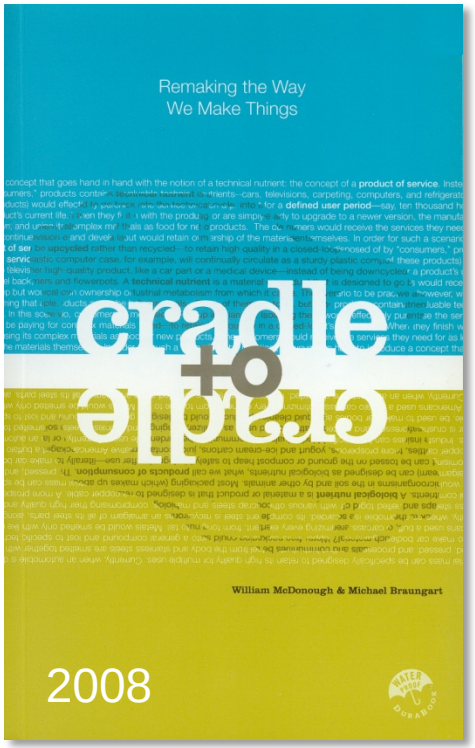
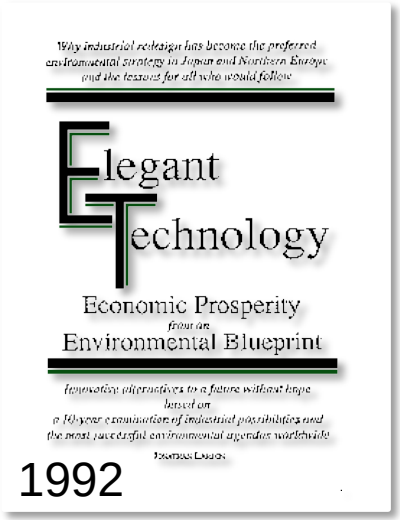
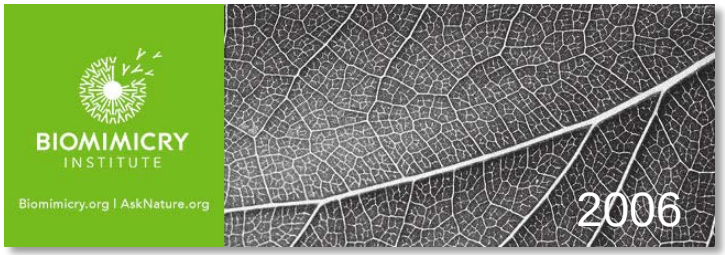
Philosophies of Sustainable Design





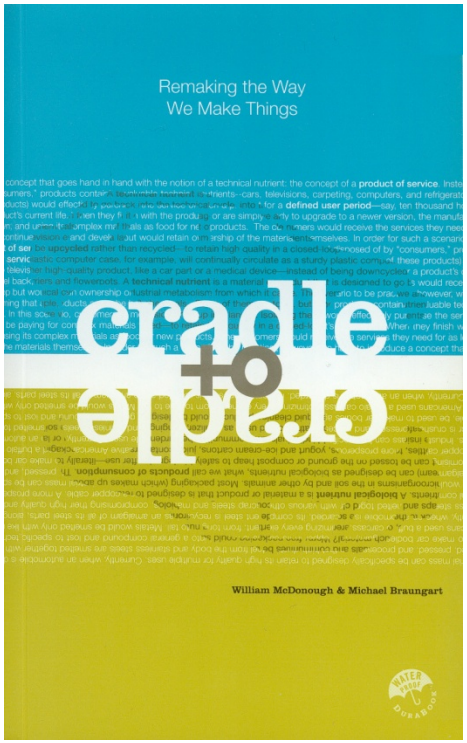


“The world will not evolve past its current state of crisis by using the same thinking that created the situation.”

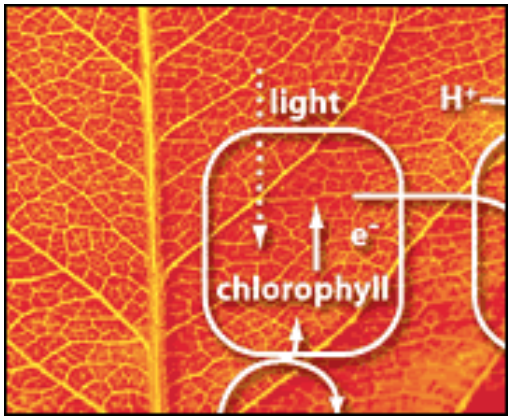
– Albert Einstein

remaking the way we make things

cradle 2 cradle



MBDC *(McDonough Braungart Design Chemistry)* is articulating and putting into practice a new design paradigm; what *Time* calls "a unified philosophy that—in demonstrable and practical ways—is changing the design of the world."



"Eco-effectiveness seeks to design industrial systems that emulate the healthy abundance of nature."

“A walking college lecture--he is also dean of the University of Virginia school of architecture--McDonough is a compendium of similar maxims, phrases and rules: "Honor commerce as the engine of change"; "respect diversity"; "build for abundance"; "eco-efficiency should be replaced by eco-effectiveness"; "design is the first signal of human intention"; "all sustainability, like politics, is local"; "I want to do architecture that is timeless and mindful.“

All this and much more come from a 48-year-old *innocent anarchist*; his language has the touch of the poet and of the bomb thrower; he looks like actor James Woods in a bow tie. He thinks abstractly, making it equally fascinating and difficult to talk to him, since he turns nearly every contribution one makes to the conversation into a refinement of his theories.” Time Magazine

William McDonough and Michael Braungart

"The growth/no-growth argument is specious," he said last week. "Growth is good. The question is, how do you want to grow?"

McDonough's guiding principle seems simple enough: the source of our environmental woes is waste. There is nothing wrong with cars, TV sets, and running shoes.

What's wrong is the waste—chemicals, heavy metals, CO_2—that's produced when we make them, use them, and, eventually, throw them away.

Eliminate that waste, and you eliminate the problem.

We don't necessarily need to make less stuff.

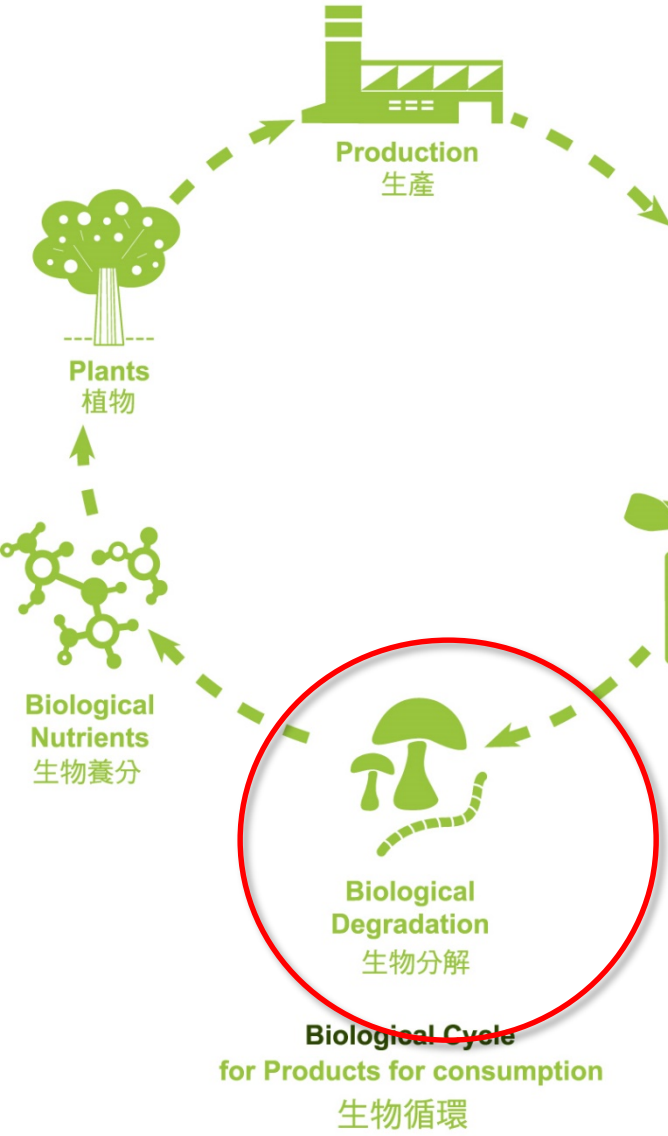
We only need to make stuff differently.

In McDonough's future, there would be only two kinds of products. The first would be made of natural substances—he calls them "biological nutrients"—and they'd be perfectly biodegradable. Had enough of those pants? Just toss them out the window, like an apple core.

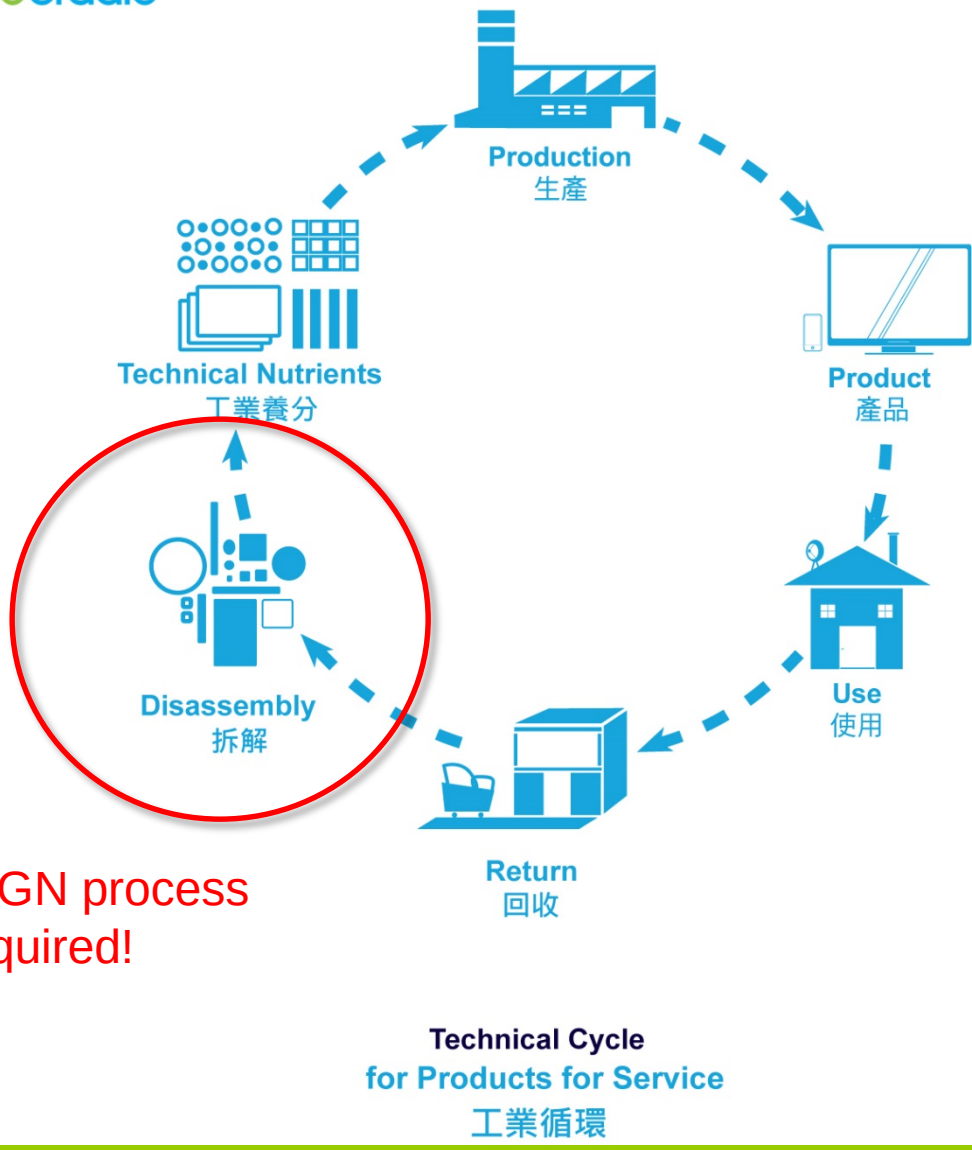
The second would be made of "technical nutrients"—steel, plastics, polymers, silicon, glass—and would be endlessly reusable; old shoes would become new shoes, old cars would be turned into new cars.

