for improving environmental performance of buildings and construction practices have long varied among the various rating initiatives. Within this context, recommendations for use of wood and wood products varied as well.

Most of the 42 green building programs in use in North America today continue to rely on prescriptive provisions. However, a shift away from prescriptive measures and toward performance and systematic assessment has begun that is reflected in Green Globes, LEED and several other rating systems, as well as in CalGreen, and in the IgCC and ASHRAE 189.1 model codes.

The move away from a prescriptive basis and toward a performance basis involves emphasis on reliance on systematic, life cycle assessment-based tools and sources of information. It is a major step forward, and a change that allows simultaneous, systematic, science-based consideration of multiple attributes rather than adherence to intuition-based single attributes.

Credit can be achieved (and invaluable information about building design can be gained) through use of life cycle assessment of at least two alternative designs or of successive iterations in the design process. Use of EPDs to inform building product choices also provides essential information while also gaining credits within leading green building programs.

Applicable worldwide, EPDs are a standardized (ISO 14025) tool for communicating the environmental performance of a product or system. Europe, Asia and Australia have been the most advanced economies to use environmental product declarations.

Next Steps: Where Proficiency in Life Cycle Assessment can Lead

Life cycle assessment (LCA) is sometimes described as mysterious and extremely complicated. Yet, what is involved is simply a thorough accounting of resource consumption, including energy, and emissions and wastes associated with production and use of a product. For a "product" as complex as a building this means tracking and adding up inputs and outputs for all assemblies and subassemblies – every framing member, panel, fastener, finish material, coating, and so on. Further, to ensure that results and data developed by different LCA practitioners and in different countries are comparable (i.e. that results allow apples to apples comparisons) LCA practitioners must strictly adhere to a set of international guidelines as set forth by the International Organization for Standardization (ISO). Tracking products and co-products through a supply chain and properly allocating resource use, emissions and wastes to various outputs can indeed be a complicated and expensive procedure for those who conduct assessments. However, for users of LCA tools, information has never been easier to access. User-friendly, low-cost (in most cases free) LCA tools allow building designers to rapidly obtain life cycle impact information for an extensive range of generic building assemblies, or with a bit more work and modest investment to develop full building life cycle analyses on their own. LCA-based data is now also available in the form of easy-to-understand, standard format environmental product declarations (EPDs) for a wide range of products.

Life Cycle Assessment Tools

LCA software offers building professionals powerful tools for comparing products and calculating the lifetime impacts of building products or assemblies. Data gathered via LCA are of particular interest to long-term building investors who are concerned about the overall impacts of their buildings and about protecting the value of their assets.

A summary of tools is available on the website of the United States Environmental Protection Agency (http://www.epa.gov/nrmrl/lcaccess/resources.html). The most popular are listed below.

For General Building Professionals

- ***ATHENA EcoCalculator for Assemblies and Impact Estimator for Buildings* (www.athenasmi.org/our-software-data/overview/):** free inventory data tool for comparing assemblies or whole buildings, based primarily on the widely acclaimed US Life Cycle Inventory Database and published Canadian data.
- **BEES (http://www.nist.gov/el/economics/BEESSoftware.cfm):** easy-to-use, US-based, free tool for product-to-product comparisons; based on proprietary, unpublished data.
- **ENVEST (http://envestv2.bre.co.uk/):** UK-based, life cycle assessment-based building design tool. It addresses only the whole building, and provides results in highly summarized "ecopoints."
- **Forest Industry Carbon Assessment Tool (FICAT) (http://www.ficatmodel.org/landing/index.html):** available for download free of charge, calculates carbon footprints of the effects of forest-based manufacturing activities on carbon and greenhouse gases along the value chain.

For Life Cycle Assessment Practitioners

- **GaBi (www.gabi-software.com):** a tool from Germany, comprised of primarily European data.
- **SimaPro (http://www.pre.nl/simapro):** a tool from the Netherlands; includes a comprehensive suite of databases for building materials applicable to the United States, Japan, and various European countries.

EPDs and Forest Certification

The wood industry has been a leader in the development of Environmental Product declarations (EPDs). An EPD is a standardized, third-party verified label that communicates the environmental performance of a product, is based on ICA, and is applicable worldwide.

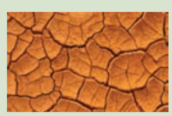
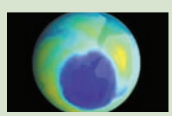
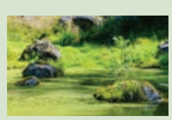
An EPD includes information about both product attributes and production impacts and provides consistent and comparable information to industrial customers and end-use consumers regarding environmental impacts. the nature of EPDs also allows summation of environmental impacts along a product's supply chain—a powerful feature that greatly enhances the utility of LCA-based information.

In the case of wood products, sustainable forest management certification complements the information in an EPD, providing a more complete picture by encompassing parameters not covered in an LCA—such as biodiversity conservation, soil and water quality, and the protection of wildlife habitat.

EPDs for wood products are available from the American Wood Council (www.awc.org) and Canadian Wood Council (www.cwc.org) at http://www.awc.org/greenbuilding/epd.php .

Impact Category Indicators Table from the Softwood Lumber EPD:

The life cycle impact assessment (LCIA) results are calculated for impact category indicators such as global warming potential and smog potential. These results provide general, but quantifiable, indications of potential environmental impacts. The various indicators and means of characterizing the impacts are summarized in this table.

Impact Assessment Categories	
Impact Category Indicators	**Characterization Model**
Global Warming Potential 	Calculates global warming potential of all greenhouse gasses that are recognized by the Intergovernmental Panel on Climate Change. The characterization model scales substances that include methane and nitrous oxide to the common unit of kg CO_2 equivalents.
Ozone Depletion Potential 	Calculates potential impact of all substances that contribute to stratospheric ozone depletion. The characterization model scales substances that include chlorofluorocarbon, hydrochlorofluorocarbon, chlorine, and bromine to the common unit of kg CFC-11 equivalents.
Acidification Potential 	Calculates potential impacts of all substances that contribute to terrestrial acidicication potential. The characterization model scales substances that include sulfur oxides, nitrogen oxides, and ammonia to the common unit of H^+moles equivalents.
Smog Potential 	Calculates potential impacts of all substances that contribute to photochemical smog potential. The characterization model scales substances that include nitrogen oxides and volatile organic com pounds to the common unit of kg O_3 equivalents.
Eutrophication Potential 	Calculates potential impacts of all substances that contribute to eutrophication potential. The characterization model scales sub-stances that include nitrates and phosphates to the common unit of kg N equivalents.

Wood Specification: Life Cycle Assessment

What to Ask Suppliers

Encourage product manufacturers to perform life cycle assessments on their products and make the results available. Ask product reps for LCA data and LCA-based EPDs for wood and all other products on the bill of materials. If lacking, encourage sourcing from manufacturers that do provide such information. Ask or consider key questions about the data that are provided in order to assess the reliability and applicability to design decisions.

Examples of such questions include:

- What are the sources of the data? How much is based on primary information obtained directly from the operations, as opposed to databases of industry-average data? Of the industry average data, is it regionally specific (U.S. as opposed to Europe) and fully transparent to users or peer reviewers?
- What assumptions are included about the functional unit and the service life of the product(s) in question? Do these correspond to the project at hand?
- What is included in any life cycle assessment or life cycle cost calculation? Sometimes, certain materials or components are excluded, e.g., the resin in a composite wood product.
- What is assumed about the products' maintenance requirements and/or impacts on building operations?
- Do the impact categories included in the results capture the important information, or might the results be skewed by leaving out key categories?

Resources

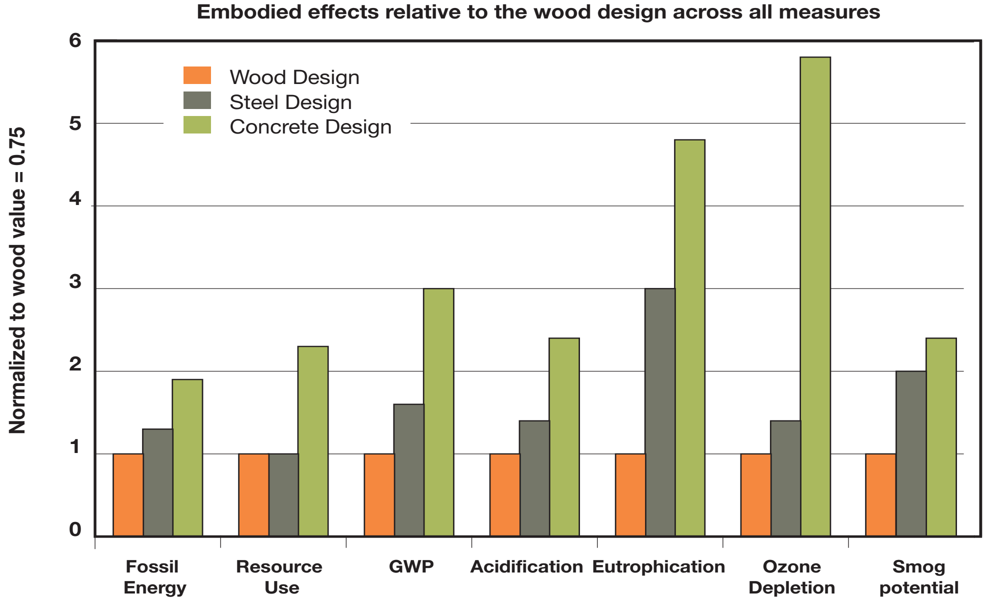
Lawrence Berkeley National Laboratory, High-Performance Commercial Building Systems (http://buildings.lbl.gov): is developing a set of life cycle cost tools for improving commercial building performance.

