Layering up to the Truly Green Skin

Terri Meyer Boake BES BArch, MArch LEED AP
Associate Professor, School of Architecture, University of Waterloo

INTRODUCTION

Ever since the building science industry first became conscious of the need for energy conservation and environmentally motivated design in buildings 3 to 4 decades ago, the building envelope has borne the brunt of much change. Such change has resulted in significant increases in insulation levels, air tightness, long-term performance, and most recently, mold resistance. Many of the energy-motivated changes have resulted in modifications to the Building Code, making the various improvements in the building envelope a legally binding requirement, but one that varies from region to region. But with continuing issues surrounding sustainable design, and more recent concerns about Global Warming and CO_2 levels in the environment, it is becoming clear that even the highest standards of construction that are being implemented today are simply not enough.

In North America, the building envelope need only be designed to meet the Building Code relevant in the area of jurisdiction. Measures that might be implemented to make the envelope more durable, contribute to a higher level of energy efficiency, reduce carbon output or generally be more environmentally friendly are for the most part, entirely optional. In a Capitalist and consumer driven society, this usually means that the extra funds required to upgrade the envelope beyond its base Building Code compliance level, are seldom spent.

With raised consciousness about the potential negative effects of Global Warming, and pressures and concerns from various sources about the environment, there is beginning to be a slow increase in the uptake on some of the voluntary measures and available assessment tools to assist in improving envelope performance. This paper will begin to examine how the various sustainable design interests and tools can be more directly used to "green the skin" of the building. Tools, initiatives, resources and focus areas can be applied in an additive sequence to ratchet up the performance of the skin, while diminishing its environmental impact.

THE LAYERS OF GREEN

Assessment of protocol in envelope design would indicate that there are clear "levels" of performance on the road to a state of "high performance". The term "high performance" has been adopted in the field of sustainable building, when judging the building as a whole, so it would be appropriate to also refer to the skin in this manner. This point of clarification is intended to more clearly define the term "sustainable", which seems to remain unscientific and holistic. High performance, does not however, define the ultimate attributes that a skin might possess when striving for a 100% "green" state.

When designing the building envelope for a high level of *holistic environmental* performance, there might be considered to be an additive system that consists of "layers of concern" that shape and specify aspects of the design. These could be initially defined to be:

1. Basic Code Compliance – meeting local building codes, national building codes, ASHRAE, and other *required* standards.
2. LEED™ – a range of performance for the envelope as would be accounted by the certification categories of Certified, Silver, Gold and Platinum, recognizing that compliance with

any level does not necessarily infer that the highest performance standard has been achieved for the envelope element, and that Platinum envelopes have been known to degrade.
3. Zero Carbon or Carbon Neutral – design of the skin to minimize its direct and indirect contribution to carbon emissions. This would include analysis of both the components that comprise the skin as well as its impact on the overall energy performance of the building.
4. Cradle to Cradle (C2C) and Design for Disassembly (Dfd) – the design of the envelope and its components to eliminate waste products and promote simple reuse.

Life Cycle Assessment is a tool that feeds into the decision making process for various aspects of each of these strategies.

It must also be stated that beyond basic code compliance, LEED^{TM}, Zero Carbon,C2C and Dfd principles are neither mutually inclusive nor mutually exclusive. They can be applied to the design of the envelope in any sequence or selectively. They are listed in this order as by the degree of magnitude of difficulty, they tend to have a somewhat logical progression, or degree of magnitude level of difficulty to achieve, in this particular order. There are aspects of LEED that can feed into the other focus areas.

LEED^{TM} AND ITS RELATIONSHIP TO SKIN DESIGN:

LEED^{TM} is beginning to function as a "motivational" tool to those in the building industry, because of its "medal" oriented rating system. Buildings are awarded Platinum (52-69 US, 70 Canada, points), Gold (39-51 points), Silver (33-38 points) or Certified (26-32 points) status based on a system of reward points. This framework definition of sustainable design has managed to extend former ideas of energy efficient design and code compliance (which were envelope dominated concerns) to include aspects that encompass the whole building, all of its systems, and all questions related to site development.

Although not directly apparent on the surface, there are diverse relationships between the design of the building envelope and LEED through potential synergies between skin design and LEED Credits in *all categories* as envelope design does impact credit potential in areas outside of "Energy & Atmosphere".

A. SUSTAINABLE SITES:

Sustainable sites deals primarily with issues of site selection, site access and site design (materials, density, drainage). Connections to the building envelope may not be obvious. The prerequisite concerns erosion and sedimentation control on site. There are eight credits offering a total of 14 potential points. Items such as green roofs and reductions in the urban heat island effect through materials selections do raise skin issues as they impact general roof design criteria. The Heat Island Credit: 7.2 gives direct preference to the use of high albedo roofing materials if a green roof is not to be used. Also included in this category could be the use of new BIPV flat roofing systems, which require different detailing to ensure proper function as both a PV element and a roofing membrane. Site selection also impacts the potential for passive solar and daylighting systems that may be part of the overall envelope strategy.