Everything would be raw material for something else.

cradletocradle®



Major DESIGN process changes required!



waste equals food

Philosophical Paradigm Shift

Waste equals food:

- Design materials and products that are food for other systems. This means designing materials and products to be used over and over in either technical or biological systems.

- Design materials and products that are safe. Design materials and products whose life cycle leaves a beneficial legacy for human or ecological health.

- Create and participate in systems to collect and recover the value of these materials and products.

biological nutrient vs technical nutrient

Utilizing *biological nutrient* and *technical nutrient* definition allows a company to virtually eliminate the concept of waste and recover value, rather than creating a future of solid waste liability and relinquishing material assets by simply delivering a physical product to a customer without a coherent relationship to the potential inherent in the product itself as a potential long term asset for the customer, nature, industry or the company itself. Cradle to Cradle Design™ turns contingent liabilities into assets.

BIOLOGICAL NUTRIENT
A *biodegradable material* posing no immediate or eventual hazard to living systems that can be used for human purposes and can safely return to the environment to feed environmental processes.

TECHNICAL NUTRIENT
A material that remains in a closed-loop system of manufacture, reuse, and recovery (the technical metabolism), maintaining its value through many product life cycles.

wool, for example…

Utilizing biological and technical nutrients allows a company to eliminate the concept of waste. Recapturing materials encourages a manufacturer to integrate higher quality materials and focus on the full product life cycle; materials are not fully relinquished to customers when products are sold if the materials and their value are recaptured following product use.

Product cycling among multiple life cycles also creates a mechanism for reconnecting with customers to market the next product generation and provides incentives for return sales.

compostable end product

compostable - yes

Biodegradable
Made from Nature...Returned to Nature Store.com

Vegware

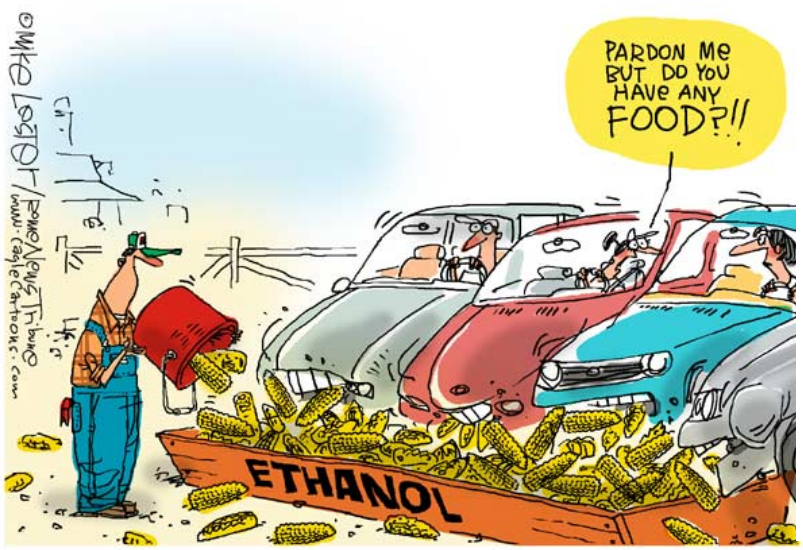
Everything here is made from wheat, potato starch or corn, and can be composted. *It is not plastic…*

BUT if it is NOT composted, then a total WASTE of potential FOOD!

Biofuel: what are the global consequences??

Biofuel is DIFFERENT! It is not composted and still contributes to CO_2 levels as you still BURN it.

When biofuels compete with food production, what happens?
Price of wheat goes up => bread and other basic food items increase in price
Price of corn goes up => processed food prices increase
Price of soybean goes up => beef becomes more expensive

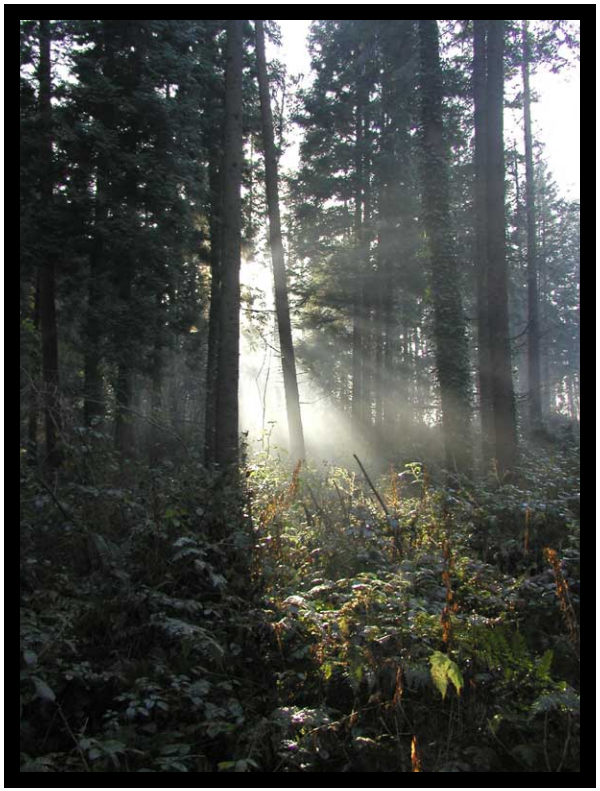


c2c vs. cradle to grave

Instead of designing cradle-to-grave products, dumped in landfills at the end of their 'life,' need to transform industry by creating products for cradle-to-cradle cycles, whose materials are *perpetually circulated in closed loops*.

Maintaining materials in closed loops maximizes material value without damaging ecosystems.

c2c vs. cradle to grave



“the cradle”

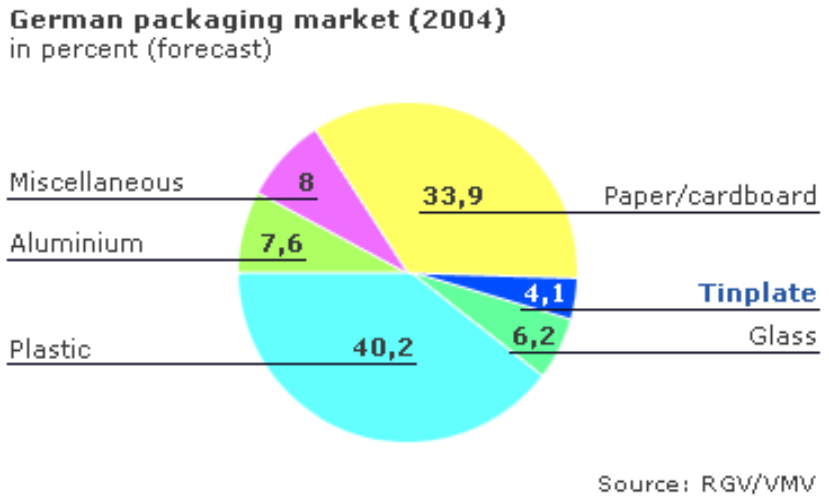
One of the primary tenets of this philosophy is “grave avoidance”.

But beyond that, REUSE OVER RECYCLING as reuse requires significantly less expenditure of additional energy and materials and often results in “downcycling” of valuable materials.

“the grave”

DOWNCYCLING

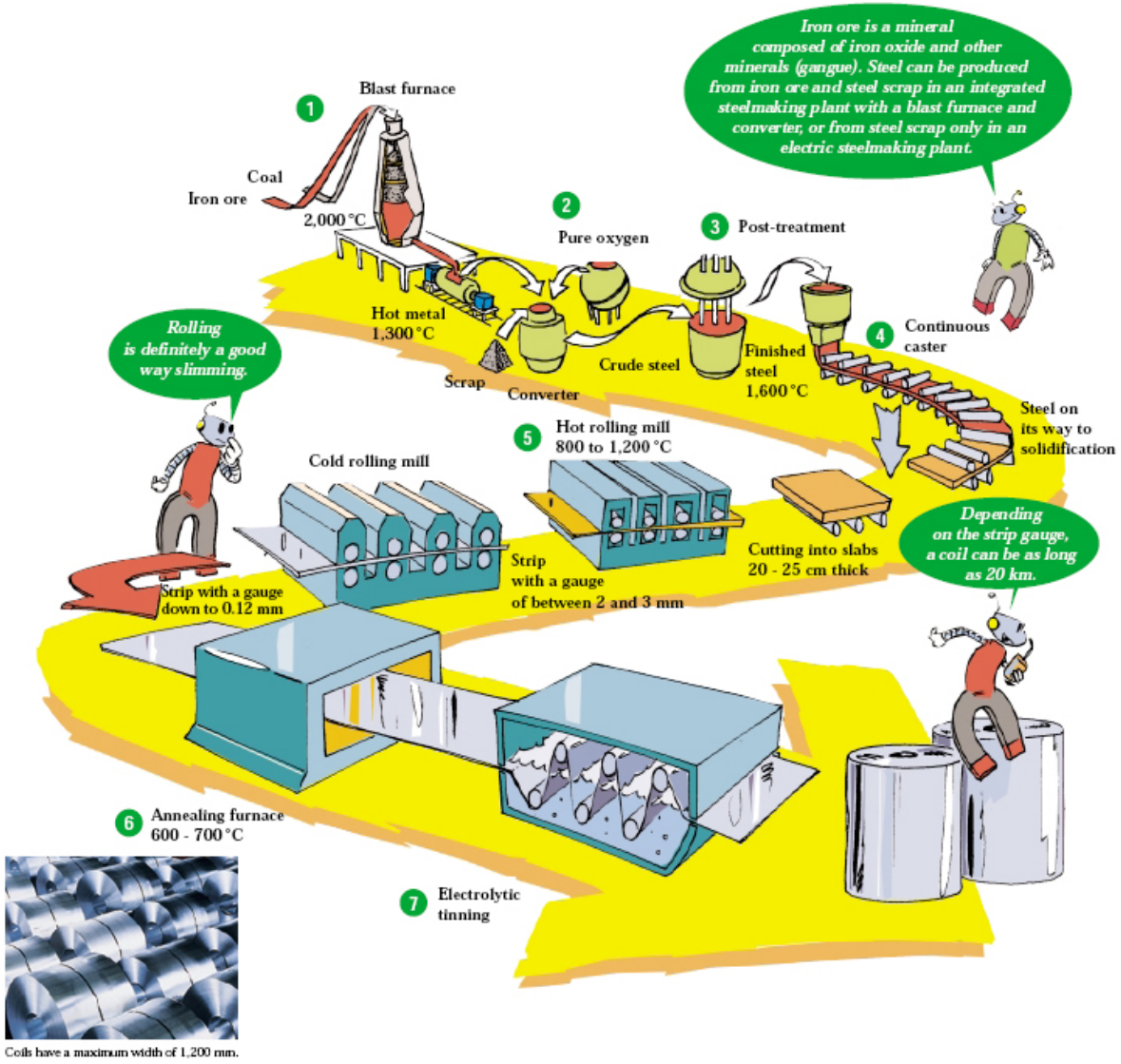
The practice of recycling a material in such a way that much of its inherent value is lost (for example, recycling plastic into park benches). This is true for the majority of major recycling efforts. Products can only be downcycled so many times before their usefulness is completely spent and they end up in landfills.