Whole Building Design Guide—Life Cycle Tools (www.wbdg.org/tools/tools_cat.php?c=3): developed by the National Institute of Building Sciences in the United States, provides a variety of life cycle cost and assessment tools.

European Commission, Life Cycle Thinking (http://lct.jrc.ec.europa.eu/): home of the International Reference Life Cycle Data System which seeks to identify improvements to goods and services in the form of lower environmental impacts and reduced use of resources across all life cycle stages. The site includes a handbook and information about the European Platform on Life Cycle Assessment and the European Reference Life Cycle Database (ELCD core database v2 with 300+ processes).

United Nations Environment Program, Life Cycle Initiative (http://lcinitiative.unep.fr/): aims to bring science-based life cycle approaches into practice worldwide.

Embodied effects relative to the wood design across all measures



Rule of Thumb

Material	Embodied energy, ranked by density MJ/m^3
Straw bale	31
Cellulose insulation	112
Mineral wool insulation	139
Aggregate	150
Soil-cement	819
Fiberglass insulation	970
Lumber	1,380
Stone, local	2,030
Concrete, block	2,350
Concrete, precast	2,780
Concrete (30 MPa)	3,180
Polystyrene insulation	3,770
Particleboard	4,400
Shingles, asphalt	4,930
Brick	5170
Plywood	5,720
Gypsum insulation	5,890
Aluminium, recycled	21,870
Steel, recycled	37,210
Glass	37,550
Carpet, synthetic	84,900
PVC	93,620
Paint	117,500
Linoleum	150,930
Steel	251,200
Zinc	371,280
Aluminium	515,700
Brass	519,560
Copper	631,164

Source: The Canadian Architect

Note: this table does not differentiate the impacts and efficiencies of source energy generation used in extraction, transportation or manufacture. For example, the Swiss Minergie rating system (www.minergie.com) weights energy carrier and sources as follows: Biomass (wood, biogas) 0,5 Waste heat (sewage, industry, etc.) 0,6 Fossil fuels 1,0 and Electricity 2,0.

Note: Cubic metres may not be an appropriate unit for comparison between materials (not a functional unit).

Comparing Environmental Impact of a Wood, Steel and Concrete Home

In this graph, three hypothetical buildings (wood, steel, and concrete) of identical size and configuration are compared. Assessment results are summarized into seven key measures covering fossil energy consumption, weighted resource use, global warming potential, and measures of potential for acidification, eutrophication, ozone depletion, and smog formation.

In all cases, impacts are lower for the wood design. Source: Dovetail Partners using the Athena Eco-Calculator (2014)

Wood Specification: Locally Produced Materials

Locally produced materials are often sought because they match a local design aesthetic and can be more durable in the local climate. However, choosing local materials also supports local economies and reduces the environmental impacts of transportation.

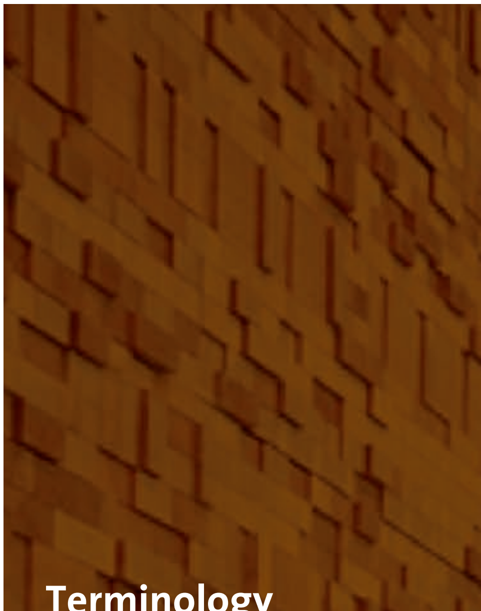
For purposes of gaining credits in green building rating systems, documentation as outlined below is important only if working within older versions of LEED (2009) or other programs where local materials were considered to be those where all materials and components originated from within a 500 mile radius. Documentation is now needed only for those materials sourced from within a 100 mile radius if seeking credits under LEED v4.

Why Locally Produced Wood Adds Value

- Locally sourced materials may be more cost-effective because of reduced transportation costs, although these savings may be offset by the higher costs associated with complying with more demanding social and environmental legislation.
- In some jurisdictions, governments have recognized the value of wood and have put in place programs and incentives to encourage the incorporation of wood into building design.
- The support of local manufacturers and labour forces retains capital in the community, thus contributing to a more stable tax base and a healthier local economy as well as showcasing the resources and skills of the region.
- Green building rating systems award credits where a prescribed percentage of locally produced materials are used in a building's design.

How to Include Locally Produced Wood in Design

- Getting to know the region is central to the practice of design. Develop relationships with local contractors and developers to determine where materials are from and what regional options are available. Being familiar with local policies that promote local materials is essential.
- Establish and maintain a library of regional materials and manufacturers for ready access during the design phase.
- It is important to set goals early in the design process for the use of locally produced wood and other materials. Assess the availability of regional materials and determine the best available products to minimize the project's environmental impacts. This may require careful research to determine what local products are available.
- The use of life cycle assessment tools may prove helpful in the decision-making process because local materials may have a significantly lower carbon footprint than imported alternatives.
- Set appropriate local materials targets based on the project's budget and ensure related requirements are captured in the construction documents along with approved alternatives.



Terminology

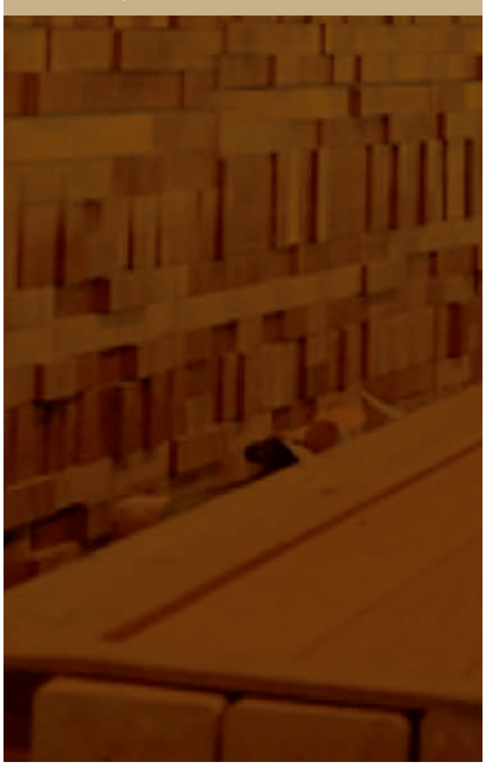
Extraction:
the removal of natural materials from the earth for the purposes of human use.

Harvested:
refers to all or part of a plant that has been collected and removed from the location of its growth.

Site of final manufacture:
the location where final assembly of components into the building product takes place.

Manufacturing process:
activities associated with the production of materials, goods, or products.

Processing:
operations involved in the manufacture or treatment of a product or material.



Wood Specification: Locally Produced Materials

What to Ask Suppliers

- Regarding the materials used to make the product, where were they extracted, harvested, or processed?
- Where was the final product manufactured?
- How far are these locations from the project site?
- How were the materials transported to the project site? Were they delivered by rail, water, or truck?
- Documentation, such as a letter from the manufacturer, or environmental information sheets, demonstrating the proportion of local materials in the total assembly of the product (based on weight) must be acquired from the manufacturer or the supplier.

Photo: Moresby Creative

Procedure

- When working with green building rating systems, it is important to establish and track information about the manufacturers and the product costs. It is also important to document the distance between the project site and the manufacturers' locations, and the distances between the manufacturers' locations and the extraction, processing, and manufacturing sites. Record the mode of travel for each raw material in each product too.
- Material technical data must be acquired from suppliers, usually in the form of environmental information sheets and technical spec sheets.
- Where appropriate, maintain a list of material costs, excluding labor and equipment.
- If working wih LEED 2009 or other rating systems patterned after LEED, for assemblies or products made with components originating from within a 500-mile (800-km) radius of the project site. If working within LEED v4, keep data only for products sourced within a 100 mile radius.
- The percentage of locally produced materials is calculated by dividing the cost of locally produced materials by the total cost of materials. Total material costs are obtained either by multiplying total construction costs by 0.45 or by calculating the actual material costs, if known.
- If only a fraction of a product or material is extracted, harvested, recovered, processed, and manufactured locally, then only that percentage (by weight) must contribute to the regional value. Furniture may be included in calculating the percentage of locally produced materials.
- Life cycle assessment tools can provide comprehensive information about the impacts of using local products. Most life cycle assessment tools provide regionally specific data.

percentage of local materials =

$$\frac{\text{total cost of local materials (\$)}}{\text{total material cost (\$)}} \times 100$$

Pre-design: calculate baseline budget

Design: estimate the total cost of materials for site work and construction sections.

or

Design: use the default budget if seeking to avoid breaking out material and labour costs.