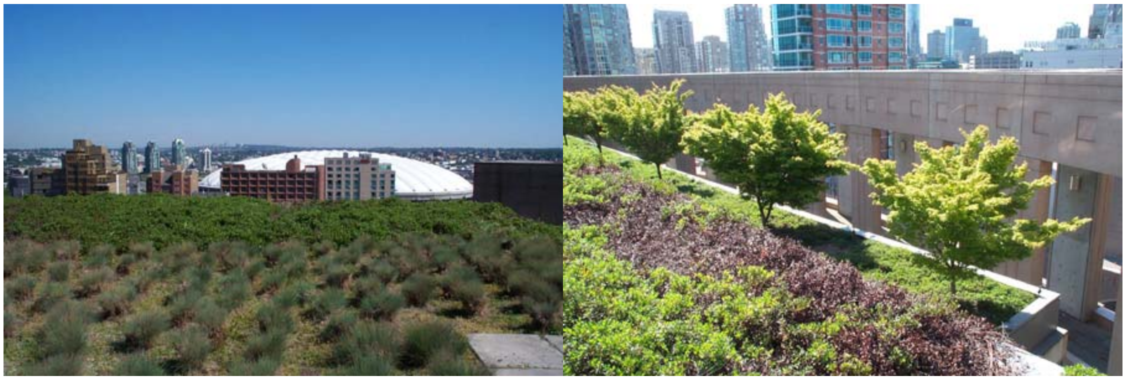

Figure 2: Vancouver Public Library. Moshe Safdie and Associates with Downs Archambault and Partners. *Sustainable Sites:* Credit 7.2 Landscape & Exterior Design to Reduce Heat Islands (roof)

Table 1a: Sustainable Sites and the Building Envelope

Credit	Pts	Name and Description	Impact on the Building Envelope
		Sustainable Sites	
Prereq		**Erosion and Sedimentation Control**: reduce negative impacts on water and air quality	none
1	1	**Site Selection:** do not develop on land which is prime farmland, habitat for any threatened or endangered species, within 100 of water ways or wetlands, lower than 5 feet above the 100 year flood or public parkland	While urban sites pose challenges with over-shadowing from nearby neighboring buildings, rural sites provide freedom for solar design, which may impact envelope design for some buildings.
2	1	**Development Density:** utilize sites within a density zone of 60000 s.f./acre (2-storey downtown development density)	Increased site density may require deeper floor-plates and more urban siting. Urban areas may have noise issues that need to be controlled in the envelope/window STI ratings.
3	1	**Brownfield Redevelopment:** remediate contaminated site for building use	none
4.1	1	**Alternative Transportation:** locate project near commuter rail, subway or bus lines	none
4.2	1	**Alternative Transportation:** include secure bicycle storage, showers and changerooms	none
4.3	1	**Alternative Transportation:** provide alternative-fuel vehicles or alternative-fuel refuelling stations.	none
4.4	1	**Alternative Transportation:** encourage car-pools/van-pools and limit new parking	none
5.1	1	**Reduced Site Disturbance:** limit site disturbance to conserve and restore habitats and biodiversity	Promotes greater care for the unbuilt, exterior part of a site. This may cause problems with construction staging for various exterior systems.
5.2	1	**Reduced Site Disturbance:** reduce the development footprint to exceed local zoning requirements for open space	Promotes greater care for the unbuilt, exterior part of a site. This may cause problems with construction staging for various exterior systems.
6.1	1	**Stormwater Management:** limit the rate and quantity of stormwater run-off	none
6.2	1	**Stormwater Management:** Include a	none

		stormwater treatment system on site to eliminate contaminants and increase infiltration.	
7.1	1	**Heat-Island Effect:** provide shade within 5 years or place parking underground or use open grid paving	none
7.2	1	**Heat-Island Effect:** use high-albedo roofing or a green roof	Choice of materials may affect reflectivity of roof. BIPV roofing may be acceptable as most are mounted on white colored membranes. High impact on the design of the roofing system.
8	1	**Light Pollution Reduction:** reduce the impact of building and site lighting on nocturnal habitats and night-sky access	May impact window design, orientation and quantity.

B. WATER EFFICIENCY:

Water efficiency is the smallest section comprising only three credits, worth 5 points. This section deals with landscaping, wastewater treatment and water use reduction. Although water efficiency may not present an obvious connection to envelope design, the inclusion of some systems, such as Green Walls and Living Machines can greatly increase the relative humidity of the interior environment, which in turn can impact a wall that may not be properly detailed and therefore prone to deterioration due to air leakage or vapor diffusion of higher humidity air. This will also create moisture issues on skylights and at intersections between the skylight and adjacent roofs due to cold climate issues.

Humidity issues at the YMCA Environmental Learning Centre (pictured below) are handled in part by high level ventilation, even in the winter months. Wood doors adjacent to this space show high signs of deterioration due to humidity and mold growth as a result of the Living Machine^{TM}.

Figure 3: YMCA Environmental Learning Centre, Charles Simon Architect
Water Efficiency: Credit 2 Innovative Wastewater Technologies: Living Machine^{TM} – adjacent doors suffering from deterioration due to the high moisture content of the room

Table 1b: Water Efficiency and the Building Envelope

Credit	Pts	Name and Description	Impact on the Building Envelope
		Water Efficiency	
1.1	1	**Water Efficient Landscaping:** reduce use of potable water for irrigation by 50%	none

1.2	1	**Water Efficient Landscaping:** use no potable water for irrigation or do not install a permanent irrigation system	none.
2	1	**Innovative Wastewater Technologies:** reduce building sewage by 50% or treat 100% of waste water on site	Use of systems such as Living Machines^{TM}, Breathing/Living Walls, Biofilters, may increase interior humidity and vapor pressure putting a higher than normal load on the envelope system for moisture control.
3.1	1	**Water Use Reduction:** reduce building water consumption by 20% over the calculated baseline	none
3.2	1	**Water Use Reduction:** reduce building water consumption by 30% over the calculated baseline	none