Downcycling does not occur with tinplate.

It is argued that the energy and material expenditure of transforming discarded plastic bottles into plastic wood is not worth the effort – therefore regarded as DOWNCYCLING the material.

Tinplate is steel with a very thin layer of tin to coat its surfaces so that it does not corrode.



Source: http://www.izw.de/fileadmin/Download/Publikationen/verpackung_mit_pfiff_en.pdf

There are two main routes for recycling steel and tinplate

- collection of production waste
- collection of used tinplate

Steel recycling is environmentally friendly, as it reduces the consumption of iron ore. Every year, more than 500 million tons of iron ore are saved worldwide by the use of steel scrap. The steel industry uses about one million tons of scrap every day to make steel around the world. This corresponds to about 42,000 t per hour or 12 t per second.

DfD

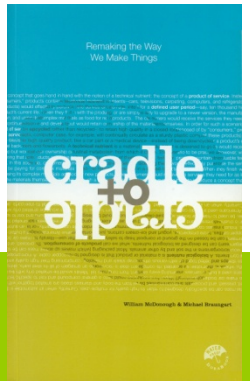
design for disassembly

DESIGN FOR DISASSEMBLY
Designing a product to be dismantled for easier maintenance, repair, recovery, and reuse of components and materials.

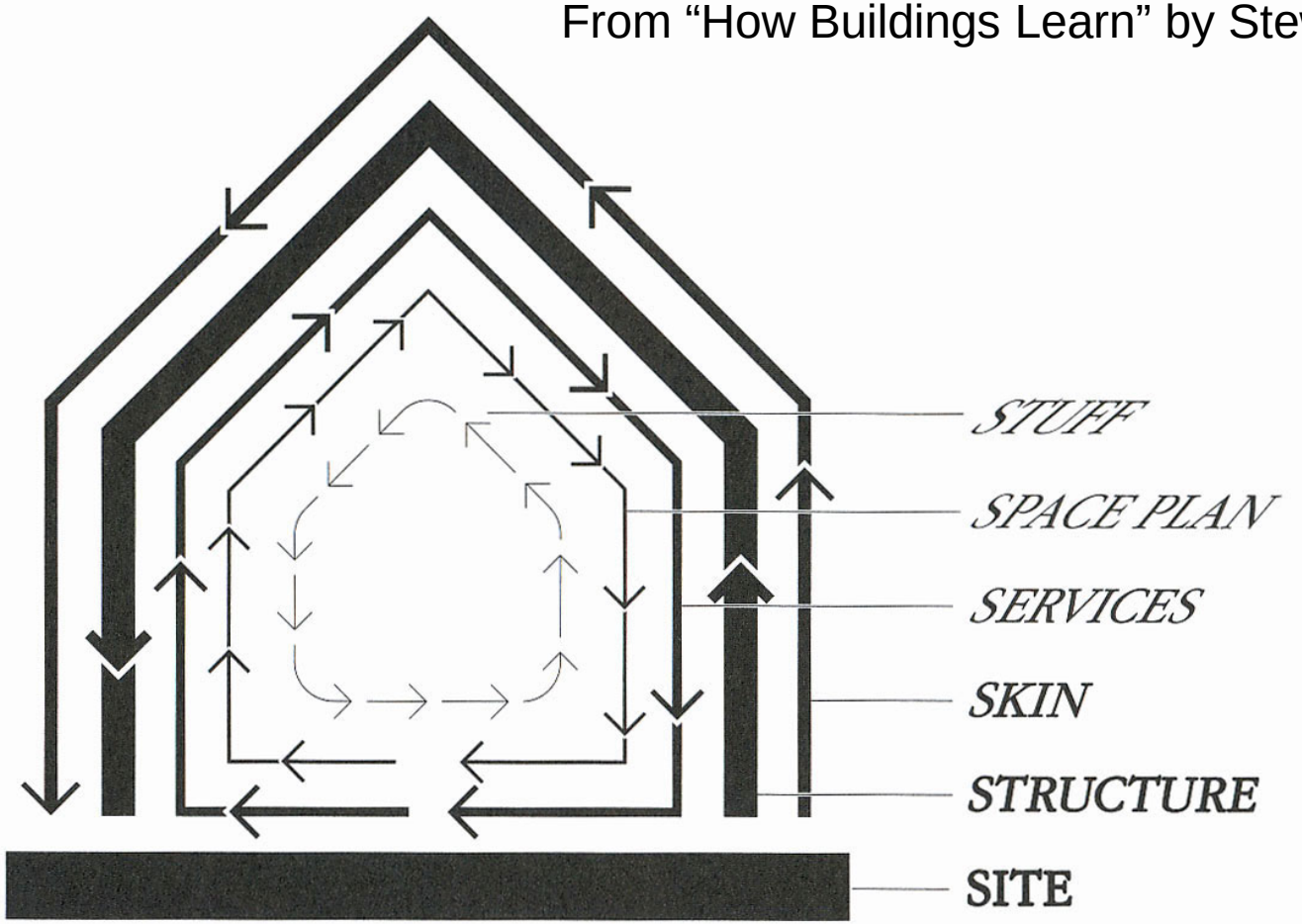
“Why take something as exquisite as a tree and knock it down? Trees make oxygen, sequester carbon, distill water, build soils, convert solar energy to fuel, change colors with the seasons, create microclimates and provide habitat.

My book "Cradle to Cradle," which I wrote with Michael Braungart, is printed on pages made of plastic resins and inorganic fillers that are infinitely recyclable. They're too heavy, but we're working with companies now to develop lightweight plastic papers. We have safe, lightweight inks designed to float off the paper in a bath of 180 degrees—hotter than you would encounter under normal circumstances. We can recapture the inks and reuse them without adding chlorine and dioxins to the environment. And the pages are clean, smooth and white.”

- William McDonough



From “How Buildings Learn” by Stewart Brand

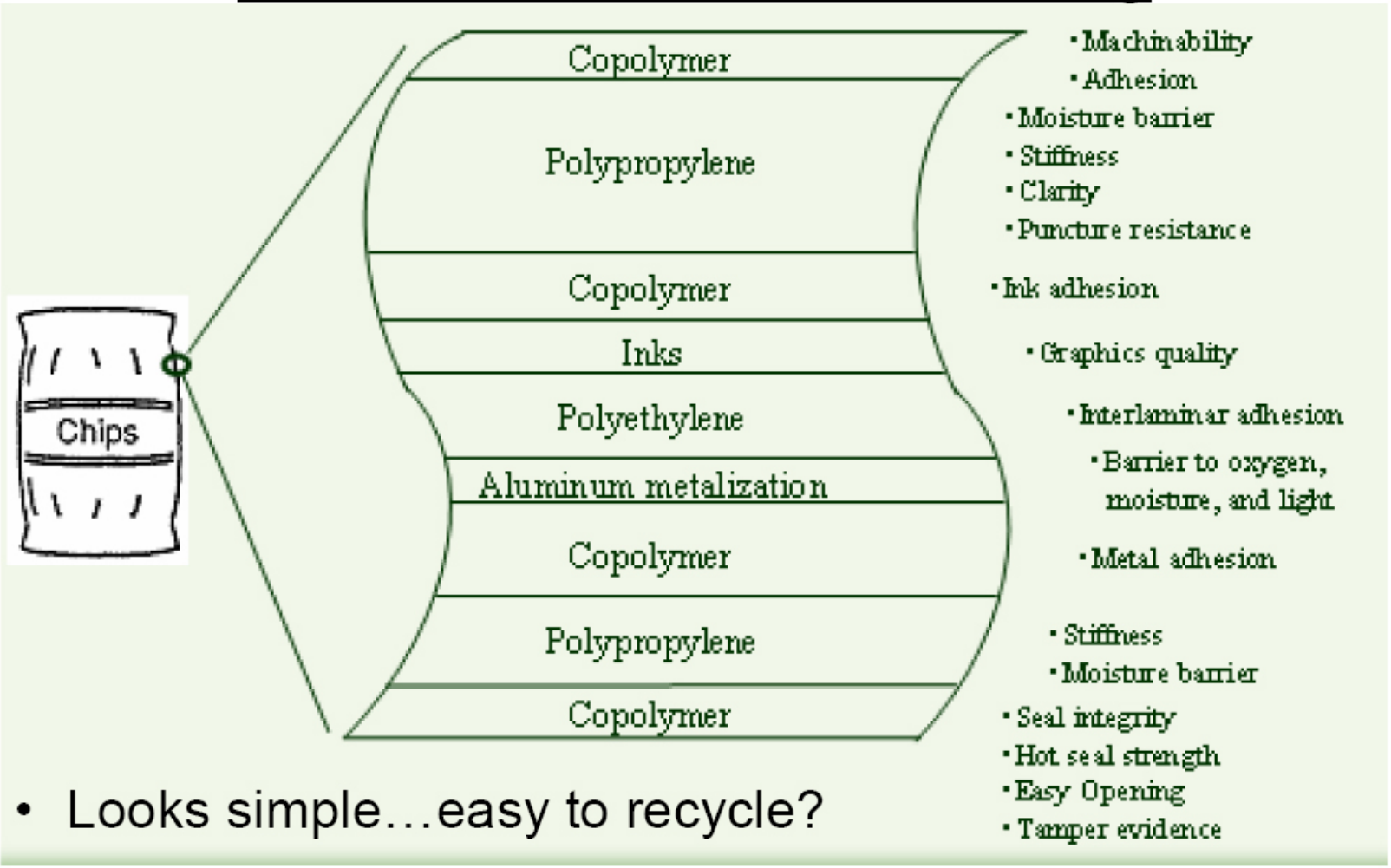


SHEARING LAYERS OF CHANGE. Because of the different rates of change of its components, a building is always tearing itself apart.

How do we take things apart?