Design: on a map, draw a 500-mile (800-km) radius around the project site, and identify major extraction and manufacturing sites.

Contract Documentation: starting with big-ticket materials, specify products from regional sources.

Construction: track regional materials on a spreadsheet. This process can be included in a larger analysis of all materials applicable to resource credits because the regional materials may contribute to other credits as well. Calculate percentages for points, and reassess as needed.

Throughout: revisit the project's budget calculations throughout design and construction to ensure the project is on track to achieve its goals.

Wood Specification: Recycled Materials

Recycled content products are made from materials that would otherwise have been discarded either during the manufacturing process (pre-consumer) or at the end of service life (post-consumer). Specifying recycled content products plays an essential part in reducing the amount of waste that goes to landfills, the energy consumption and greenhouse gas emissions associated with new product manufacture, and the impacts of ecosystem degradation associated with resource extraction.

The use of wood products with recycled content is relatively straightforward. Products such as:

- **particleboard**
- **oriented strand board**
- **parallel strand lumber**

are cost effective, familiar to the trades, and can contribute a high proportion of recycled content to the overall calculations. Furniture is generally not included in calculating the percentage of recycled content.

Why Recycled Materials Add Value

- Building products that include some or all recycled content reduce the need for virgin materials in new construction. Using recycled materials reduces the need to landfill these materials. It also reduces the environmental impacts associated with extracting and processing virgin materials.
- Buying recycled-content building products helps to ensure that materials collected in recycling programs will be used again in the manufacture of new products. Benefits of maximizing the recycled content in materials include the ability to:
  - › Demonstrate performance against corporate responsibility and sustainability policies without incurring a cost premium
  - › Reduce materials cost; e.g., where locally reprocessed demolition materials are cheaper than virgin materials
  - › Provide a competitive edge through differentiation
  - › Make reclamation and recycling more economic
  - › Satisfy the values held by clients and their employees
  - › Complement other aspects of sustainable design
- Green building rating systems award credits where a prescribed percentage of materials containing recycled content is used in a building's design.

How to Include Products Containing Recycled Content in Design

- Many products with higher levels of recycled content are available from mainstream manufacturers—who subject the products to the usual tests—in high volumes, and at costs that are competitive with equivalent products containing less recycled material.
- It is important to set goals early in the design process and to document them in the specification documents as part of the project's overall green building goals. Set appropriate recycled content targets based on the project's budget and ensure related requirements are captured in the construction documents along with approved alternatives.
- Increasing the recycled content of building materials need not impact design nor restrict the choice of products. Simply select products containing higher levels of recycled material in place of products containing lower amounts.
- The use of life cycle assessment tools may prove helpful in the decision-making process because some materials with recycled content may require more frequent care and maintenance.
- Coordinate recycled material procurement with a construction waste management plan in order to make use of on-site salvaged deconstruction and demolition waste.

Terminology

Recycled content:
the proportion, by mass, of recycled material in a product or packaging. Only pre-consumer and post-consumer material is considered as recycled content, as defined under ISO 14021 Environmental Labels and Declarations—Self-Declared Environmental Claims (Type II Environmental Labelling).

Pre-consumer recycled material:
material diverted from the waste stream during a manufacturing process. Materials generated in a process and capable of being reclaimed within the same process (such as rework, regrind or scrap) are excluded.

Post-consumer recycled material:
material generated by households or by commercial, industrial, or institutional facilities in their role as end users of a product that will no longer be used for its intended purpose.

Assembly recycled content:
the recycled proportion of a material that is calculated by dividing the weight of the recycled content by the overall weight of the assembly.

Resources

Construction Specifications Institute, GreenFormat (www.greenformat.com): database of products containing recycled content.

Scientific Certification Systems (www.scscertified.com/gbc/recycledmaterials.php): products made from pre-consumer or post-consumer material can qualify for recycled content certification.

Wood Specification: Recycled Materials

What to Ask Suppliers

- Material technical data must be acquired from suppliers, usually in the form of environmental information sheets and technical spec sheets that clearly spell out the proportion of recycled content in the total assembly of the product (based on weight). Recycled content percentages should be provided for post-consumer and pre-consumer content.
- Make sure that the supplier provides the manufacturer's contact information so that additional information can be obtained if required.
- 14021 Environmental Labels and Declarations—Self-Declared Environmental Claims (Type II Environmental Labelling) is the international standard used to verify recycled content in products.

Photographer: Peter Powles

Procedure

Where possible, take ownership of core tasks, including:

- Estimate, at key stages in the project, the potential baseline and good practice levels of recycled content for the project as a whole.
- Identify opportunities that might deliver "quick wins" in terms of offering higher recycled content, and determine how the project can meet the client's requirement.
- Negotiate and agree how the contractor will meet a request for good practice; e.g., agree on the actual levels of recycled content to be used, through discussions with contractors and project cost consultants.
- Prepare specifications that stipulate the requirements to be met by the contractor and trades.
- Advise the client about the documentation process and the need to check that the product complies with the project requirements.
- Establish and track information about the manufacturer, product cost (excluding labour and equipment), and proportion of pre-consumer and post-recycled content in the raw materials of each product.

recycled content value ($) =
(% post-consumer recycled content ($) × materials cost) +
(% pre-consumer recycled content ($) × materials cost)*

* = some rating systems may apply a factor for pre-consumer recycled content

Pre-design: calculate baseline budget

Design: estimate total material costs for site work and construction sections.

or

Design: use the default budget method of 45% of materials.

Design: start with big-ticket items: identify materials and products with recycled content, integrate into design, and specify early.

Construction: track recycled content of materials in a spreadsheet with other materials; calculating percentages for points, and reassess as needed.

Throughout: revisit the project's budget calculations throughout design and construction to ensure the project is on track to achieve its goals.

Wood Specification: Salvaged Materials

Salvaging and reusing wood and wood-based products reduces demand for virgin materials and reduces waste, thereby lessening impacts associated with the extraction and processing of virgin resources.

A considerable portion of the wood used in construction (such as formwork, bracing, and temporary structures) and the wood in demolished buildings can be salvaged and reused. Reuse strategies divert material from the construction waste stream, thus reducing the need for landfill space and mitigating environmental impacts associated with water and air contamination.

Greater Texas Foundation, Bryan Texas
Photo courtesy of Page

Why Salvaged Materials Add Value

- Salvaged materials such as structural members and flooring add significant character to design. Frequently, salvaged wood products are sourced from old-growth timbers; these offer close grain finish and are extremely hard wearing.
- Some salvaged materials are more costly than new materials because of their "one of a kind" quality and because of the high cost of labour involved in the recovery and refurbishing processes.
- Reused materials refer to items that were "fixed" components on-site before construction began. To comply with most rating systems, these items must no longer be able to serve their original functions and must then be installed for a different use or in a different location.
- Demolished wood is considered salvaged wood. However most rating systems treat wood that continues to serve its original function (e.g., walls, ceilings, flooring) in a renovation project under a different category.

How to Include Salvaged and Reused Wood in Design

- The incorporation of salvaged materials as a design strategy affects cost estimates, the demolition phase (if salvaging from the project site), and the ultimate design development of the project.
- Coordination among the owner, design team, and contractor should begin early in the pre-design phase and continue through design development. Then knowledge of the site and building areas to be salvaged can be creatively and efficiently worked into the design, and opportunities to bring in salvaged materials from off-site can be incorporated into the project.
- Rating systems award credits for a prescribed percentage (by cost) of both on-site and off-site salvaged or reused materials.

Terminology

Refurbished materials:
products that could have been disposed of as solid waste; refurbishing includes renovating, repairing, restoring, or generally improving the appearance, performance, quality, functionality, or value of a product.

Remanufactured materials:
items that are made into other products; e.g., framing off-cuts that are chipped and used as landscape mulch.

Salvaged materials or reused materials:
those recovered from existing buildings or construction sites and reused; e.g., structural beams and posts, flooring, doors, and cabinetry.

Resources

***Old to New Design Guide, Salvaged Building Materials in New Construction* (www.lifecyclebuilding.org)** detailed reviews of the use of salvaged materials in real-life case studies in British Columbia.

***Green Building Resource Guide* (www.greenguide.com/about.html) and Salvaged Building Materials Exchange (www.greenguide.com/exchange/):** a database of >600 green building materials and products selected for their usefulness to the design and building professions, and a searchable online database of green building products.