C. ENERGY AND ATMOSPHERE:

Energy and atmosphere, includes three prerequisites – fundamental building systems commissioning, *minimum energy performance*, and CFC reduction in HVAC&R equipment. The prerequisites are followed by six credits for energy performance, renewable energy and additional building monitoring, with a potential value of eight points. The optimization of energy performance in the building accounts for 10 potential points in this category – out of a maximum of 69 or 70 for the entire building evaluation. Energy performance issues will include overall wall design, insulation levels, air-tightness, selection of systems and materials for high thermal values, selection of glazing systems for high thermal value, and conversely, selection of glazing systems to increase passive solar gain where applicable.

Prior to the adoption of LEED, energy efficiency might have been the only motivation to improving envelope related design strategies. Within the holistic sustainable design framework provided by LEED, the *apparent* importance of these issues has been revised to represent only 25% of the potential credits. This is likely the normative area where interests of skin design may be thought to be the most important.

Energy efficient building envelope design may also include passive solar strategies, differentiated façade design, shading devices, double skin façades, etc. Such envelope design strategies will be able to positively impact potential LEED credits under energy optimization, as well as crossing over into areas of Indoor Environmental Quality and Innovation Credits.

The emergence of Building Integrated Photovoltaic systems (BIPV) presents new considerations in envelope design and can create an even more efficient envelope if it is capable of also producing electricity.

Figure 4: Lillis Building, University of Oregon
Energy Efficiency: Credit 1: Optimize Energy Performance: Crystalline PV is integrated into the south façade glazing and skylights – serving a double function as a shading device.

Figure 5: BC Gas (Terasan Gas) Musson, Cattell Mackey Partnership
Energy Efficiency: Prereq 2: Minimum Energy Performance: Solar shading to reduce energy consumption. Differentiated façade strategies as a function of orientation.

Table 1c: Energy and Atmosphere and the Building Envelope

Credit	Pts	Name and Description	Impact on the Building Envelope
		Energy & Atmosphere	
Prereq		**Fundamental Building Systems Commissioning:** verify design, installation and calibration of the fundamental building systems	Although not directly linked to the envelope, certain choices in envelope design can be validated with commissioning as a requirement.
Prereq		**Minimum Energy Performance:** ensure a minimum energy efficiency to comply with ASHRAE 90.1-1999[1]	Requires the design of an efficient, well-insulated building envelope to meet the minimum level – good since a permit can be purchased without meeting this base criteria!
Prereq		**CFC Reduction in HVAC&R Equipment**: base building HVAC&R equipment is to use no CFC-based refrigerants	none
1	**1 - 10**	**Optimize Energy Performance:** exceed the ASHRAE 90.1-1999 energy performance standard for regulated systems	Many of these points drive decisions in envelope design: super insulation, high quality roofing, wall, window and curtain wall systems. This area can also encourage passive solar design strategies for heating, which can impact envelope design strategies.
2.1	1	**Renewable Energy:** include on-site renewable energy systems to provide at least **5%** of the total energy use of the building	Some envelope implications, as a good envelope that reduces heating and cooling requirements can lower all energy requirements and possibly make 100% use of renewables more achievable. Encourages use of PV and BIPV, which must be incorporated into envelope systems (windows, skylights and roofs).
2.2	1	**Renewable Energy:** include on-site renewable energy systems to provide at least **10%** of the total energy use of the building	
2.3	1	**Renewable Energy:** include on-site renewable energy systems to provide at least **20%** of the total energy use of the building	
3	1	**Best Practice Commissioning:** complete additional verification of systems design, construction and calibration	Post occupancy evaluations can help to ensure that occupants have been properly educated to prevent improper functioning of building. This can reinforce the effectiveness of decisions made on the building envelope if extra costs were involved to predict the generation of

			energy savings.
4	1	**Ozone Protection:** ensure that base building HVAC&R and fire suppression systems do not use HCFCs or Halons	No significant impact.
5	1	**Measurement and Verification:** install metering equipment for key efficiency issues including lighting systems, motor loads, chiller efficiency, cooling load, and several others	This can help to ensure that occupants have been properly educated to prevent improper functioning of building. This can reinforce the effectiveness of decisions made on the building envelope if extra costs were involved to predict the generation of energy savings.
6	1	**Green Power:** engage in a minimum two-year contract for renewable energy to supply at least 50% of the building's electricity	none

D. MATERIALS AND RESOURCES:

Of interest to skin design is the addition of Materials and Resources Credit 8: Durability to the Canadian version of LEED™ which will have a high impact on skin related decisions.

Materials and resources, with 14 points generated in seven credits, this section has only one prerequisite: storage and collection of recyclables. The credits focus on building reuse; waste management; reused, recycled or certified materials; as well as local or regional materials. This portion of the LEED requirements has a high impact on issues of skin design and specification – and inversely, the particular design and materials selection/specification of the building envelope has extreme impact potential on the award of these points.

Building Re-use (Credits 1.1, 1.2 and 1.3) The first 3 credits that pertain to the reuse of buildings will impact both the overall design of the envelope as they will infer the inclusion of elements that may or may not be ultimately desirable when trying to achieve an energy efficient envelope. It is important to note when reviewing the envelope reuse credits that it is expected that "degraded" or "non-energy efficient" elements such as roofing materials are expected to be directed to the waste stream.