- That were not intended to be taken apart
- Not designed to be taken apart
- Are glued or connected via means that make it next to impossible
- That are assembled in layers that degrade at different rates of speed
- That are highly complex
- That mix benign materials with toxic ones (paint, glue, coatings…)

Cross-section of a Snack Bag

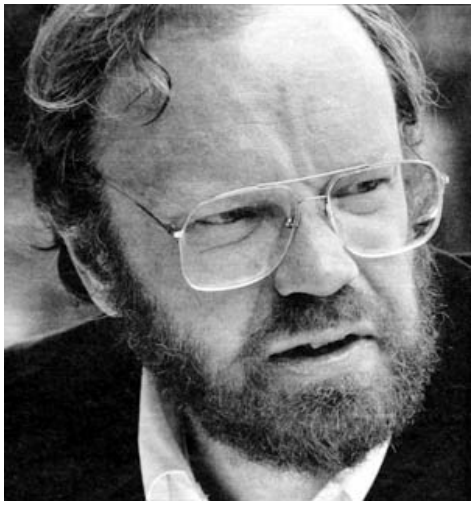


- Looks simple…easy to recycle?

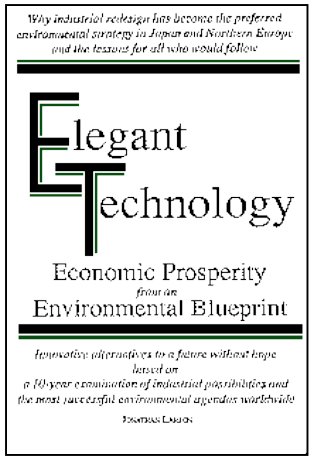
Source: http://www.eng.uc.edu/~pbishop/69

This product is neither easy to recycle nor suitable for composting.

philosophy of design for disassembly (DfD)



Jonathan Larson



DFD is a subset of the emerging environmental redesign movement which assumes that:

a) humans cause pollution (apes and dolphins may be bright but they have never caused a toxic waste dump)
b) humans are conscious beings
c) pollution is caused by the conscious acts of these humans
d) the more difficult the act of humans, the more planning it takes
e) the truly difficult pollution problems are caused by acts of significant planning and design.

Therefore:

Pollution is a function of design!

source: http://www.elegant-technology.com/TVnewide.html

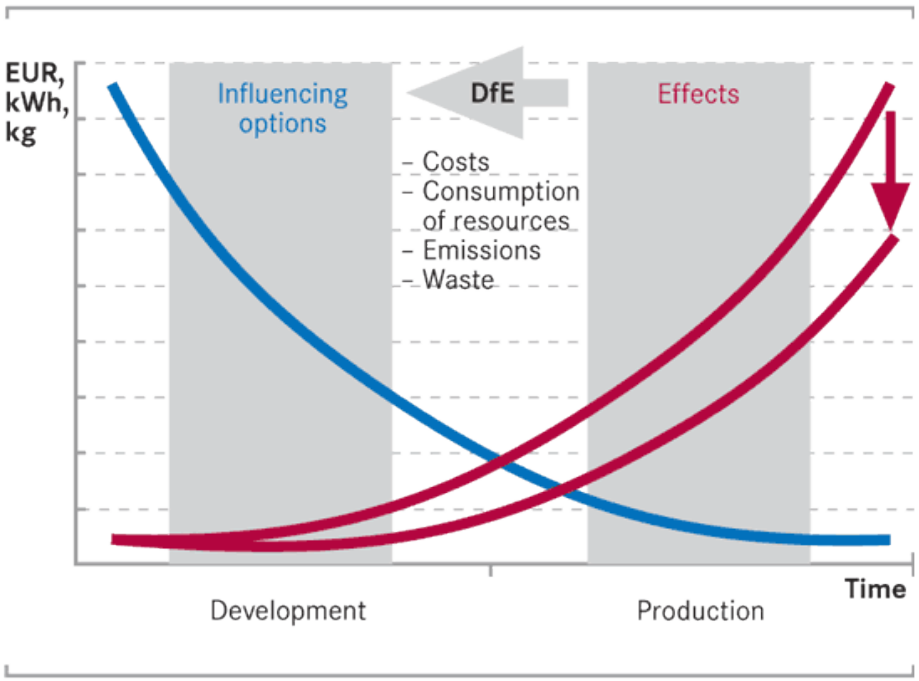
the Germans have already done it

“The Germans, who are no slouches when it come to technological creativity, have passed what may be the world's most interesting environmental law. Because they are running out of places to hide their garbage, they now require manufacturers to take responsibility for recycling. The principle is: You made it--you figure out what to do with it when its useful life has ended. Three general strategies to cope with this legislation have emerged: Some products are designed for easy disassembly and resource recovery, others are being reformulated to biodegrade on their own, while other products and processes are designed out of the system altogether. By assigning total product life responsibilities on the original technological creators, the Germans are forcing into existence a whole new generation of industrial excellence.”

- *Jonathan Larson*

mercedes benz + DfE

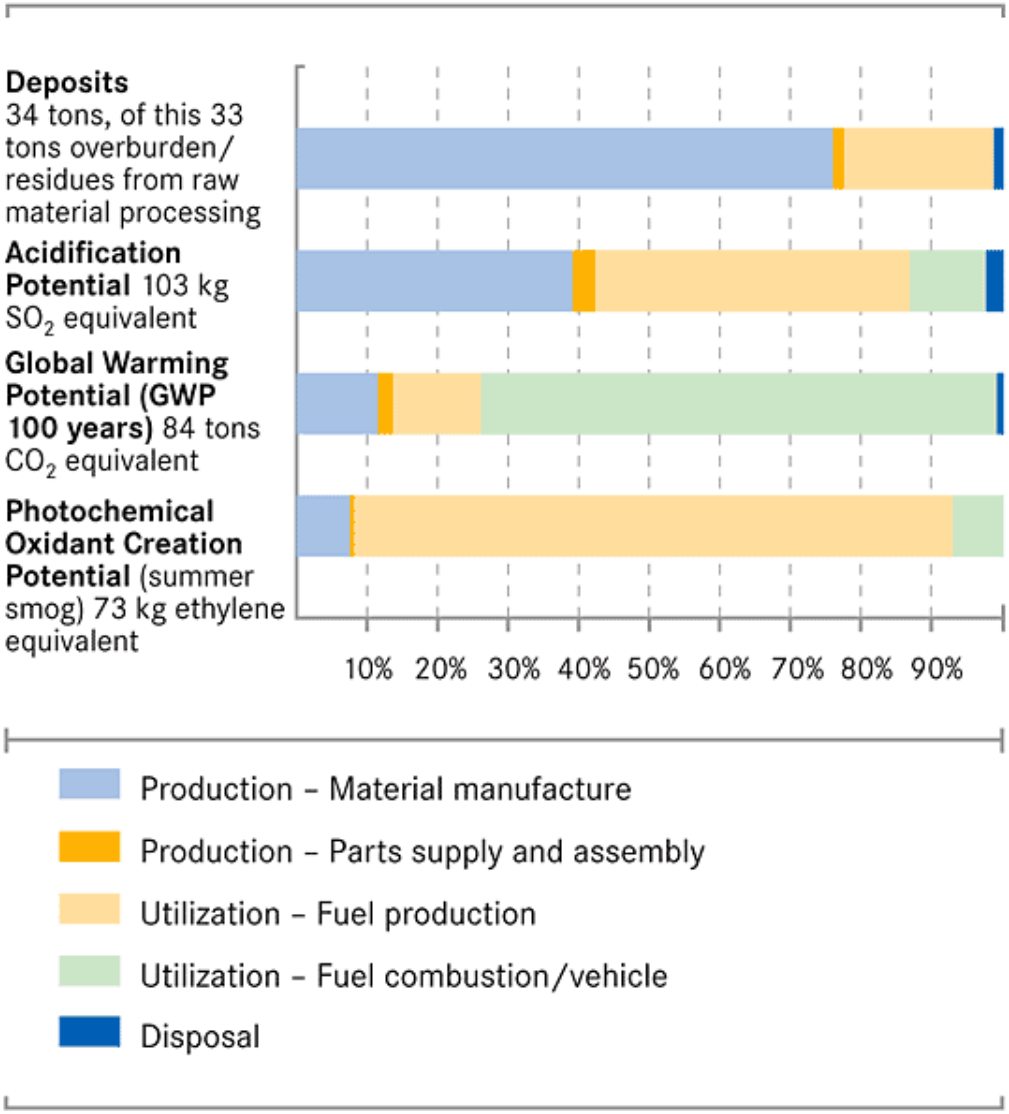
Influence and effects of Design for Environment (DfE)



DfE starts as early as the early development stages. This is because even minor measures taken at this early point in time can have significant effects at a later stage – and yield tangible reductions in the consumption of resources, in emissions, in waste volumes and in costs. By contrast, it is extremely difficult and costly to modify a vehicle component at an advanced stage of development or as late as the production stage.

DfE = Design for the Environment

Environmental impact on the lifecycle stages of a passenger car using the example of the Mercedes-Benz E-Class



Renewable materials in the new E-Class station wagon

Raw materials	Used in
Flax, sisal, hemp	Door trim, backrest cover driver's seat
Coconut fiber/latex compound	Seat backrests and upholstery
Wood veneer	Trim strips, panels
Wool, cotton	Seat and head restraint covers
Reprocessed cotton	Insulation, seat cushions, parcel shelf brackets in sisal/cotton compound with plastic matrix

Recycling applications in Chrysler Group vehicles

Component	Recycled material (100 %)
Spare tire protector	Crumb rubber
Transmission oil filter	Polyamides (PA66)
Headlamp bezels; I/P top cover; speaker grille	Polycarbonates (PC)
Lamp housing	PC/acrylonitrile-butadiene-styrene
Battery case; splash shields, wheel house	Polypropylene (PP)
Package shelf tray, door trim panel	PP with wood (fiber/flour)
Mirror bracket	Polyethylene terephthalate (PET)
Acoustic pad	Resinated cotton
Air dam	Thermoplastic olefin TPO

A house is likely not even as complex, when you really get right down to it…

“The European environmentalists I know consider the American infatuation with consumerist strategies to be utterly infantile. If the last twelve years have taught us anything, it is that peoples and nations who know how to successfully produce, eventually dominate those who merely know how to shop.”

-Jonathan Larson

The most comprehensive work on Design for Disassembly has identified the more detailed areas associated with Design for Recycling, these are:

- Designing for ease of disassembly, to enable the removal of parts without damage.
- Designing for ease of purifying, to ensure that the purifying process does not damage the environment.
- Designing for ease of testing and classifying, to make it clear as to the condition of parts which can be reused and to enable easy classification of parts through proper markings.
- Designing for ease of reconditioning, this supports the reprocessing of parts by providing additional material as well as gripping and adjusting features.
- Designing for ease of re-assembly, to provide easy assembly for reconditioned and new parts.