Building Materials Reuse Association (www.bmra.org): represents companies and organizations involved in the acquisition and/or redistribution of used building materials.

Used Building Materials Exchange (www.build.recycle.net): free online marketplace for buying and selling recyclables and salvaged materials.

Wood Specification: Salvaged Materials

Procedure

- For rating system documentation purposes, maintain a list of reused and salvaged materials and corresponding costs.
- The percentage of salvaged and reused wood employed on a project is based on the cost of salvaged/reused materials divided by the total cost of materials. The cost will be the actual cost paid or, if the material came from on-site, the replacement value. The replacement value can be determined by pricing a comparable material in the local market (excluding labour and shipping). When the actual cost paid for the reused or salvage material (from either on-site or off-site) is below the cost of a comparable new item, use the higher value in the calculations.
- Furniture may be included if it is used consistently in the calculations of both salvaged materials and total materials used on a project.

percentage salvaged/reused materials =

$$\frac{\text{cost of reused materials (\$)}}{\text{total material cost (\$)}} \times 100$$

Pre-design: assess opportunities for reusing materials and the extent of site demolition involved and set goals accordingly.

Design: incorporate salvaged or reused materials into the design. Working with salvaged structural lumber requires the involvement of an experienced engineer. More than usual structural redundancy may need to be built into the design.

Contract documentation: identify resources and outline measures for the use of salvaged materials. Assemble a spreadsheet to track the proportion of salvaged materials in the project (as a function of materials cost, excluding labour).

Tender: work with the contractor to locate sources for these materials and document and track their cost and quantity during construction. This recordkeeping will aid the project team in the credit submission process.

Construction: advise the builder and trades of the scope and requirements of the salvaged products; alert them to specific responsibilities. Track materials and products that have been reclaimed, salvaged, or reused.

Wood Salvaged from Warehouse

Seattle District headquarters for the U.S. Army Corps of Engineers is a LEED Gold project which was partially funded through the U.S. GSA's Design Excellence Program. All of the wood used in the project was salvaged from a 1940s-era warehouse that previously occupied the site—a total of 200,000 board feet of heavy timber and 100,000 board feet of 2x6 tongue and groove roof decking.

Federal Center South – Building 1202 Seattle, WA Architect: ZGF Architects LLP
Photo: Benjamin Benschneider

What to Ask Suppliers

- Ensure that all costs are declared at the outset. Some salvaged materials are offered at prices that appear to be cost effective, but some costs may be hidden, such as the need for reprocessing.
- When dealing with salvaged wood products, clarify the presence of any toxic substances such as lead or asbestos, and ensure all costs and responsibilities for decontamination are taken into account.
- Confirm that documentation is available for the product's provenance and history.

Wood Specification: Acoustics

For centuries, wood has been the material of choice for architects and designers intent upon delivering the highest quality of acoustic performance. From a violin to an entire concert hall, wood plays a role in delivering memorable acoustical experiences. Wood produces sound by direct striking and it amplifies or absorbs sound waves that originate from other bodies. For these reasons, wood is an ideal material for musical instruments and other acoustic applications, including architectural ones.

Why Acoustic Performance Adds Value

- Architects and designers have a responsibility to design functional and safe environments. It is very difficult, if not impossible, to meet these goals without considering acoustics. Moreover, it is extremely challenging to deal retroactively with poor acoustic environments. Doing so can severely impact a building's value.
- Privacy is a major issue for building occupants. Designers must provide for adequate levels of sound insulation. Acoustical problems arise when sound transmits through the structure or when reverberation occurs via hard reflective surfaces. Sometimes fire safety design features can have deleterious effects on sound transmission because of the requirements for hard, non-combustible materials, wall and floor penetrations, etc.
- Post-occupancy evaluations of buildings have revealed that poor acoustic performance is a common problem in buildings with large areas of hard, acoustically reflective surfaces. Such surfaces are frequently found in green buildings where the use of absorbent surfaces is often minimized due to indoor air quality concerns.
- Wood is not as acoustically lively as other surfaces and can offer acoustically absorptive qualities. Generally, a wood-finished building is not as noisy as a complete steel or concrete structure.
- Most green building rating systems do not recognize the importance of acoustic performance.

Richmond Olympic Oval Roof

How to Include Acoustic Performance in Design

- Acoustics are integral to the functioning of almost every type of indoor environment, from open offices to worship centres. Some building environments can even become dangerously loud and therefore unsafe for the occupants. In order to effectively address these issues, building acoustics should be considered in the design phase.
- Optimal acoustic design must consider a wide range of factors, such as building location and orientation, planning and location of sound-sensitive functions, adequate insulation of partitions, insulation or spatial separation of noisy mechanical equipment, and measures to enhance audibility.
- To determine the effects of a material's surface on the acoustics, the acoustic absorption and scattering properties of the material's surface are measured. Any unabsorbed sound energy is reflected back into the space. Not only does the amount of sound energy reflected by a surface affect the sound field, but where the energy is reflected to is also a major factor. The extent to which sound energy is scattered over a defined area, relative to absorption, is of importance to acousticians.

Terminology

Sound Transmission Class: determined in accordance with American Society for Testing and Materials' ASTM E 413 Standard Classification for Rating Sound Insulation.

Impact Insulation Class: calculated according to American Society for Testing and Materials' ASTM E 989 Standard Classification for Determination of Impact Insulation Class.

Post-occupancy evaluation: involves systematic evaluation of opinion about buildings in use, from the perspective of the people who use them. It assesses how well buildings match users' needs, and it identifies ways to improve building design and performance, and fitness for purpose.

Resources

www.acoustics.com: provides a comprehensive range of resources including a database of products, design guides, and best practices.

What to Ask Suppliers

- Acquire Sound Transmission Class and Impact Insulation Class ratings for key components and assemblies, and for any potential interior finishes used as acoustical controls.
- Learn about any synergistic environmental benefits, such as indoor air quality performance and whether the product is certified by a third-party forest certification system.

Procedure

- Consider ambient noise issues during schematic design: site the building, and the zone spaces within the building, to provide occupants with protection from undesirable outside noise.
- Specify in the contract documents an appropriate Sound Transmission Class rating of perimeter walls in terms of response to external noise levels.
- Provide noise attenuation of the structural systems and implement measures to insulate primary spaces from impact noise.
- Mitigate acoustical problems associated with mechanical equipment, and mitigate noise and vibration associated with plumbing systems.
- Specify acoustical controls to meet the acoustical privacy requirements.
- Specify measures to meet speech intelligibility requirements for the various spaces and activities.
- If in doubt about any acoustical issue, retain the services of a qualified acoustics expert.

Standards and Best Practices for Acoustic Design in Buildings

Building codes used in the United States generally require sound isolation for multiple occupancy dwelling units. A Sound Transmission Class (STC) of not less than 50 is commonly specified. However, it is recognized that sounds may still be audible, though speech not understood, on the other side of a wall insulated to STC 50. For this reason, an STC of 60 is recommended in sensitive areas. Canadian research has identified the following sound-insulation objectives for multi-family buildings.

- Inter-unit walls and floors: Sound Transmission Class 55 or higher
- Inter-unit "hard" floors: Impact Insulation Class 55 or higher
- Inter-unit carpeted floors: Impact Insulation Class 65 or higher

Sources:International Building Code (Model Code), Chapter 12.
Burrows, J. and Craig, B. 2005. Sound Control in Multi-Family Wood-Frame Buildings. (http://www.soundivide.com/uploads/content_file/multi-family_sound-control-en-277.pdf)

University of Washington

In 2012, the University of Washington in Seattle added nearly 1,700 student housing beds by constructing three residential halls and two apartment buildings, all of which include five stories of wood-frame construction over two stories of concrete. Designed by Mahlum Architects and winner of a recent WoodWorks Wood Design Award, the 668,800-square-foot project is the first of four phases planned to add much-needed student housing to the urban campus.

"Acoustics are important for any multifamily housing project, but especially for student housing," says Anne Schopf, FAIA, a design partner with Mahlum. "Mitigation measures must be weighed against budget, which is why we brought in experts from Seattle-based SSA Acoustics for the design of this project."

Because they knew single stud walls would not provide adequate performance, SSA recommended staggered stud walls between residential units. Since there is no rigid connection between the gypsum board on each side (except at the plate), a staggered stud wall performs better than a single stud wall. Double stud walls perform better than a staggered stud design because plates are separated by an air space, so they used double stud walls between residential units and common spaces (e.g., lounges, staircases, and elevators) and service areas.

In the floor/ceiling assembly, they paid careful attention to the installation of resilient channels, which are often one of the main causes of failed floor/ceiling assemblies from an acoustical standpoint. In fact, there is a difference of 8 to 10 IIC and STC points between assemblies with resilient channels versus those without.

Channel installation has fairly straightforward requirements; for example, screws for the gypsum board should never touch the framing behind the resilient channel.