Materials Re-use may require additional effort in sourcing components. Care must be taken to ensure that the materials chosen meet with local code requirements for reuse as some authorities limit wood reuse, for example, depending on its ultimate role in the building. If species types are not clear, some types of wood may be unsuitable due to their potential weathering problems.

Recycled Content credits also require additional investigation when sourcing and specifying materials. It is also important to consider whether or not the materials used in the building envelope have potential for recycling when they are no longer useful in the building: the "Cradle to Cradle" concept.[2] This will also affect the way we build and fasten products as design for disassembly may be required at some point in the life of the building.

Figure 6: Liu Centre for Asian Studies, UBC, Architectura
Materials and Resources: Credit 4 Recycled Content – timber framing. The building also uses flyash in its concrete – a waste product of the steel industry.

The idea behind the *Regional Materials* credits focuses on embodied energy issues as a function of transportation costs. The requirements for this credit have been eased from the USGBC version due to the larger travel distances inherent to Canada. The limiting distance as within a 500-mile (800 km) radius and refers to the location of final assembly of the materials into the manufactured product – the materials themselves may come from further afield. Shipping via train or boat is preferred to truck due to CO_2 and infrastructure concerns.

Figure 7: C.K. Choi Institute for Asian Studies, UBC, Matsuaki Wright Architects
Materials and Resources: Credit 4 Recycled Content (both the timber frame and brick veneer cladding) Reuse of brick for cladding can bring concerns regarding the "life left" of the product from the point of view of durability and weathering.

Table 1d: Materials and Resources and the Building Envelope

Credit	Pts	Name and Description	Impact on the Building Envelope
		Materials & Resources	
Prereq		**Storage and Collection of Recyclables:** provide facilities for storage and separation.	No significant impact.
1.1	1	**Building Reuse:** retain **75%** of walls, floors and roof of existing building on site	Large impact on envelope design. Envelope must be able to accommodate existing conditions and limitations of materials and orientation previously chosen.
1.2	1	**Building Reuse:** retain **95%** of walls, floors and roof of existing building on site	As above
1.3	1	**Building Reuse:** retain **50%** of interior non-shell/non-structure portions of existing building on site	Little impact on envelope.
2.1	1	**Construction Waste Management:** recycle and/or salvage 50% of site waste (construction, demolition and land clearing) to limit material going to landfill	This does not necessarily impact envelope design, but if construction strategies for envelopes generate waste, this must be directed to recycling or salvaging operations. This would include cut-offs of wall studs and sheathing components and gypsum board, for example. Therefore design systems to limit waste from initial principles. Preference for use of prefabricated components on site. Reuse of concrete and other forms.
2.2	1	**Construction Waste Management:** recycle and/or salvage 75% of site waste (construction, demolition and land clearing) to limit material going to landfill	
3.1	1	**Resource Reuse:** source 5% of building materials as salvaged, refurbished or reused	Source such materials and include them in assemblies where applicable and where the use of

3.2	1	**Resource Reuse:** source 10% of building materials as salvaged, refurbished or reused	such materials upholds energy and durability criteria of envelope systems. This would include the use of recycled wood products for cladding and floor finishing, for example.
4.1	1	**Recycled Content:** source 7.5% of building materials: (post-consumer product + ½ post industrial).	Requires consideration when sourcing systems and products to verify their recycled content as this must be entered into a calculation of recycled content for all materials in the building project.
4.2	1	**Recycled Content:** source 15% of building materials: (post-consumer product + ½ post industrial)	
5.1	1	**Regional Materials:** ensure that at least **10%** of building materials and products are manufactured within a 500mi radius of the site, or up to 1500 mi if shipped by rail or water.	When specifying any envelope components, check to see that the location of material source and manufacturing meets this requirement. This may be of concern for specialty systems such as glazing, curtain wall, etc.
5.2	1	**Regional Materials:** ensure that at least **20%** of the building materials and products are harvested, extracted or recovered within a 500mi radius of the site. or up to 1500 mi if shipped by rail or water.	As above.
6	1	**Rapidly Renewable Materials:** ensure that at least 5% of the building materials are made from plants harvested within a ten-year cycle)	This may impact materials selection for components: use of wheat board, strawbale, bamboo and generally plants that are harvested within a 10 year cycle. Durability of such materials if used as an interior wall/ceiling finish, cladding system or main support system as in strawbale construction.
7	1	**Certified Wood:** specify at least 50% of building materials to be wood-based and certified from environmentally responsible forestry operations.	Important in specification of wood framed wall systems, wood window frame systems and exterior deck and screen elements that are wood based, as well as formwork and temporary structures on site.
8 *Canada only*	1	**Durability:** Minimize material use and construction waste over a building's life resulting from premature failing of the building and its constituent components and assemblies	This credit is new to the Canadian Version of LEED and has potentially a great impact when specifying higher quality components for all envelope assemblies (walls and roofs) as well as all glazing and window systems. The credit is more difficult than many to document and prove in order to gain the credit points.

E. INDOOR ENVIRONMENTAL QUALITY:

Indoor environmental quality is the largest category with two prerequisites, IAQ performance and environmental tobacco smoke control, eight credits and a total of 15 points. The credits in the indoor environment quality cover many issues of air quality, including ventilation and carbon dioxide monitoring, low-emitting materials, construction IAQ, controllability of systems, thermal comfort and daylight access. This category places high emphasis on occupant comfort and well-being – issues that are not addressed in other mandatory code requirements – this category falling outside issues of life safety, structural integrity and minimum energy requirements.