Four categories which are related to the four important areas of disassembly and recycling, these are:

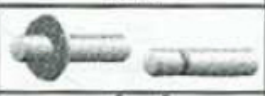
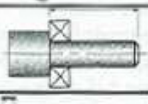
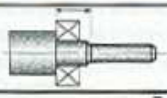
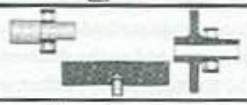
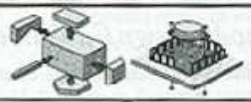
- Materials, enabling the disassembled materials to be easily recycled but the principles can apply equally to disassembled parts for Re-manufacture or reuse.
- Fasteners and Connections, enabling easy and quick disassembly.
- Product Structure, enabling rapid and economic disassembly.
- Avoidance of glues, adhesives and toxic coatings

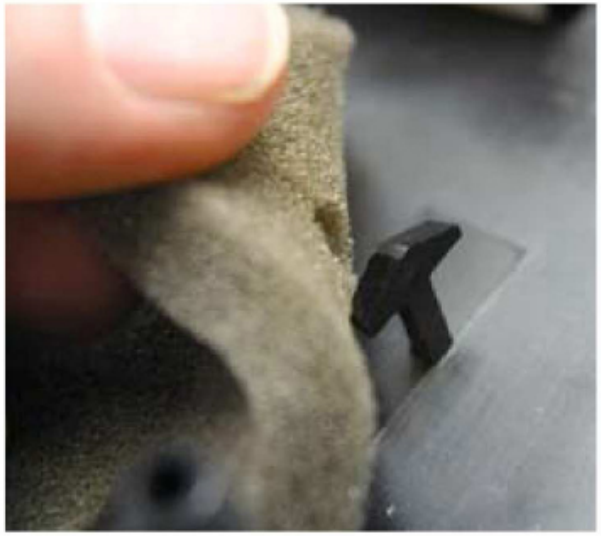
as simple as

vs

?

Joints suitable for Disassembly

Guideline	Don't	Do
Use attachments that are easy to disassemble		
Minimize the number of fasteners		
Use the same fasteners		
Ensure easy access for disassembly		
Use simple standard tools		
Avoid long disassembly paths		
Design for damage free dissassembly		
Use the same tools for assembly and disassembly		
Use one disassembly direction to avoid reorientations		
Design for multiple detachments with one operation		



"Design for environment surprisingly coincides very well with design for manufacturability"

- Development engineer at IBM

Source: http://www.moea.state.mn.us/publications/betterbydesign.pdf

Material Flows

- Assuming disassembly is possible, material flows must be identified that acknowledge whether a material is:
  - RECYCLABLE
  - COMPOSTABLE
  - DISPOSED (no choice but to be waste)
  - TOXIC (avoid if possible)

Acknowledgement for the following content and diagrams to the thesis of Scott Proudfoot, 2017.

RECYCLABLE

- McDonough and Braungart's concept of technical nutrients, man-made substances that can be renewed by industry, is here termed recyclable.
- Effective recycling depends on the strict meaning of re-cycling, returning materials back to their original use.

COMPOSTABLE

- Compostable materials emerge from the concept of biological nutrients. Plant matter is harvested, used, and left to decompose at end of life.
- Leveraging the environment for production and disposal creates a far smaller ecological footprint than mined materials.

DISPOSED

- Materials extracted for a single use encompass most of what we build with today. Many of these, like gravel, will not be exhausted any time soon. However they form the bulk of waste.
- Downcycled materials also appear here, as they are designed for only one use in their current form.

TOXIC

- A surprising number of building materials are toxic to their occupants or the environment.
- Removing these from use is a priority, as managing them in waste streams is a long term problem without immediately obvious or economically viable solutions.

TOXIC RED LIST

Compiled by the Living Future Institute:

- Alkylphenols
- Asbestos
- Bisphenol A (BPA)
- Cadmium
- Chlorinated Polyethylene and Chlorosulfonated Polyethlene
- Chlorobenzenes
- Chlorofluorocarbons (CFCs) and Hydrochlorofluorocarbons (HCFCs)
- Chloroprene (Neopene)
- Chromium VI
- Chlorinated Polyvinyl Chloride (CPVC)
- Formaldehyde (added)
- Halogenated Flame Retardants (HFRs)
- Lead (added)
- Mercury
- Polychlorinated Biphenyls (PCBs) Perfluorinated Compounds (PFCs)
- Phthalates
- Polyvinyl Chloride (PVC)
- Polyvinylidene Chloride (PVDC)
- Short Chain Chlorinated Paraffin
- Wood treatments containing Creosote, Arsenic or Pentachlorophenol
- Volatile Organic Compounds (VOCs) in wet applied products

https://living-future.org/declare/about/red-list/

White List (Masterformat)

Div.	Material	End of life
03	~~Concrete~~	~~Downcycled~~
04	Mortared masonry	Reusable
	~~Glued masonry~~	~~Inseparable~~
	~~Toxic glazes, pigments~~	~~Toxic~~
05	Steel	Recyclable
	Aluminum	Recyclable
	Copper	Recyclable
	Stainless steel	Recyclable
	Galvanized steel	Recyclable
	~~Lead~~	~~Toxic heavy metal~~
	~~Mercury~~	~~Toxic heavy metal~~
06	Wood	Compostable
	Polyethylene	Recyclable
	~~Polyvinyl chloride~~	~~Toxic chlorine~~
	~~Pressure treated lumber~~	~~Toxic arsenic and creosote~~
	~~Neoprene~~	~~Toxic chlorine~~
	~~Chlorinated plastics~~	~~Toxic chlorine~~
	~~Epoxy~~	~~Toxic bisphenol A~~
	~~Formaldehyde glues~~	~~Toxic~~
	~~Composites~~	~~Inseparable~~
07	Tyvek (spun polyethylene)	Recyclable
	Polyethylene film	Recyclable
	Cellulose fibres	Compostable
	Straw	Compostable
	Rockwool	Recyclable

Div.	Material	End of life
	~~Polystyrene foam~~	~~Landfilled~~
	~~Flat roofing products~~	~~Toxic, inseparable~~
	~~Painted metal roofs~~	~~inseparable~~
	~~Caulking~~	~~Inseparable~~
08	Aluminum and steel frames	Recyclable
	~~Vinyl frames~~	~~Toxic chlorine~~
	Glass	Recyclable
	~~Coated glass~~	~~Inseparable~~
	~~Laminated glass~~	~~Inseparable~~
	~~Tinted glass~~	~~inseparable, possibly toxic~~
	~~"Smart windows"~~	~~Inseparable, possibly toxic~~
09	~~Plaster~~	~~Downcycled~~
	~~Gypsum board~~	~~Downcycled~~
	Fastened panelling	Recyclable or compostable
	~~Tile~~	~~Downcycled~~
	~~Concrete flooring~~	~~Downcycled~~
	Wood flooring	Sometimes recyclable
	~~Vinyl flooring~~	~~Toxic~~
	~~Fluid applied flooring~~	~~Inseparable~~
	Carpet	Some are recyclable

Sticky things…

The following finishes are only appropriate where the base material and finish can biodegrade together.

Most paints	~~Inseparable~~
Glued anything	~~Inseparable~~
Composites	~~Inseparable~~

Not so simple Vinyl Trim

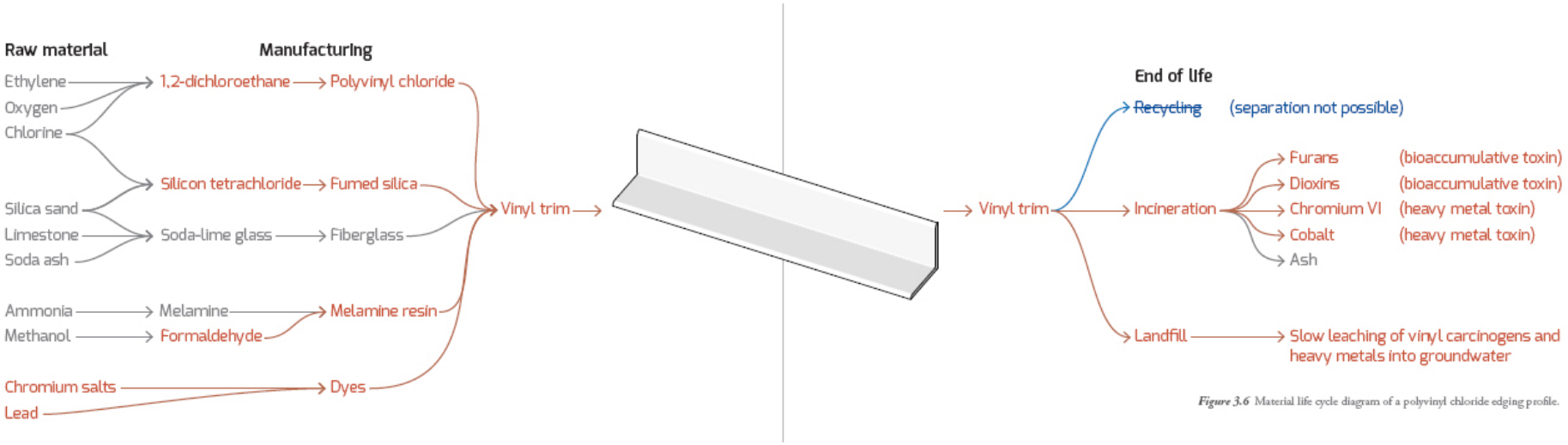


Figure 3.6 Material life cycle diagram of a polyvinyl chloride edging profile.

An inherent issue with any building product manufactured from PVC:

- Window frames
- Roofing membranes
- Plumbing pipes
- Baseboards, trim, etc.

Not so innocent Wood??

Wood is naturally biodegradable so most wood exposed to the environment has been protected with toxic materials to slow degradation.