"We used enhanced acoustical walls between rooms in the same unit," says Mohamed Ait Allaoua, managing partner of SSA Acoustics. "Although not a typical approach in multifamily buildings, this is important in student housing projects where people within a relatively small space have different needs—if one student wants to watch TV in the living room, for example, while another is studying in the bedroom."

Wood Specification: Passive Design and Framing Techniques

Passive design is an approach to building design that uses the building architecture to leverage natural energy sources, minimize energy consumption, and improve thermal comfort. Passive buildings rely heavily on high-performing building envelope assemblies and passive solar energy.

Wood is an attractive material for passive design because of how it combines thermal mass with a number of performance merits, including water resistance, structural integrity, and finish quality.

Why Passive Design Adds Value

- The ultimate goal of passive design is to fully eliminate requirements for active mechanical systems (and associated fossil fuel-based energy consumption) and to optimize occupant comfort.
- Passive design and optimal building envelope performance can:
  - Help reduce or even eliminate utility bills
  - Improve the quality of the interior environment
  - Reduce greenhouse gas emissions associated with heating, cooling, mechanical ventilation, and lighting
  - Reduce the need for mechanical systems and their associated costs
  - Make alternative energy systems viable

How to Include Wood as Part of Passive Strategies in Design

Optimum value engineering (OVE) uses advanced principles to optimize the use of wood for framing by:

- Expanding the spacing between exterior and interior wall studs to as much as 24 inches (61 cm) on-centre
- Eliminating headers at non-bearing interior and exterior walls
- Using header hangers instead of jack studs
- Eliminating cripples on hung windows
- Eliminating double plates; using single plates with connectors by lining up roof framing with wall and floor framing
- Using two-stud corner framing with drywall clips or scrap lumber for drywall backing instead of studs

Structural insulated panels and pre-fabricated wood panels:

- Most structural insulated panels consist of an insulating foam core sandwiched between oriented strand board. Structural insulated panels are gaining market share in the residential and light commercial building market because they are quick to assemble and provide excellent energy performance
- Wall panels reduce thermal bridging/migration, control air leakage, and keep heating and cooling costs to a minimum compared to a conventionally framed wall

Airtight construction—build tight then ventilate right:

- The following areas of the building envelope should be sealed, caulked, gasketed, or weather-stripped to minimize air leakage:
  - Joints around fenestration and door frames
  - Junctions between walls and foundations, between walls at building corners, between walls and structural floors or roofs, between walls and roof or wall panels
  - All other openings in the building envelope
  - Passive design framing and carbon-neutral wall assembly
- Passivhaus pre-fabricated wall assembly with effective insulation reaching as high as R32
- Helped by cross-laminated technology and quality
- Insulation, including wood-fibre insulation
- High-performing wood-frame, aluminum-clad, triple-glazed windows

Terminology

Passivhaus standard:
The most rigorous European standard, Passivhaus, regulates input energy to a maximum 0.55 MBTU/ft²/y (15 kWh/m²/y) for heating/cooling/ventilation. A building that qualifies for this standard has to meet clearly defined criteria, which include (for a building constructed at a latitude of 40 to 60° in northern Europe):

- A total energy demand for space heating and cooling of less than 0.55 MBTU/ft²/y (15 kWh/m²/y)
- A total primary energy use for all appliances, domestic hot water, and space heating and cooling of less than 4.4 MBTU/ft²/y (120 kWh/m²/y).

Passive design building:
Passive design buildings share core features with Passivhaus in that they rely on four common strategies:

- A high level of insulation, with minimal thermal bridges
- A high level of utilization of solar and internal gain
- An excellent level of air tightness
- Good indoor air quality

Resources

Passive House Institute US
www.passivehouse.us

Passive House Institute
www.passiv.de

Does research and development on efficient energy use and the design and construction of passive houses.

What to Ask Suppliers

- Ask if key wood product suppliers are able to participate in the integrated design process in order to discuss innovative methods of employing wood in the project.
- Request information about the framing techniques available for the proposed project.

Procedure

Step-by-step approach to incorporating passive strategies in building design:

Pre-design: perform bioclimatic and solar site analyses

Pre-design: organize an integrated design process with key project team members in order to review passive design strategies that include (but are not limited to):

- Passive solar power
- Orientation of building
- Thermal performance and effective insulation of the building envelope
- Location and size of windows
- On-site renewable energy generation
- HVAC system size requirements

Design: conduct an energy simulation model with the help of a certified energy advisor to analyze the various design and construction strategies and to verify that the project will meet the proposed energy use targets.

Cross-laminated timber (CLT)
Photo credit FPInnovations

Kiln Apartments, Portland, OR
GBD Architects
Photo credit: Eckert & Eckert Photography

Kiln Apartments

Kiln Apartments is an 18,000 square foot building, located in a pedestrian- and bicycle-friendly neighborhood in North Portland featuring 19 for-lease apartments and ground floor retail. Inspired by pleasant childhood memories in the Pacific Northwest, the apartments are designed to evoke the comfortable qualities of a well-crafted, single-family home with an eclectic mix of personal touches.

Kiln Apartments was a research and design effort to develop the most energy efficient market-rate apartment building possible. It is pursuing an aggressive, energy efficiency program called "Passive House." Originated in Germany in the 1990s as Passivhaus, there are approximately 20,000 buildings constructed to meet this standard (almost exclusively in Europe). Energy performance goals for the project are ambitious; Kiln Apartments is seeking to become one of the largest Passive House certified buildings in the United States. As a point of reference, certification for this building will require energy performance that is approximately 65-75 per cent better than Portland's already industry leading code requirements.

Design strategies include:

A highly insulated envelope;high-performance, triple-pane wood windows; space heating through wall-mounted, hot water radiant heaters served from solar thermal roof panels; continuous (24 hours a day) ventilation through a centralized heat recovery ventilator; and deeply inset, south-facing windows protected from unwanted solar heat gain by sunshades. Kiln Apartments construction was completed in June 2014.

source: www.gbdarchitects.com/portfolio-item/kiln-apartments/

What is Integrated Design and Why is it Important for Passive Design?

An integrated design is a design in which all major components of the building are considered and designed as a totality, i.e., as an interdependent system. Integrated design means optimizing the entire system, not just parts, with complete analysis of potential synergies and trade-offs; for example, higher building envelope performance can lead to reductions in mechanical equipment size and long-term operating costs.

Wood Specification: Certified Wood

Forest certification verifies the sustainability of forest management. Third-party chain-of-custody certification traces wood material from point of harvest to its end use, including all stages of processing, transformation, manufacturing, and distribution; it may also include on-product labelling. More than 50 independent forest certification programs exist worldwide, reflecting the diversity of forest types, ecosystems, and owernership.

The two largest umbrella certification programs are the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification schemes (PEFC). PEFC endorses the Canadian Standards Association (CSA), the Sustainable Forestry Initiative (SFI) and the American Tree Farm System (ATFS), three standards functional in North America in addition to FSC. While the various programs differ, most promote sustainable forest management through principles, criteria, and objectives.

Why Certified Wood Adds Value

- Wood is an excellent environmental choice for any new construction or renovation project. It grows naturally. It is renewable and recyclable. Wood from well-managed forests is sustainable over the long term. Forest certification shows customers that the wood comes from well-managed forests.
- By providing a credible means to assure customers that wood products come from legal and responsible sources, third-party forest certification can provide an incentive for sustainable forest management and continual improvement of forest practices.

How to Include Certified Wood in Design

- Green rating systems offer optional credits for including third-party certified wood-based materials among the building components; the contribution of certified wood to total cost of installed materials determines the points awarded. Most rating systems include wood used in structural framing and in general dimensional framing, flooring, subflooring, wood doors, and finishes.
- There are four primary forest certification programs operating in North American today: SFI, FSC, CSA, and ATFS. All but FSC are endorsed by PEFC, a European-based organization that evaluates and provides mutual recognition of forest certification standards worldwide. Certification in all cases requires third-party verification against a published, transparent standard. Different rating systems allow for different certification programs, with some more inclusive than others.
- The feasibility of using certified wood should be determined at the outset of the design process. Establish a project goal for certified wood products that is consistent with the desired rating system. Identify components of the design that can use certified wood, and research the availability of wood products from certified sources that can support design goals.

Terminology

Chain of custody:
a procedure for tracking a product from the point of harvest or extraction to its end use, including all successive stages of processing, transformation, manufacturing, and distribution.

Sustainable forestry:
management that maintains and enhances the long-term health of forest ecosystems for the benefit of all living things while providing environmental, economic, social, and cultural opportunities for present and future generations.

Resources

www.dovetailinc.org/files/DovetailCertReport0310b.pdf

a summary report examining and comparing the various forest certification programs operating in North America.

www.sfiprogram.org

provides information about the Sustainable Forestry Initiative (SFI) forest and wood certification program.

www.us.fsc.org

provides information about the Forest Stewardship Council (FSC) forest and wood certification program.

www.forestfoundation.org/american-tree-farm-system

provides information about the American Tree Farm System (ATFS) forest certification system.

www.csasfmforests.ca

provides information about the Canadian Standards Association (CSA) forest and wood certification program.