Maintaining a high ventilation rate, combined with reduced toxicity as a result of specified components or processes within the building, is the primary goal. Second, in the interest of occupant comfort and satisfaction, the section promotes *perimeter control* of “systems” by the occupant. This would include levels of heating, cooling, direct sunlight or daylight.

Occupant control of perimeter systems, as well as ventilation requirements (i.e. operable windows) has a large potential impact on the design of envelope systems. These criteria will affect the selection and design of window systems to include a higher than normal percentage of operable units, with highly durable mechanisms for control. Control of the operation of windows outside of occupancy hours may require computerized override systems to prevent unnecessary losses during unoccupied hours from windows that have been accidentally left open. It will also increase the inclusion of operable shades in the building perimeter, which may be incorporated into envelope systems. These may be located on the interior or exterior of the building, or integrated into the wall system itself.

Issues of mold in the building envelope (migrating to the interior) or building itself due to improper ventilation practices are dealt with in the IEQ credit categories. Detailing of the envelope system to prevent mold, although not directly stated, is inferred in this category.

Figure 8: Mountain Equipment Coop, Toronto, Stone Kohn and Vogt Architects
Indoor Environmental Quality: Credit 8 Daylighting – use of glazing to daylight the space can increase heat loss (winter) or heat gain (summer) if not properly detailed and specified

Figure 9: C.K. Choi Institute for Asian Studies, UBC, Matsuaki Wright Architects
Indoor Environmental Quality: Ventilation Effectiveness + Control of Perimeter systems

Post occupancy assessment of systems is always important. The operable windows on the C.K. Choi Building may provide user control and ventilation, but feedback indicated that the style of window and its method of opening were uncomfortable for the users. The extreme height and inward tilt was found to feel “threatening”, and the upward flow of air was not immediately felt.

Table 1g: Indoor Environmental Quality and the Building Envelope

Credit	Pts	Name and Description	Impact on Building Envelope
		Indoor Environment Quality	
Prereq		**Minimum IAQ Performanc**e: establish indoor air quality performance to meet the ASHRAE 62-999 voluntary ventilation standard	Operable windows provide fresh air and significant air exchange and also promote passive heating and daylighting. Building envelope must incorporate ventilation strategies. Tightly sealed envelope systems are not encouraged except in specialized uses where adequate air quality is provided in total by the HVAC systems.
Prereq		**Environmental Tobacco Smoke Control:** ensure non-smokers experience no exposure to environmental tobacco smoke	Operable windows pose a difficulty if they are near areas where smokers congregate. Check building layout.
1	1	**Carbon Dioxide Monitoring:** install a CO_2 monitoring system which reports on ventilation performance and allows operational adjustments	Use of operable windows or trickle vents in envelope systems can provide natural ventilation to reduce CO_2 levels. This can impact overall envelope design, materiality and operable glazing ratios.
2	1	**Ventilation Effectiveness:** provide effective delivery and mixing of fresh air to meet ASHRAE 129-1997 standard for mechanically ventilated buildings OR demonstrate suitable air flow patterns for naturally ventilated buildings.	Well-designed window layout will provide cross-ventilation and a means to free air-conditioning during shoulder seasons. Use of windows promotes potential for passive solar. Rolls into other envelope concerns.
3.1	1	**Construction IAQ Management Plan:** maintain indoor air quality during construction and pre-occupancy phases	No significant impact.
3.2	1	**Construction IAQ Management Plan:** conduct an appropriate building flush-out to eliminate any air problems resulting from construction/renovation processes	No significant impact.
4.1	1	**Low-Emitting Materials:** specify **adhesives and sealants** which are low in volatile organic compounds (VOCs)	Check specs to see that low VOC adhesives and sealants are used in the envelope assemblies.
4.2	1	**Low-Emitting Materials:** specify **paints and coatings** which are low in VOCs	Check specs to see that low VOC paints and coatings are used in the envelope assemblies.
4.3	1	**Low-Emitting Materials:** specify **carpets** which are low in VOCs	No significant impact.
4.4	1	**Low-Emitting Materials:** specify **composite wood products** which are low in VOCs	Check specs to see that low VOC wood products and glues are used in the envelope assemblies.
5	1	**Indoor Chemical and Pollutant Source Control:** employ floor grills at entries and appropriate exhaust and plumbing in areas where water and chemical concentrate mixing occurs	No significant impact.

6.1	1	**Controllability of Systems:** provide at least one operable window and one lighting control zone per 200 s.f. within 15 feet of the perimeter wall	Operable windows and skylights with blinds can provide airflow, temperature control and lighting control for perimeter areas. This must be incorporated into the envelope assembly.
6.2	1	**Controllability of Systems:** provide airflow, temperature and lighting controls for at least 50% of occupants in non-perimeter areas	Non-perimeter occupants can still rely on diffuse natural light if care is taken to bounce light deeper into the building, such as with light-shelves, skylights or roof monitors. These systems are integral with the envelope design.
7.1	1	**Thermal Comfort:** ensure compliance with ASHRAE 55-1992 for thermal comfort to include humidity control	Designing daylight systems to avoid direct beam light will prevent thermal discomfort from intense solar heat gain. If thermal mass is being used, it will likely have a noticeable effect on the temperature control in the buildings. Diffuse light can provide illumination without undue heat gain. Daylighting design impacts envelope design.
7.2	1	**Thermal Comfort:** install a permanent monitoring system for temperature and humidity and provide operator control over humidification/dehumidification	No significant impact.
8.1	1	**Daylight and Views:** ensure a minimum of 2% daylight factor to 75% of occupied spaces	The envelope must be designed to promote daylighting and provide adequate and properly placed windows to achieve the daylight factor required. Windows must be selected that do not compromise the insulation integrity of the envelope. May require spectrally selective glass to be considered. May require light shelves, shading devices, deflectors or other envelope modifications.
8.2	1	**Daylight and Views:** ensure direct line of site to vision glazing for 90% of regularly occupied areas	