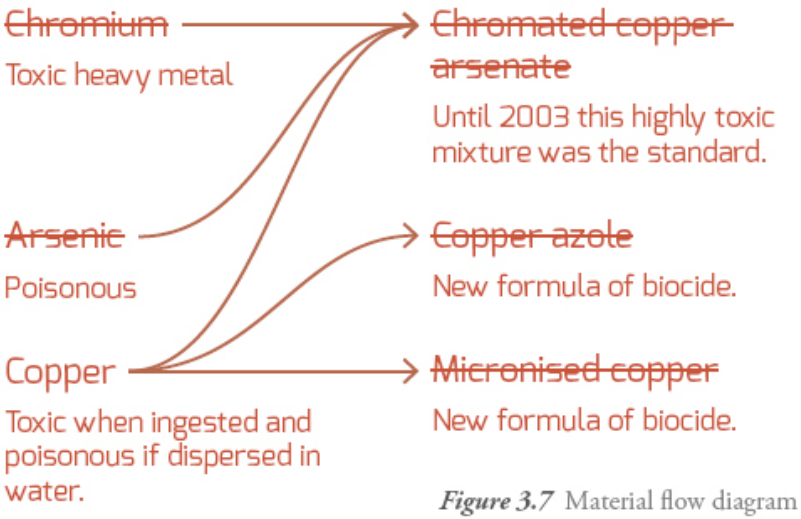
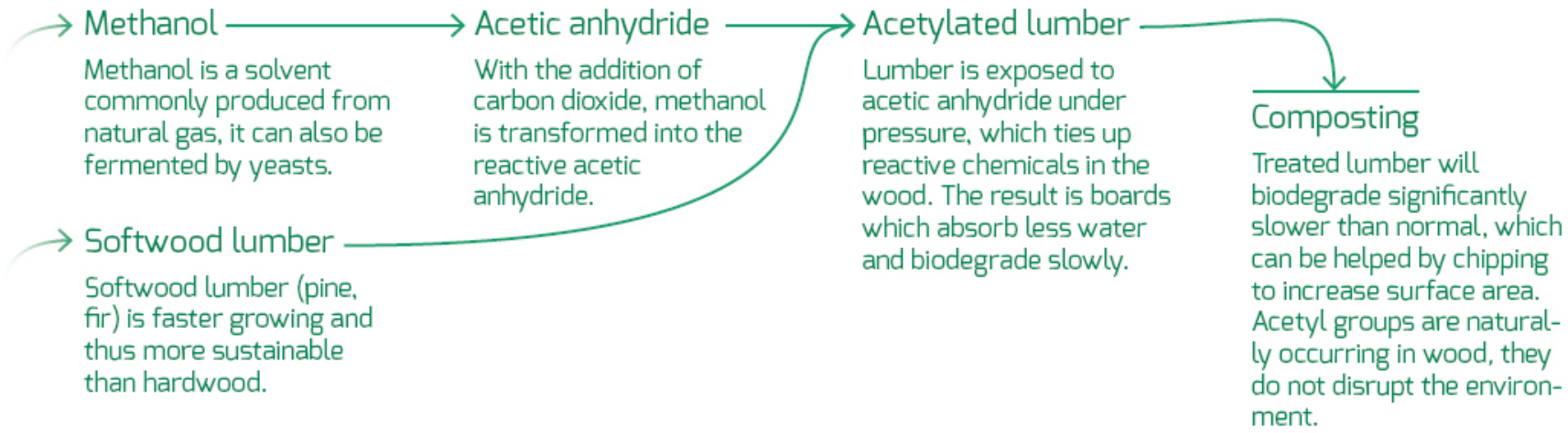


Figure 3.7 Material flow diagram for wood treatments

Changed Wood Treatment Required



Cellulose Insulation

Cellulose insulation has the lowest environmental footprint of all insulation types. To render the fluffy paper fibres fireproof however, boric acid (borax) and ammonium sulfate are added. Borax is an environmental toxin, which relegates the eminently compostable paper fibres to landfill. Ammonium sulfate, on the other hand, while not renewable is commonly used as fertilizer. Substituting a greater quantity of ammonium sulfate for boric acid will produce cellulose insulation that can be safely composted.

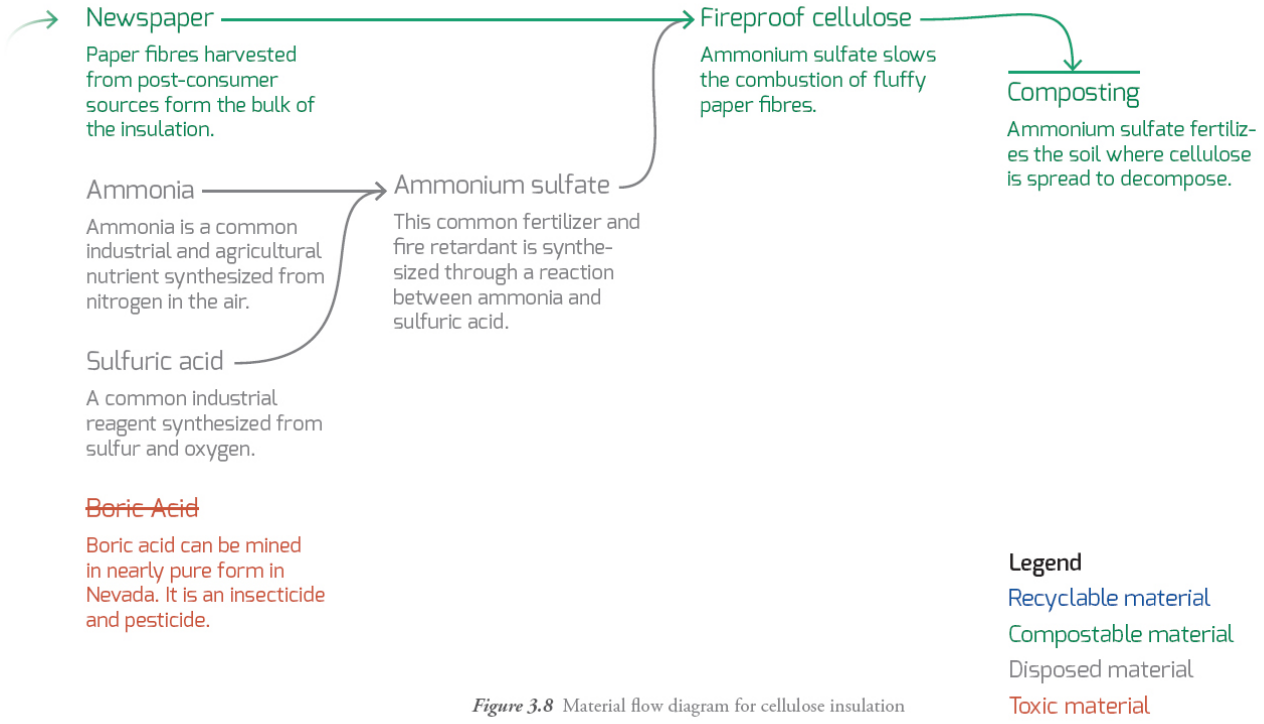


Figure 3.8 Material flow diagram for cellulose insulation

Rockwool Insulation

Rockwool is growing more and more popular for building insulation. Marketing materials often tout its environmental friendliness, however, the rock fibres are held together by a toxic thermo-set phenol formaldehyde adhesive. Post-industrial recycling of small quantities is practised, though there is no widespread collection system for post-consumer rock-wool. By replacing the formaldehyde adhesive with a thermoplastic polymer such as nylon, the materials can be separated at end of life. Nylon can be recovered by solvent dissolution, and cleaned rock fibres can then be remelted into fresh wool.

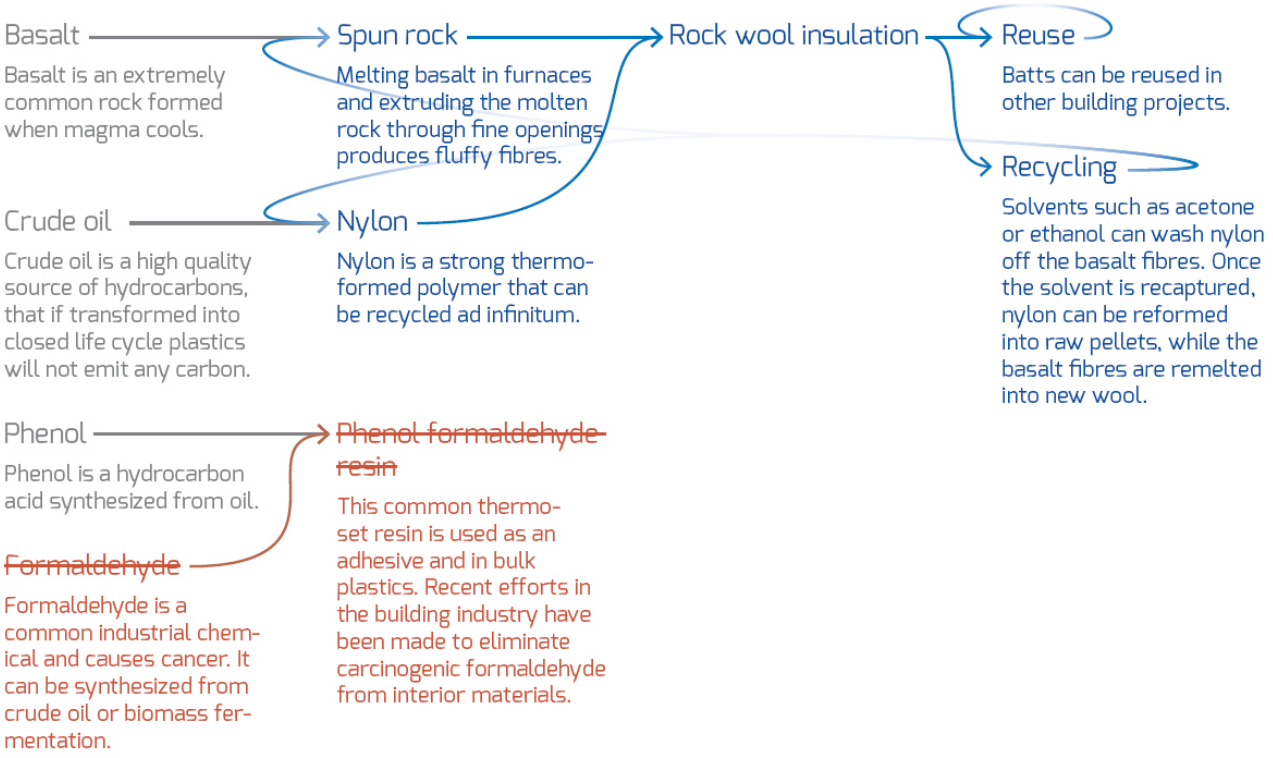


Figure 3.9 Material flow diagram for rock wool insulation

Wood Adhesive

Recent advances in soy glue promise to remove formaldehyde emissions from composite wood products. However, a deeper dive into the chemistry of soy flour adhesives reveals that the new ingredient is a curing polymer blend called Kymene. This chlorinated hydrocarbon does not emit formaldehyde but will produce the persistent toxins dioxin and furan when burned. Research into soy glue chemistries is ongoing, but there may be no good solution. Any biodegradable glue will fail to be waterproof enough for structural use.