Procedure

- Determine which certification system the wood will be sourced through.
- Specify the requirement for certified wood in the contract documents.
- Track certified wood purchases and retain any associated chain-of-custody documentation.
- Collect copies of vendor invoices for each certified wood product.
- Maintain a list that identifies the percentage of certified wood in each purchase.
- Develop a spreadsheet for calculating the amount of new wood, pre-consumer recycled wood, and certified wood needed for the project. For each wood product, specify the percentage of certified wood to be used, based on cost.

percentage of certified wood =

$$\frac{\text{certified wood material value (\$)}}{\text{total new wood material value (\$)}} \times 100$$

Pre-design: check to see which certified wood products are readily and locally available and work these into the design.

Pre-design: check which forest certification is acceptable. This will depend upon the green building rating system the project is following (many have adopted an inclusive approach).

Design: focus on big-ticket items that can contribute to multiple credits.

-or-

Where dealing with large volume of a certain type of wood product (e.g., framing lumber), price regionally available certified wood to determine whether a rating system credit can be achieved.

-or-

Weigh the value of using certified wood against the use of local wood that has other environmental merits. Do a life cycle assessment to determine the best option.

Design: create a baseline budget and assess the goals.

Contract Documentation: tabulate and calculate the required percentage of certified wood in a spreadsheet. Reassess as needed.

Construction: advise the builder and trades of the scope and requirements of the certified wood products. Track materials and products that are required to be from certified sources and obtain certificates as necessary.

Percy Norman Aquatic Centre

During the 2010 Olympic and Paralympic Winter Games, the new Percy Norman Aquatic Centre in Vancouver, British Columbia was a venue for curling events and a marshalling area for athletes. In keeping with the Vancouver Board of Parks' ongoing commitment to sustainability, this facility was built to meet Leadership in Energy and Environmental Design (LEED®) Gold criteria.

The Aquatic Centre features a solid wood roof supported on Douglas-fir glulam beams that span up to 130 ft (43 m) across the main pool area. At the east end of the building, the beams are supported on outwardly inclined Douglas-fir glulam columns of similar cross-section, with steel structure V supports picking up the other end of the beams. It features glulam beams made from certified wood.

What to Ask Suppliers

- Identify vendors, suppliers, and manufacturers and coordinate with them early to ensure a supply of the "brand" of certified wood that is acceptable to the particular green building rating system.
- Ask for copies of all relevant chain-of-custody certificates and confirm they are in good order for all relevant products prior to purchasing them.
- The market currently does not hold competitive materials to wood (concrete, steel, glass, plastics) to the same level of accountability for chain-of-custody certification. Ask suppliers of non-wood products about the level of stewardship and standards that apply to these other materials.

FOREST MANAGEMENT CERTIFICATION:

Canadian Standards Association's (CSA) Sustainable Forest Management Standards (www.csasfmforests.ca)

- CSA is an independent, not-for-profit organization accredited to develop standards in Canada.
- CAN/CSA Z809 and CAN/CSA Z804 are both National Standards of Canada based on internationally recognized criteria that are adapted to local conditions through a transparent public participation process.
- CSA offers a PEFC product label and a chain-of-custody certification standard.

Forest Stewardship Council (FSC) (https://us.fsc.org)

- FSC is an international non-governmental organization that promotes responsible management of forests.
- It endorses regional standards based on its international principles and criteria adapted to local conditions.
- It offers a product label and a chain-of-custody certification standard.

Programme for the Endorsement of Forest Certification (PEFC) (www.pefc.org)

- PEFC is the world's largest certification umbrella organization. As an international non-government organization, it supports sustainable forest management through assessment and endorsement of national forest certification schemes.
- The standards of the Canadian Standards Association (CSA), the Sustainable Forestry Initiative (SFI) and the American Tree Farm System (ATFS) are endorsed by PEFC.

Sustainable Forestry Initiative (SFI) (www.sfiprogram.org)

- SFI is a non-profit organization that promotes responsible forest management in the USA and Canada.
- It offers a product label and a chain-of-custody certification standard.

American Tree Farm System (www.forestfoundation.org/american-tree-farm-system)

- ATFS is the largest and oldest sustainable family woodland system in America, internationally recognized, meeting strict third-party certification standards.
- ATFS is a program of the American Forest Foundation.

Terminology

Source-separated collection:
requires individual, clearly labelled bins for sorting each recyclable material on site.

Commingled collection:
allows mixed recyclables to be collected on site and sorted at the depot. While convenient for small projects, diversion rates tend to be lower than source-separated recycling.

Construction waste management plan:
a document specific to a building project which outlines measures and procedures that divert construction waste materials from landfill and incineration facilities.

Tipping fees:
charged by a landfill for disposal of waste; typically quoted per tonne.

Resources

Whole Building Design Guide

www.wbdg.org/resources/cwmgmt.php

US EPA Construction & Demolition Materials

Reducing and recycling C&D materials conserves landfill space, reduces the environmental impact of producing new materials, creates jobs, and can reduce overall building project expenses through avoided purchase/disposal costs. Changing how we think about these materials will create a more sustainable future.

http://www.epa.gov/epawaste/conserve/imr/cdm/

Building Materials Reuse Association (www.bmra.org): resources to facilitate building deconstruction and salvage of building materials in North America.

Wood Specification: Construction Waste Management

The objectives of construction waste management are to divert construction and demolition debris from landfill and give it a higher value purpose. Recyclable and recovered wood-based materials can be directed to various manufacturing processes, while reusable materials are diverted to the appropriate use.

Why Construction Waste Management Adds Value

- Reducing, reusing, and recycling clean wood waste reduces demand for virgin resources, minimizes the environmental impacts associated with resource extraction, processing, and transportation, and alleviates pressure on limited landfill space.
- The recycling of wood waste is straightforward and affordable. Most urban centres provide recycling services for clean (non-treated) wood waste. Wood chip products are typically sold as hog fuel and also sold for animal bedding, composting, and mulching.
- Reducing waste can reduce costs associated with transporting and disposing of waste. Changes in the economics of recycling—i.e., the advent of market competition for both raw and recycled materials, increased disposal costs, more stringent waste disposal regulations, and decreasing landfill capacity—have made the development of a waste management plan an important consideration in the design process.

How to Include Construction Waste Management in Design

- Waste minimization informs the entire design and construction process. The creation of a waste management plan during the design phase embeds the goals of the project from the outset. For example, demolished wood on the site can either be repurposed in the new design or recycled, depending on its quality.
- Waste minimization starts with strategies established during the preliminary design phase that are aimed at not creating waste in the first place. Efficient design, the use of shop-fabricated components, modular construction, and ordering materials cut to size will ensure waste is minimized and may save money in transportation costs.
- Wood lends itself to dismantling, but designing for disassembly requires upfront thinking. Structural wood members in particular can typically be reclaimed and reused for the same or similar purposes with only minor waste.
- Ensure that products are installed in a way that will not generate waste in the future. For example, nailing rather than gluing the wood flooring offers easier removal later.
- Reuse materials where possible by developing a down-scale plan. A down-scale plan identifies the products to be reused and describes their subsequent destination for them, including contact information for service providers and details of the logistics.
- Consider how off-cuts can be used, such as for shims or as chips for landscape mulch.
- Generally, construction waste includes recycled and/or salvaged non-hazardous construction and demolition debris. Treated wood is not recyclable. To minimize the need to deal with treated wood waste, ensure the design includes adequate weather protection for exposed wood features, and plan for easy ongoing maintenance.

Wood Specification: Construction Waste Management

What to Ask Suppliers

- From preliminary design onward, it is important to liaise with suppliers regarding waste management solutions. Having a solid understanding of manufacturing processes, how materials are delivered, and the waste they generate during installation is necessary prior to finalizing the project specification documents.
- Work with manufacturers to minimize unnecessary packaging and make arrangements for pallets to be picked up after use.
- Ask suppliers for information about a product's recyclability and end-of-life impacts.
- Ask if suppliers have a take-back program to minimize the generation of waste in the future.

Procedure

- Document the diversion of construction waste by tracking all construction waste by type, the quantities of each type diverted, and the total percentage of waste diverted from landfill disposal.
- Some green building rating systems provide conversion factors to estimate the weight of construction waste if exact material weights are not available.
- Calculate construction waste, by weight or by volume, but be consistent throughout.

$$\text{percentage of diverted construction waste} = \frac{\text{amount diverted through recycling and salvage}}{\text{total waste generated by the construction project}}$$

Design: make design adjustments early, based on input from the contractor and other consultants, to minimize waste generation during construction. Consider standard product sizes, and application and installation processes and the waste they may generate.

Design: research the range of available waste management options and identify large-volume recyclables early in the design process.

Contract Documentation: determine which materials will be source separated on site and which (if any) will be collected in commingled bins.