F. INNOVATION AND DESIGN PROCESS:

Innovation and design process allows a building to obtain as many as four design innovation points, as well as one additional point for including a LEED accredited professional in the design process. The design innovation points may be awarded for achievements such as lifecycle analysis, community development or education of occupants. Substantially exceeding one of the earlier credits, may also merit an innovation point. So for example if adequate passive and active systems were incorporated into the design as to allow the building to function independent of the grid, this would qualify for an innovation point. If the energy performance optimization exceeds the maximum permitted by point EA #1, 64% of MNECB or 60% of ASHRAE 90.1, an extra point may be awarded. A point is also given for the involvement of a LEED Accredited Professional, which may be somewhat self-serving to the system, but does encourage a higher level of sustainable design education of the profession to pass through the accreditation exam process. Successful implementation of C2C or Zero Carbon targets are now eligible for an innovation point.[3] The achievement of a carbon neutral building has taken the Aldo Leopold Foundation Building in Wisconsin to a Platinum level.[4]

Figure 10: *Innovation and Design Process:* Caisse de Depots et Placements, Montreal
Double skin wall construction.

Increased interest in innovative sustainable design construction methods that have more recently been imported from European models, such as double skin wall façade systems, can also qualify for an innovation point. These buildings are normally more sustainable motivated, and the double skin wall system will also impact issues of perimeter control, access to natural ventilation, indoor air quality, thermal quality, envelope performance as well as protection of shading devices in harsh climates. Such systems can now be seen in the Telus/William Farrell Building designed by Busby and Associates in Vancouver, the Caisse de Depots et Placement, in Montreal, the Centre for Cellular and Biomolecular Research at the University of Toronto, by Benisch, Benisch with Architects Alliance and the Seattle Justice Center by NBBJ Architects. However, decisions to include such product and material intensive systems may well work against aspects of Zero Carbon design. Therefore, the benefits would have to be carefully weighed against the additional use of material, associated energy and the potential for energy savings over the long term.

Figure 11: *Innovation and Design Process:* Centre for Cellular and Biomolecular Research, University of Toronto, Benisch and Benisch. Double skin façade construction in progress. The building also uses innovative planning to separate less climate controlled corridor spaces from highly controlled laboratories. Two storey planted atriums will be located at the corners of the south face of the building.

Table 1f: Innovation and Design Process and the Building Envelope

Credit	Pts	Name and Description	Impact on the Building Envelope
		Innovation & Design Process	
1	1 - 4	Innovation in Design: extra credits are awarded for substantially exceeding a LEED performance credit, OR for	A well designed energy efficient building, if shown to perform better than its benchmark due to the inherent superior envelope strategies may be eligible for one or more innovation credits as a

		significant performance in other categories, such as acoustic performance, life-cycle costing or education of occupants.	function of the areas incorporated. Innovative wall systems, double skin façade systems, passive solar systems, can potentially earn these credits.
2	1	LEED Accredited Professional: include a LEED accredited professional in the project team	No inherent link to building envelopes, but inclusion of such an individual would be helpful in working with trade-offs and synergies in the envelope design.

It is evident that, given the pervasiveness of the need well designed, durable, energy efficient envelopes in both the Energy and Atmosphere as well as Materials and Resource sections of the LEED Credit System, that it would be difficult to attain even a Certified Label without significant incorporation of reasonably considered envelope design. The added incorporation of concerns regarding Indoor Environmental Quality (mold issues) can easily assist in taking the *project* to a Platinum level, but do not necessarily ensure a high performance envelope.

THE IMPACT OF ZERO CARBON STRATEGIES ON THE DESIGN OF THE ENVELOPE

Zero Carbon is perhaps the newest sustainable design initiative and is the subject of a massive amount of current research and development. As such, there are not any clear and simple guidelines to follow when considering designing building envelopes or buildings to meet this important target.[5] Being carbon neutral can be achieved in more than one way. It can refer to the practice of balancing carbon dioxide released into the atmosphere from burning fossil fuels associated with the building, its construction, materials and processes, with renewable energy generated on site that creates a similar amount of useful energy, so that the net carbon emissions are zero, or alternatively using only renewable energy. Carbon can also be offset by creating "sinks" within the scope of the building project that will remove carbon from the atmosphere.

Unlike other aspects of green skin design, this layer requires a high level of computation that is based on the combination of energy performance, climate/region, as well as material specifications. There are aspects of envelope design that are difficult to separate from their carbon impact on the overall performance of the building as well as manufacturing and transportation implications for the project in general. There are some recently launched tools such as the Athena Impact Estimator for Buildings[6] as well as the Athena Eco Calculator[7], both of which are useful in calculating more specific environmental impacts that include CO_2 as well as other emissions.