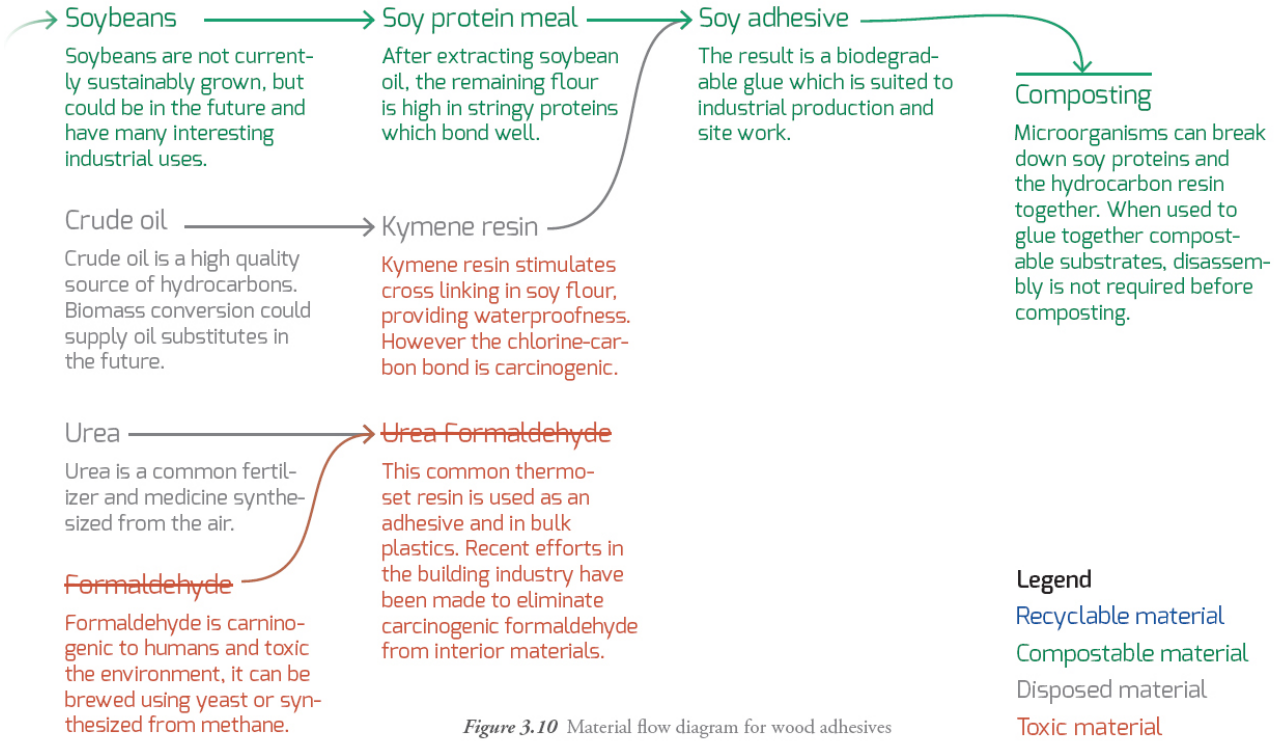
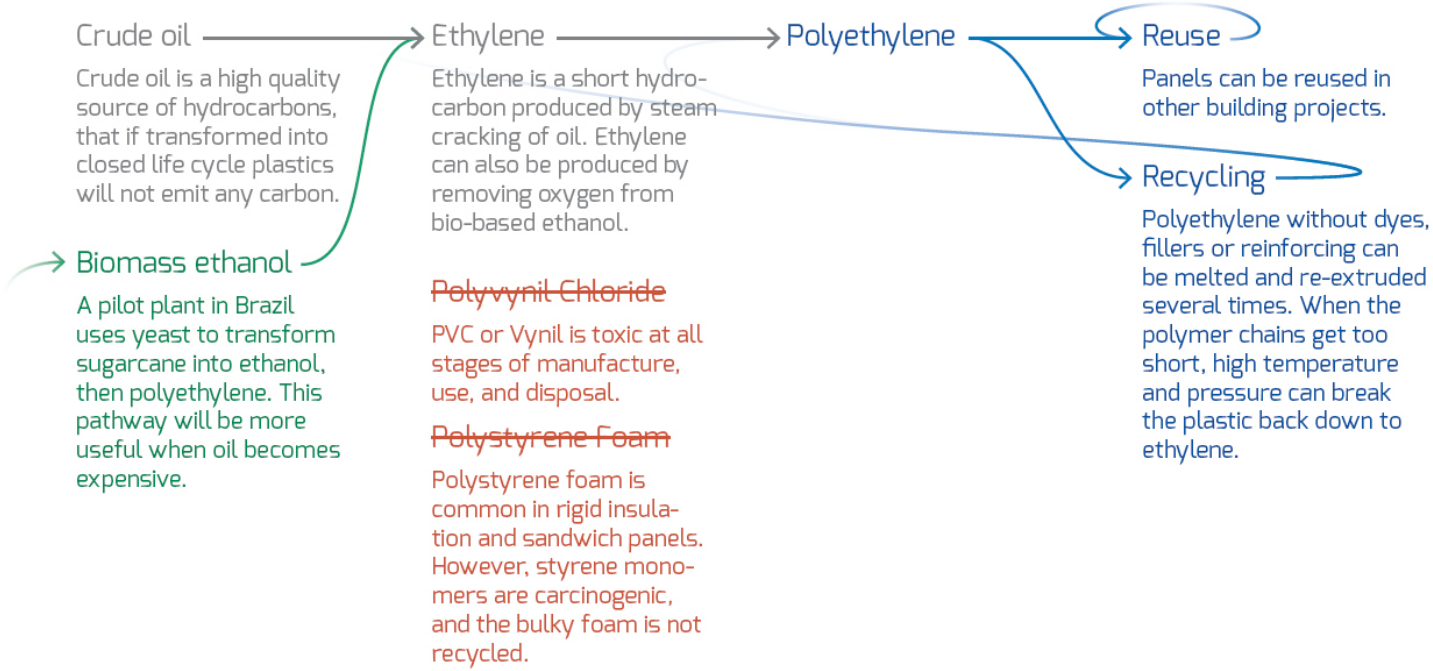
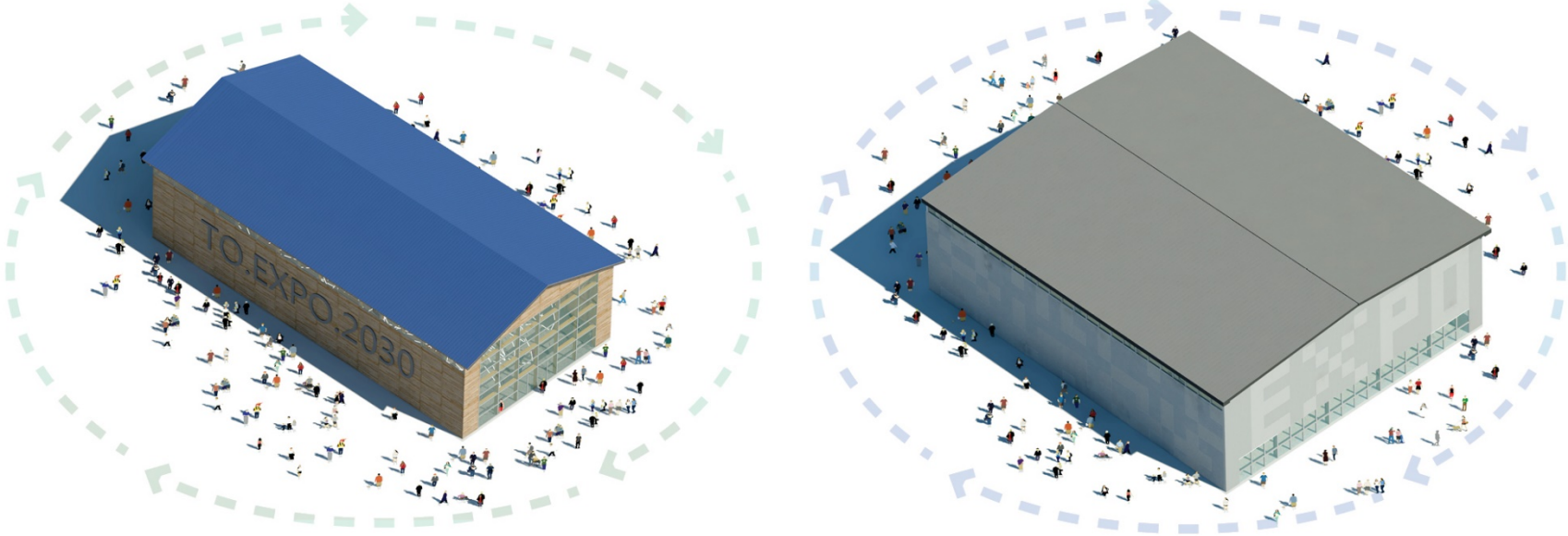


Figure 3.10 Material flow diagram for wood adhesives

Polyethylene

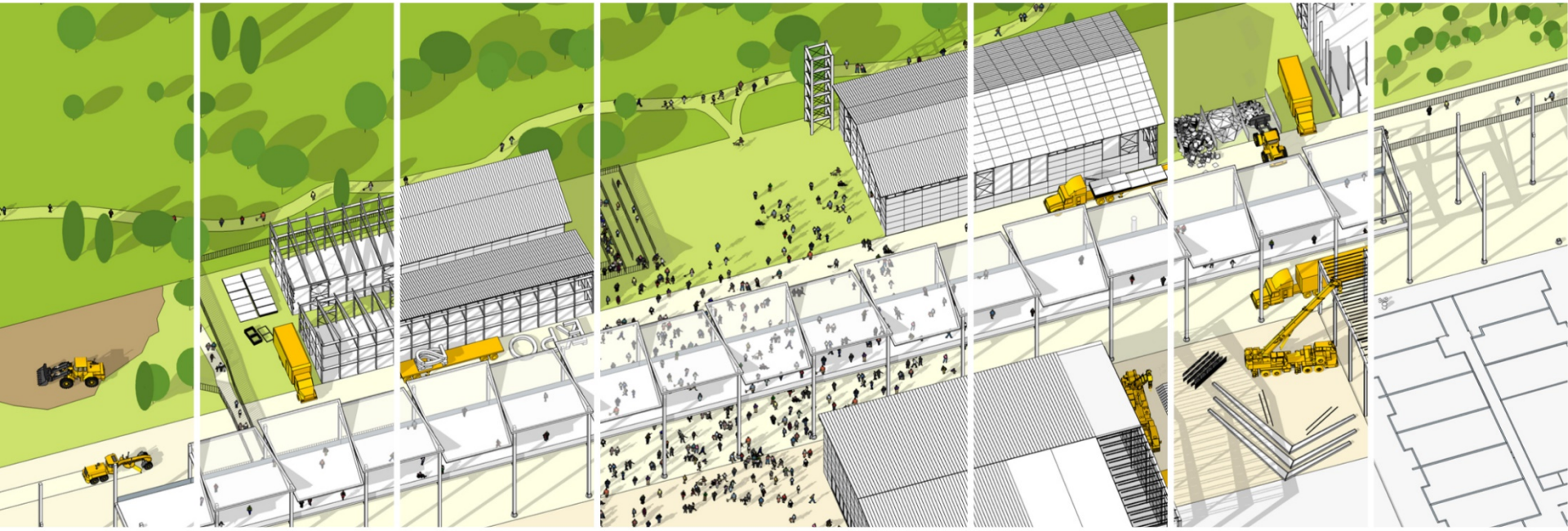
The challenge in designing the life cycle of plastic building components is selecting nontoxic chemistries that can be recycled. Polyethylene is the best construction plastic for closed life cycles. It is the world's most common polymer, synthesized from simple hydrocarbon precursors without toxic chlorine bonds. Polyethylene and PET in beverage bottles, are the only two commonly recycled plastics. When several cycles of use have weakened or contaminated polyethylene it can be chemically broken down the original monomers for feedstock recycling.