Tender: ensure the general contractor understands waste diversion tracking and documentation and orients subcontractors to trade-specific responsibilities.

Construction: on a spreadsheet, tabulate diverted construction waste, record the contact information of the receiving facilities, and calculate diversion percentages.

Construction: coordinate with the contractor at frequent intervals during construction to ensure the project is on track to achieve the waste management goals.

Construction Waste, the Numbers

"Municipal Solid Waste (MSW) and Construction and Demolition (C&D) Wood Waste Generation and Recovery in the United States" by Dovetail Partners Inc.

The softwood and hardwood forests of the United States provide wood products that are used in many applications including: lumber and other building materials; furniture; pallets and other forms of containers and crating; posts and poles; and a wide-range of consumer goods. This wide array of products generates waste wood when these products are disposed at the end of their useful lives. This waste wood is typically included in the categories of Municipal Solid Waste (MSW) and Construction & Demolition (C&D) wood, with the total amount generated in 2010 estimated at 70.62 million short tons; this amount is difficult to track and may be understated.

Since wood is a significant portion of both MSW and C&D waste streams, and since wood can be reused for a host of products (e.g., energy, fiber, or chemical-based), its recovery presents a significant opportunity. Also, since most MSW and C&D waste streams are located near population centers, the opportunity for creating useful consumer products is high (pool of natural resources near markets).

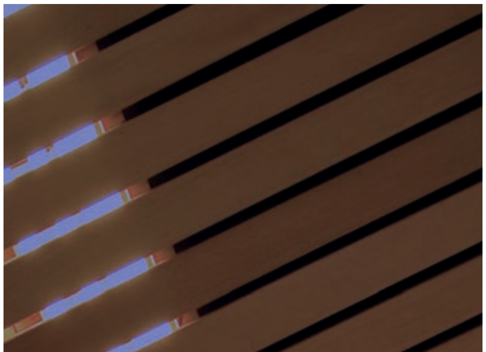
Sources: Dovetail Partners, Inc. "Municipal Solid Waste (MSW) and Construction and Demolition (C&D) Wood Waste Generation and Recovery in the United States", September 22, 2014, http://www.dovetailinc.org/report_pdfs/2014/dovetailwoodrecovery0914.pdf

Getting to Zero Waste

Achieving zero construction waste depends on designing products and industrial processes so their components can be dismantled, repaired, and/or recycled. The goal is to promote pre-fabrication, "right-sizing" of components, and the closing of the loop of the product life cycle. Zero waste means linking communities, businesses, and industries so the waste of one becomes another's feedstock. It means preventing pollution at its source. It means new local jobs in communities across the country. The role of wood as a product and as a feedstock for other processes is integral in the quest to reach zero waste.

Reusability and Recyclability of Wood Waste Depends on the Quality and End Purpose of the Wood

- Demolished wood components are often not reusable or recyclable unless they are taken apart. Check if the local recycling centres can handle nail removal.
- The use of wood waste as an alternate daily cover for landfills is not an acceptable means of waste diversion under green rating systems.
- While the use of used wood for firewood for wood-burning stoves and fireplaces is not a generally acceptable means of waste diversion, burning clean wood waste to generate industrial process heat and/or electricity is considered appropriate diversion methodology.



Wood Specification: Durability

Durability is defined as the ability of a building or any of its components to perform the required functions in a service environment over a period of time without unforeseen cost for maintenance or repair.

Using durable materials, as well as appropriate building applications and design, minimizes materials use. It also minimizes construction waste that would result from inappropriate material selection or premature failure of the building and its constituent components and assemblies. Using durable materials, while sometimes involving greater up-front costs, can result in significant savings in terms of reduced-cost maintenance and repairs later in a building's life.

Why a Durable High-performance Wood Building Envelope Adds Value

- Durable envelope design delivers the benefits of lower operation costs and a healthier building. Good design will ensure that wood materials last and weather well in various climates and physical contexts. Strategies may include minimizing contact of moisture with untreated wood, allowing for ventilation to both sides of untreated wood and designing structures to shed water.
- Planning for maintenance, deconstruction, and adaptability can extend the life of building components and of the building as a whole. Designing with wood allows for the use of easily demountable components and connections, and for the use of fasteners that ease deconstruction, facilitate maintenance, and increase the potential future reuse of building materials and components. In addition, the incorporation of easily accessible systems (such as removable panels, etc.) reduces the need for extensive renovations or even replacement in the future.
- In general, as durability performance increases, so do the environmental merits of the project as a whole. A durable assembly can dramatically reduce energy consumption because the elements providing thermal performance are protected and maintain their functionality over the life of the building. Utilizing energy modeling software that incorporates building envelope performance criteria such as insulative value and air tightness will help designers to better understand the impacts of material choices—particularly the use of wood, in accomplishing an energy-efficient, durable envelope.
- Indoor air quality can also be improved by using durable materials that have zero or low emissions and that prevent moisture accumulation and mould or mildew growth.
- Durable materials and components that follow carefully considered design details can potentially remain useful in the materials cycle for longer periods of time, thus reducing the need for new materials and the environmental costs of resource extraction, production processes, and waste disposal.
- Assessing life cycle costs based on design service life of the structure and the building envelope can be helpful in evaluating alternative design approaches for the building.
- Some green building rating systems encourage high-performance and durable envelope design, either explicitly through the development of a Building Durability Plan, or indirectly by setting goals for energy efficiency, thermal comfort, and indoor air quality (all of which are facilitated through the design of the building envelope).
- With proper design and construction, wood-frame buildings resist damage from moisture, insects and other organisms, and provide decades of service equivalent to other building types.
- Wood structures are adaptable and allow for design flexibility to meet changing needs. When they have been designed properly with local climate impacts in mind, wood buildings can last centuries. Further, when part of a well-planned regular maintenance program, wood products will last well beyond their planned service life. When it is time to refurbish, wood products can be re-used and recycled.

How to Include Durability Considerations in Design

- Develop a Building Durability Plan at the concept stage, and review the plan during design for implementation during construction. Components of particular relevance are major structural elements (including foundations), building cladding assemblies, roofing assemblies, and those elements likely to have significant impacts on the building's operation or performance (excluding mechanical and electrical equipment).
- Early on, optimize the design of all components of the building envelope by using energy simulation and life cycle assessment tools to analyze overall envelope performance.
- Make informed decisions about the components of the building envelope (i.e., based on life cycle performance).
- To minimize premature deterioration of walls, roofs, and floors, select design strategies that are appropriate to the geographic region.
- Reduce construction problems by specifying realistic and achievable levels of workmanship that are based on practical construction methods and readily available technologies.
- Follow a building envelope commissioning process to ensure performance and durability standards are correctly established at the outset and followed through during construction and operation.

Terminology

Building Durability Plan (BDP): provides a framework within which durability targets are set and establishes criteria for durability performance of a building.

Design service life: the period of time during which a product is expected by its designers to work within its specified parameters.

Commissioning: accomplishes higher energy efficiency, environmental health, and occupant safety; improves indoor air quality by making sure the building components are working correctly and the plans are implemented with the greatest efficiency using standard protocols and peer review processes.

Resources

Guideline on Durability in Buildings CSA S478-95 (R2007) (available for purchase from www.shopcsa.ca): referenced by LEED, this guideline provides a set of recommendations to assist designers in creating durable buildings.

ISO 15686-5:2008 – Buildings and constructed assets – Service life planning – Part 5: Life-cycle costing (www.iso.org/iso/catalogue_detail?csnumber=39843): life-cycle costing enables comparative cost assessments to be made over a specific time, by taking into account initial capital costs and future operational costs. .

WoodWorks (www.woodworks.org/Publications/informationSheets.aspx): a primer on durability and wood.

What to Ask Suppliers

- It is important to get information about what the expected service life of the building envelope products will be in the context of the building's assembled condition.
- Ensure that the scope and limitations of product warranties are fully understood.
- Enquire about care and maintenance solutions for proposed materials and convey this information to the building operator.

The Building Durability Plan

A Building Durability Plan (BDP) requires the design professional (usually a building envelope consultant) to agree to the following points:

- The building is designed and constructed with the intent that the predicted service life will equal or exceed the design service life.
- Where the service life of a component or assembly design is shorter than that of the building, those components or assemblies are designed and constructed to be readily replaced.
- The service life is predicted by documenting demonstrated effectiveness, by modeling of the deterioration process, or by testing.
- A quality management program is developed and documented.
- Quality assurance activities need to be carried out to verify that the predicted service life is achieved.
- The building envelope construction is in general conformance with the design details, and is co-signed by the building science professional and the general contractor.
- The BDP is endorsed, implemented, and signed by the building owner.

Procedure

Step-by step approach to incorporating durability considerations into the design:

Pre-design: determine durability goals by establishing performance targets for the design service life of the structure and building envelope (50 years is standard).

Design: create a BDP; review the details with the design team, owner, and builder; update the Plan at milestones throughout the project.

Contract documentation: confirm that the BDP is developed and signed by a building science professional, and that it is endorsed, implemented, and signed by the building owner.