To achieve a truly carbon neutral state, all building envelope materials must be brought to the site by vehicles powered by either bio-fuel or electricity that has been generated in a sustainable fashion. All power tools used to construct the envelope would be powered by energy cleanly generated onsite. This would require the use of solar or wind power or by generators powered by bio-fuel. If using electricity from the grid, it would be supplied by renewable sources ("Green Power"). Concrete would only be used if it was manufactured using renewable energy, and the carbon dioxide from cement production was sequestered. Flyash may be used to offset some of the cement content in that this assists in reducing the net carbon cost of another industry and is a waste product. The use of concrete would be limited to those elements where it is structurally necessary, as in foundations, or where its thermal mass value is essential to the passive design strategies or systems.

The building envelope materials would either be locally manufactured, from sustainably forested lumber, milled using renewably-powered sawmills, or would be recycled. Locally grown wood, recycled metal and glass and local clays or cob could be used. The forestry practices associated with the construction of the Aldo Leopold Center are exemplary in this regard. This will make use of some information already gathered in the associated LEED credits. The use of other manufactured materials, such as aluminum for curtain wall, glass, metals, plastics, etcetera, would reduce the carbon neutrality of the building. Much like the production of concrete, their manufacturing processes would be held accountable to the carbon neutral equation. To balance their carbon "expense" it would be necessary to design the building (project – so this could include site development strategies and landscape) to convert some of the CO_2 cost into oxygen. This aspect of qualification is far more stringent than LEED which awards credits for low VOC materials but does not address any aspect of their carbon production. For instance, a LEED credit is earned for using low VOC carpet, but there is not a reward for avoiding its use, which would be preferable in the long term.

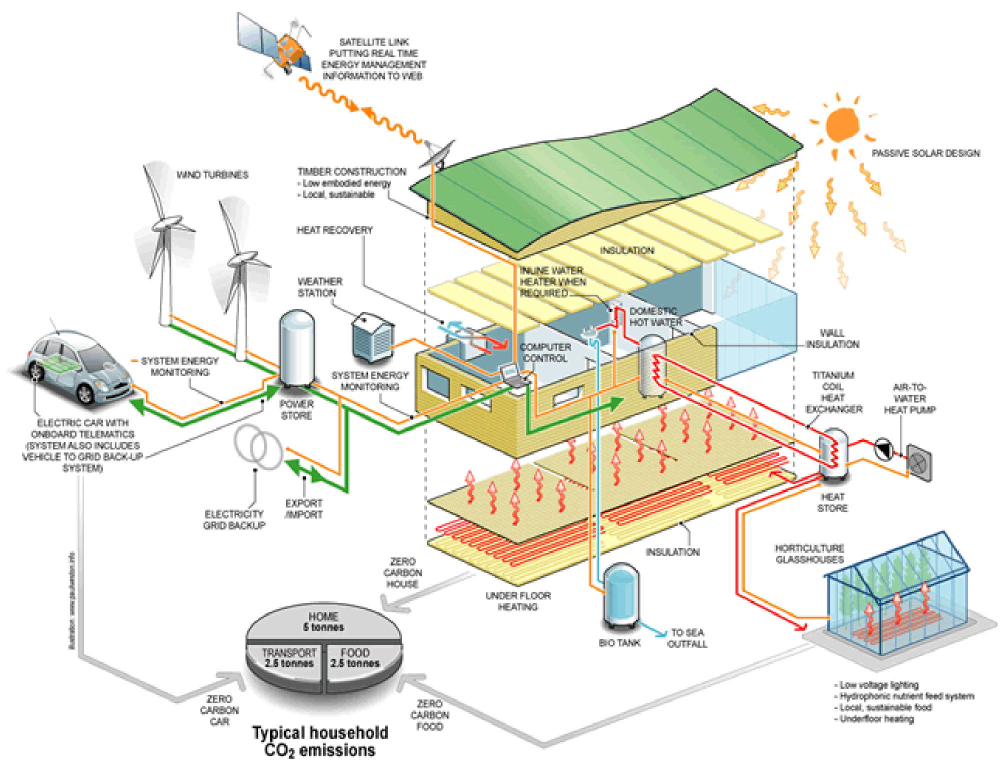

Figure 12: A Zero Carbon House in a Severe Climate[8]

The building would need to be constructed so that it could be expected to last for 50-100 years, and if it needed to be demolished, the materials could all be reused, or returned to the earth as in composting. This feeds well into Cradle 2 Cradle ideologies and Design for Disassembly methods. No construction or demolition debris could be land filled or be transported from the site. Therefore any waste or scraps would be required to have a designed "use" or "place" in the project.

The envelope itself would need to meet high performance and energy efficient criteria as the primary means for reducing the need for non passive heating and cooling methods. This reflects back on some LEED criteria that might already have been considered. It would be constructed to maximize passive design, including the use of solar energy for heating, and natural ventilation for cooling so to minimize requirements for additional mechanical heating and cooling. All southern windows would have seasonal shading geometry, so they would be shaded in summer, but not in winter. East, west and north glazing would also need to be controlled for heating and cooling. Green building techniques would be used throughout, similar to those discussed under the LEED™ criteria.