Contract documentation: use a commissioning procedure to confirm that the building envelope construction is in general conformance with the design details, and that is co-signed by the building science professional and the general contractor.

Contract documentation: circulate copies of the reports on the building envelope design review and the building envelope field review, and of the BDP.

Forte
Architecture by Lend Lease
Photo Credit: Lend Lease

World's Tallest Modern Residential Building Constructed of Timber

Designed and constructed by Lend Lease, Forté is a residential boutique apartment building containing 23 units, located in Melbourne, Australia. Certified with a 5 Star Green Star residential rating, Forté features one bedroom, two bedroom and penthouse apartments, all designed with dual aspect to maximize sunlight and natural ventilation.

Forté is the first residential building in Australia to use Cross Laminated Timber (CLT) as a structural solution. With the exception of the first storey which is concrete, the remaining nine storeys are constructed with CLT panels, including the walls, floors, stair shafts and the elevator core.

Over the past several years, a number of tall wood projects have been completed around the world, demonstrating successful applications of new wood and mass timber technologies. The Perkins + Will "Survey of International Tall Wood Buildings" report takes a look at ten international tall wood buildings (including Forté), and presents some common lessons learned from the experiences of various stakeholders, including the Developer/Owner, Design Team, Authorities Having Jurisdiction (AHJ), and Construction Team for each project.

One of the comments with respect to durability in the report is: Survey "participants from residential building projects indicated they believe mass timber to be a very durable structural option, appropriate for long term capital and operational investment and to support high-quality finishing in a high-end residential context."

Source: Survey of International Tall Wood Buildings, 2014, Perkins + Will
http://www.rethinkwood.com/tall-wood-survey

Terminology

Indoor air quality:
the nature of air inside a building that affects the health and well-being of building occupants. Quality is considered acceptable when no known contaminants exist at harmful concentrations as determined by authorities, and when a substantial majority (80% or more) of the people exposed do not express dissatisfaction with it (American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62.1-2007).

Volatile organic compounds (VOC):
carbon compounds that participate in atmospheric photochemical reactions (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides and carbonates, and ammonium carbonate). The compounds vapourize at normal room temperatures.

Contaminants:
unwanted airborne elements that may reduce air quality (ASHRAE Standard 62.1 – 2007).

Off-gassing:
the emission of volatile organic compounds from synthetic and natural products.

Material safety data sheet (MSDS):
presents information about chemicals, chemical compounds, and chemical mixtures; provides the volatile organic compound concentration of a product, typically in grams per litre (g/L).

Urea formaldehyde:
a component of glues and adhesives; a preservative in some paints and coating products. Commonly found in pressed wood products such as hardwood, wall paneling, particleboard, and fibreboard.

Wood Specification: Indoor Air Quality (Low Emitting Materials)

Bare wood can be considered to be hypo-allergenic because it does not emit toxic vapours. Solid wood products can be used in locations where occupants are known to have environmental sensitivities. Increasingly, coatings, resins, and binders used in wood products are available in low- or non-toxic formulations.

Why Indoor Air Quality Adds Value

- Despite the fact that solid wood is not a harmful material, it is frequently combined with products that can adversely affect occupant well-being. It is therefore important to fully understand the toxicity of the solvents, glues, sealants, flame retardants, resins, and preservatives used in and on some wood products.
- For example, urea formaldehyde (UF) is commonly found in resins associated with particleboard and medium density fibreboard (MDF) production. Urea formaldehyde has been classified as a known carcinogen by the World Health Organization. It also has a range of other health effects including being a bronchial irritant and an asthma trigger.
- Indoor air quality certification standards exist for composite wood products (e.g., flooring, cabinetry, panels) to verify that the products meet strict emission limits. These certification standards include GreenGuard® and Floorscore®.

How to Include Low-emitting Materials in Design

- During the preliminary design stage, research non-toxic alternatives such as composite wood products that contain no added urea formaldehyde.
- For most green building rating systems, all composite wood products—including particleboard, MDF, plywood, wheat board, strawboard, panel, substrates, and door cores, and associated laminate adhesives—should contain no added urea formaldehyde resins.
- Identify target emission limits for products and stipulate performance standards in the project specifications (ideally, within the specific section applicable to a particular trade or supplier).
- Consider making the submission of indoor air quality compliance documentation a condition of product approval.
- Indicate what must be provided in the way of cut sheets, material safety data sheets, certificates, and test reports.
- Products such as plywood and oriented strand board (OSB) use the red/black-coloured phenol-formaldehyde resin. While formaldehyde is still present in this type of resin, there are almost no emissions compared to those containing urea formaldehyde.
- Strive to eliminate the use of toxic materials altogether through alternative installation strategies, such as using mechanical fasteners for flooring and paneling in lieu of glues (which also aids in future disassembly).
- Stress the importance of meeting indoor air quality requirements during tender and again when the contract is awarded. Include requirements in subcontracts and purchase orders.
- Communicate indoor air quality goals to the construction team to ensure successful implementation.

Resources

Environmental Choice EcoLogo Program (www.industries.ul.com/environment/): presents a listing of products and services that are EcoLogo certified and meet the applicable environmental standards; certified products are generally low in or have no VOCs.

Green Seal (www.greenseal.org): database of certified products and services; certified products are generally low in or have no VOCs.

South Coast Air Quality Management District (www.aqmd.gov): source-specific standards to reduce air quality impacts that are referenced by most rating systems.

FloorScore™ Program, Resilient Floor Covering Institute (www.rfci.com/): a program that certifies flooring products including wood flooring, developed together with Scientific Certification Systems.

GREENGUARD Indoor Air Quality Certification Program (www.greenguard.org/en/CertificationPrograms/CertificationPrograms_indoorAirQuality.aspx): indoor air quality certification standards for low-emitting materials.

Wood Specification: Indoor Air Quality (Low-emitting Materials)

What to Ask Suppliers

- Early on in the planning phase, ask about the production of materials and obtain the relevant material safety data sheets describing the volatile organic compound and urea formaldehyde emissions of products.
- Make sure suppliers provide manufacturer contact information so companies can be contacted for additional information.
- If in doubt, request independently audited data from a reputable third-party agency such as the South Coast Air Quality Management District in southern California (www.aqmd.gov).

Examples of Volatile Organic Compound (VOC) Emission Limits Relevant to Wood Products

Adhesives: architectural applications	Volatile organic compound limit (g/L)
Wood flooring adhesive	100
Subfloor adhesive	50
Contact adhesive	80
Structural wood member adhesive	140
Drywall and panel adhesives	50
Multi-purpose construction adhesives	70
Top and trim adhesive	250
Substrate specific applications	
Wood	30
Architectural coatings	
Clear wood finishes:	
• Varnish	350
• Sanding sealers	350
• Lacquer	350
Flats	50
Stains	250
Wood preservatives	350

Source: South Coast Air Quality Management District (southern California), Rule #1168 July 2005 and Rule #1113 January 2004

Formaldehyde Regulations and Structural Wood Products

Structural wood products such as plywood and oriented strand board (OSB) are manufactured to meet stringent product standards, including Voluntary Product Standard PS 1-07 for Structural Plywood and Voluntary Product Standard PS 2, Performance Standard for Wood-Based Structural-Use Panels. Because wood products produced under these standards are designed for construction applications governed by building codes, they are manufactured only with moisture-resistant adhesives that meet Exterior or Exposure 1 bond classifications. These adhesives, phenol formaldehyde and diphenylmethane diisocyanate (MDI), are chemically reacted into stable bonds during pressing. The final products have such low formaldehyde emission levels that they easily meet or are exempt from the world's leading formaldehyde emission standards and regulations.

Source: /www.apawood.org/level_b.cfm?content=srv_env_form

Procedure

For most rating systems, low-emitting materials credits function on a pass or fail basis. Best practices in tracking indoor air quality hinge upon the maintenance of a list of each indoor product used on a project. Include the manufacturer's name, product name, and specific VOC data (g/L, less water) for each product, as well as the corresponding allowable VOC from the referenced standard.

All adhesives, sealants, paints, and coatings used on the interior of the building (inboard of the weatherproofing system and applied on site) must comply with the applicable VOC concentration limits and meet the certification standards. Shop-applied products are exempt from meeting the volatile organic compound limits.

A volatile organic compound budget procedure allows for specialty applications for which there is no low-VOC product option. It involves the comparison of a baseline case with a design case. The baseline application rate should not be greater than that used in the design case.

Design: maintain a list of each of the following wet products to be used on site:

- Adhesives and aerosol adhesives
- Sealants and sealant primers
- Paints and coatings

Tender: obtain MSDS or environmental information sheets from all subcontractors prior to using the products on site, with the product's VOC data in g/L. Check the referenced standard to ensure the materials are in compliance.

Construction: if the materials are not in compliance, return the relevant paperwork to the subcontractors and request substitutions that meet the referenced standard VOC limits. Non-complying products are not allowed on site.