DESIGNING THE EXTERIOR WALL FOR DISASSEMBLY AND C2C

The premise of C2C is that "waste equals food" and that we must "remake the way we make things".[9] When we look at this strategy with respect to the building envelope, it might be simpler to comprehend if we take the position that all materials that are used in creating the wall must simply be prevented from becoming waste. The wall must be built with materials and in such a manner that when the useful life of the building is at an end, it can be taken apart and all of its components reused with minimal reconditioning. C2C places a high preference on reuse as any degree of recycling often results in down-cycling, thereby both degrading the resource value of the materials in the elements as well as requiring the use of additional energy to remanufacture the material into a less wasteful new element.

Thinking about the composition of the wall with disassembly in mind, begins to determine material selections as well as the construction and subsequent deconstruction process. Material considerations must not only include the larger components that comprise the building envelope, but also fasteners and methods of insulation. For example, screws are simpler to remove without damaging other elements than are nails or staples. Sprayed in place insulations cannot be reused as their removal requires significant destruction of the element, in addition to the residue of the sprayed in place foam being cleanly removed from other components. Limited kinds of insulation materials are biodegradable, so could qualify as "food". Materials such as gypsum wall board are not durable enough to endure removal without significant damage, thereby precluding any reuse. There is also a preference for the use of homogeneous materials as these are more easily handled and therefore reused. Composite materials can be more difficult to reuse if the separation of the components is necessary. Separation usually requires additional energy and processing, which can in turn contribute to CO_2 production, working against a Carbon Neutral objective.

All materials can be taken through Cradle to Cradle Certification on two different levels. This certification can be applied to the envelope materials, sub assemblies and finished products. The system been designed to include all manner of materials and products, not only those that are clearly architectural in nature.[10]

Cradle to Cradle™ Technical/Biological Nutrient Certification: This is a binary, pass-fail approach designed for those materials and simple products that are homogeneous in nature. This certification only encompasses the Material and Nutrient (Re)utilization criteria.

Cradle to Cradle™ Product Certification: This is a three-tiered approach consisting of Silver, Gold, and Platinum levels to reflect continuing improvement along the cradle-to-cradle trajectory. This certification contains the following five categories of metrics: Materials, Nutrient (Re)utilization, Energy, Water, and Social Responsibility.

Where the LEED Materials categories look predominantly for contribution to off-gassing, the C2C criteria examine a wide range of health risks associated with health of humans, other organisms and the environment. This infers that materials that might have been acceptable in the LEED review for Certification may not be acceptable when evaluated for C2C compliance. Therefore although C2C might be considered as a higher level of requirement for a green envelope design, above the LEED requirements, it might be necessary to consider material selection for compliance to both systems simultaneously, with the more stringent requirements in hand.

Thinking about building envelope design with disassembly in mind will extend the thoroughness required in design development as the designer must not only specific a high performing wall system, but also design its construction and deconstruction methodology. Dfd also requires that the contractor and construction workers be educated in the process and intentions so that their actions do not inadvertently undermine the process.

CONCLUSION

It is not difficult to see how intrinsically connected are the interests of high performance building envelope design and the LEED™ Credit system, Zero Carbon, C2C and Design for Disassembly strategies.

As a growing number of jurisdictions, governments and organizations look to adopt LEED™ Standards for their new and renovated construction, it becomes increasingly important for designers to understand the system and the impact of the tool on building envelope design and performance. As LEED itself has been designed as an effective environmental marketing tool, so can it be used as *a starting point* to more effectively ensure better skins on buildings as the LEED rating system can be used to increase both the quality of construction as well as the level of design and detailing in building envelopes. As a tool with rising credibility, it will be able to be increasingly used to justify skin related decisions in our architectural design teaching and practices.

As can easily be seen when looking at more advanced criteria as represented in the interests of Zero Carbon Building, Design for Disassembly and Cradle 2 Cradle design and certification, the use of LEED alone will be insufficient to elevate high performance envelope design to an environmentally adequate level. Although not at all simple to design, specify or implement, the fully integrated application of Zero Carbon, C2C and Dfd strategies will be critical to the creation of a genuine "green skin" on the building.

FIGURES:

All photographic images included in this paper are by the author.

ENDNOTES:

[1] *New Building:* Reduce design energy consumption to comply with NRC's CBIP requirement for a **25%** energy reduction compared to the reference building designed to meet the Model National Energy Code of Canada for Buildings 1997.
Major Renovations to Existing Buildings: Reduce design energy consumption to comply with NRC's CBIP requirement for a **10%** reduction compared to the reference building designed to MNECB 1997.

[2] McDonough & Michael Braungart. Cradle to Cradle: Remaking the Way We Make Things. New York: North Point Press, 2002.

[3] USGBC Web site http://www.usgbc.org/News/PressReleaseDetails.aspx?ID=3315

[4] Aldo Leopold Legacy Center Web site http://www.aldoleopold.org/Visit/LegacyCenterbrochure.pdf

[5] Efforts are underway during the 2007/8 academic year to develop a new suite of Zero Carbon Studios at a number of schools. Material will be posted through SBSE in 2008.

[6] Athena Institute Web site http://www.athenasmi.ca/tools/docs/ImpactEstimatorFactSheet.pdf

[7] Athena Institute Web site http://www.athenasmi.ca/tools/ecoCalculator/index.html

[8] Illustration developed with ESD and Michael Rea. © Paul Weston 2007
http://www.zerocarbonhouse.com/

[9] McDonough & Michael Braungart. Cradle to Cradle: Remaking the Way We Make Things. New York: North Point Press, 2002.

[10] MBDC Cradle 2 Cradle Certification. http://www.mbdc.com/certified.html