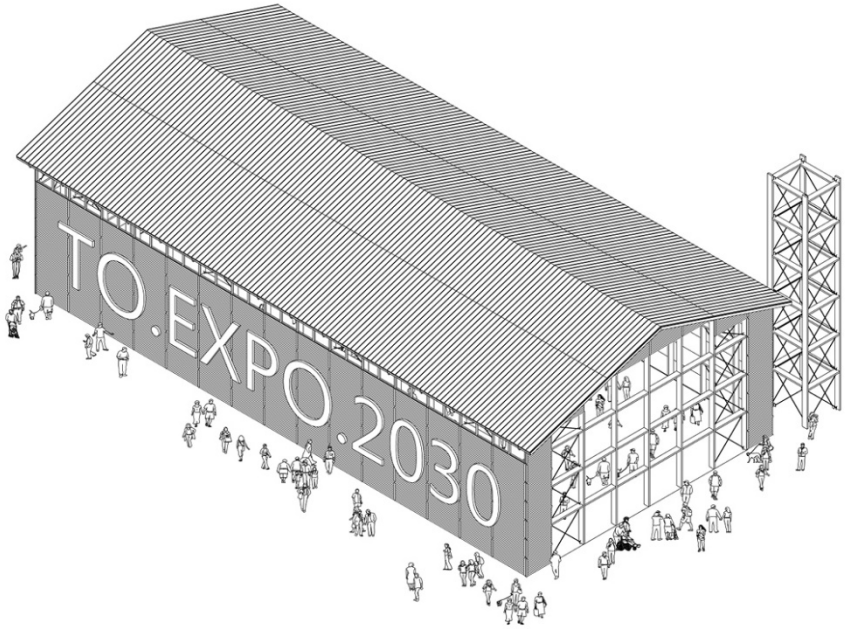
Scott Proudfoot - Reconstruction Site

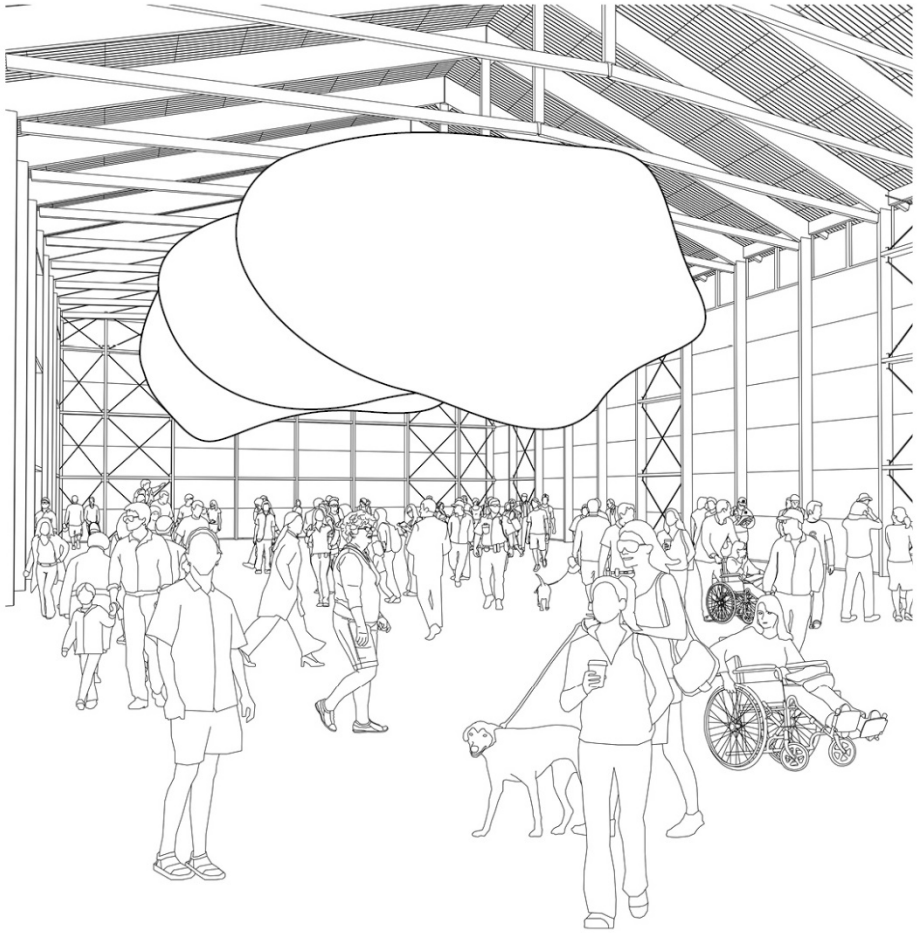
Design of generic compostable and recyclable pavilions for Expo 2030



Scott Proudfoot - Reconstruction Site

Time lapse of Expo site from construction through use and regeneration.





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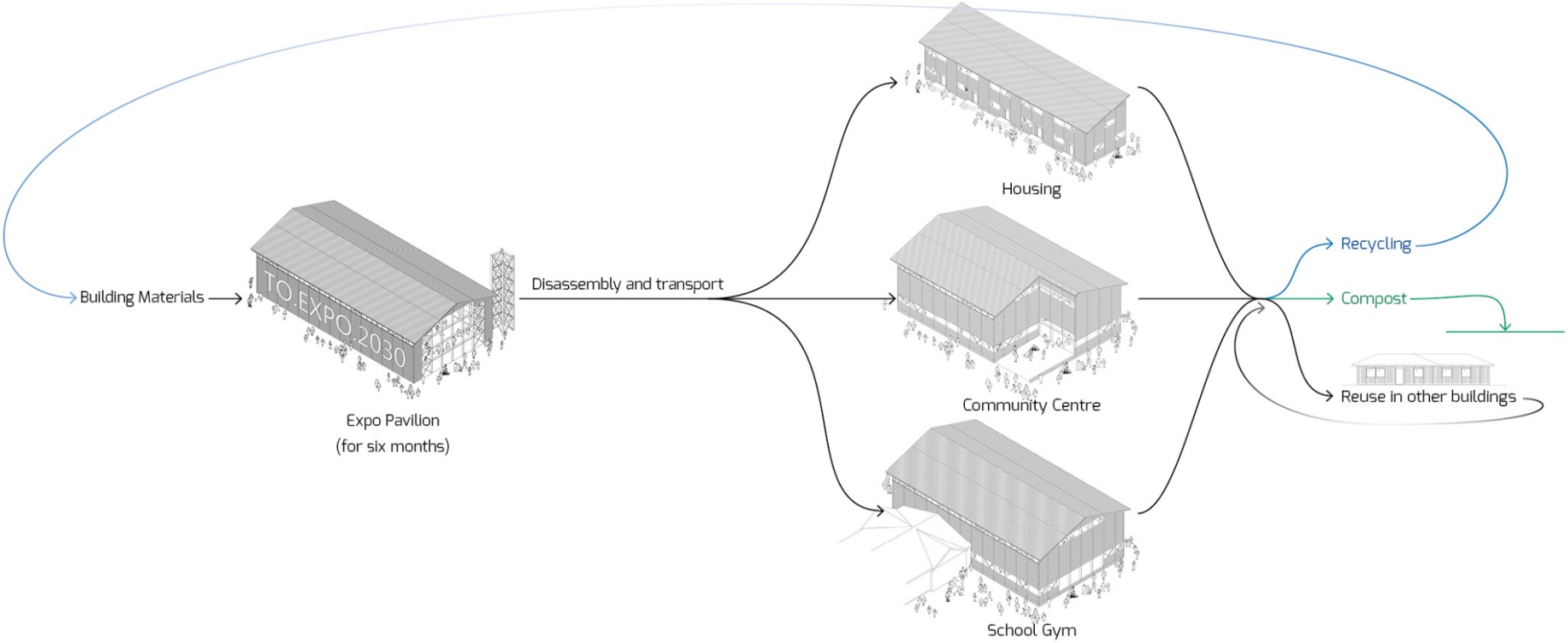
Compostable Pavilion



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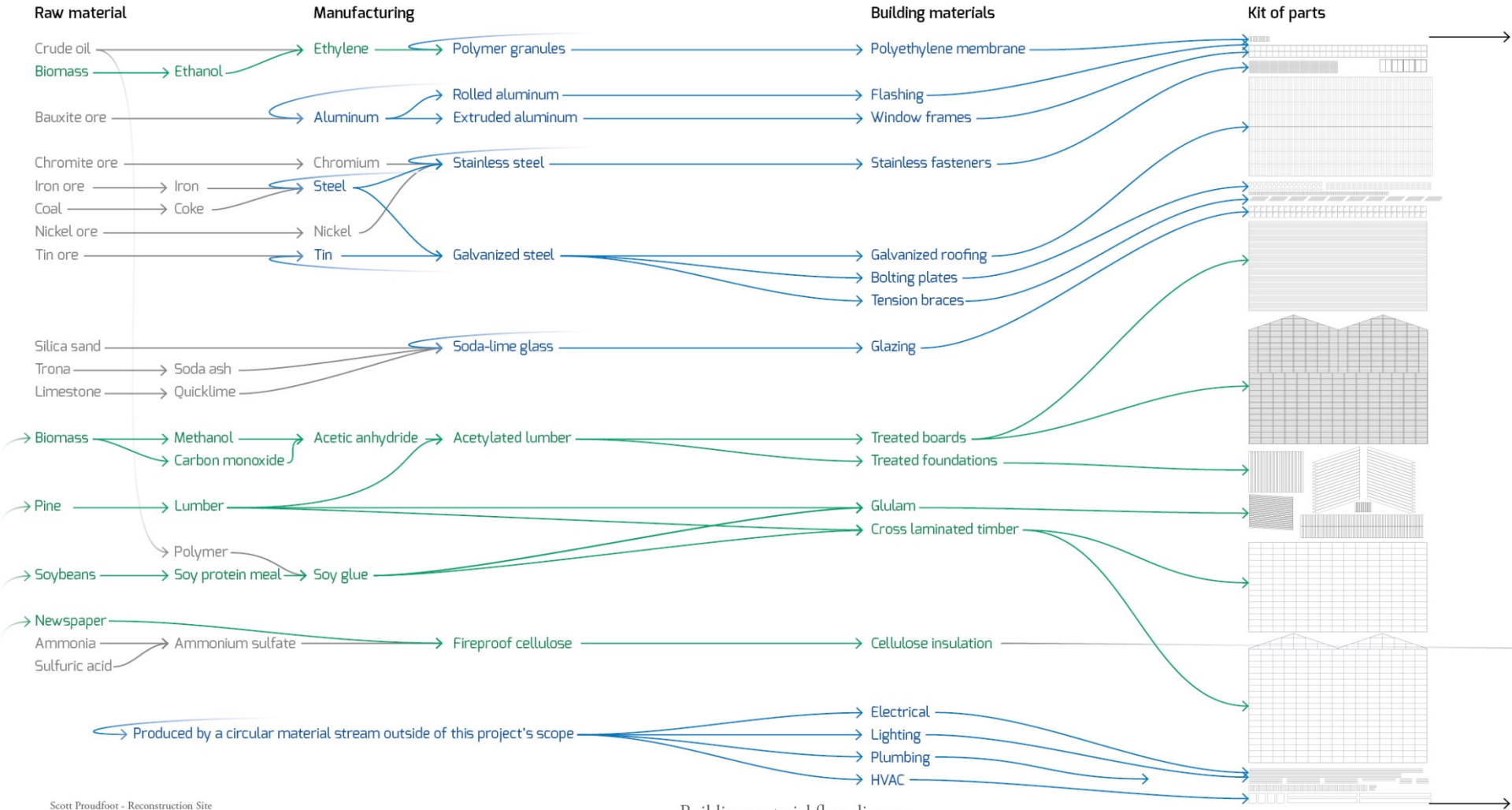
Pavilion life cycle diagram


ARCTIC WATERSHED



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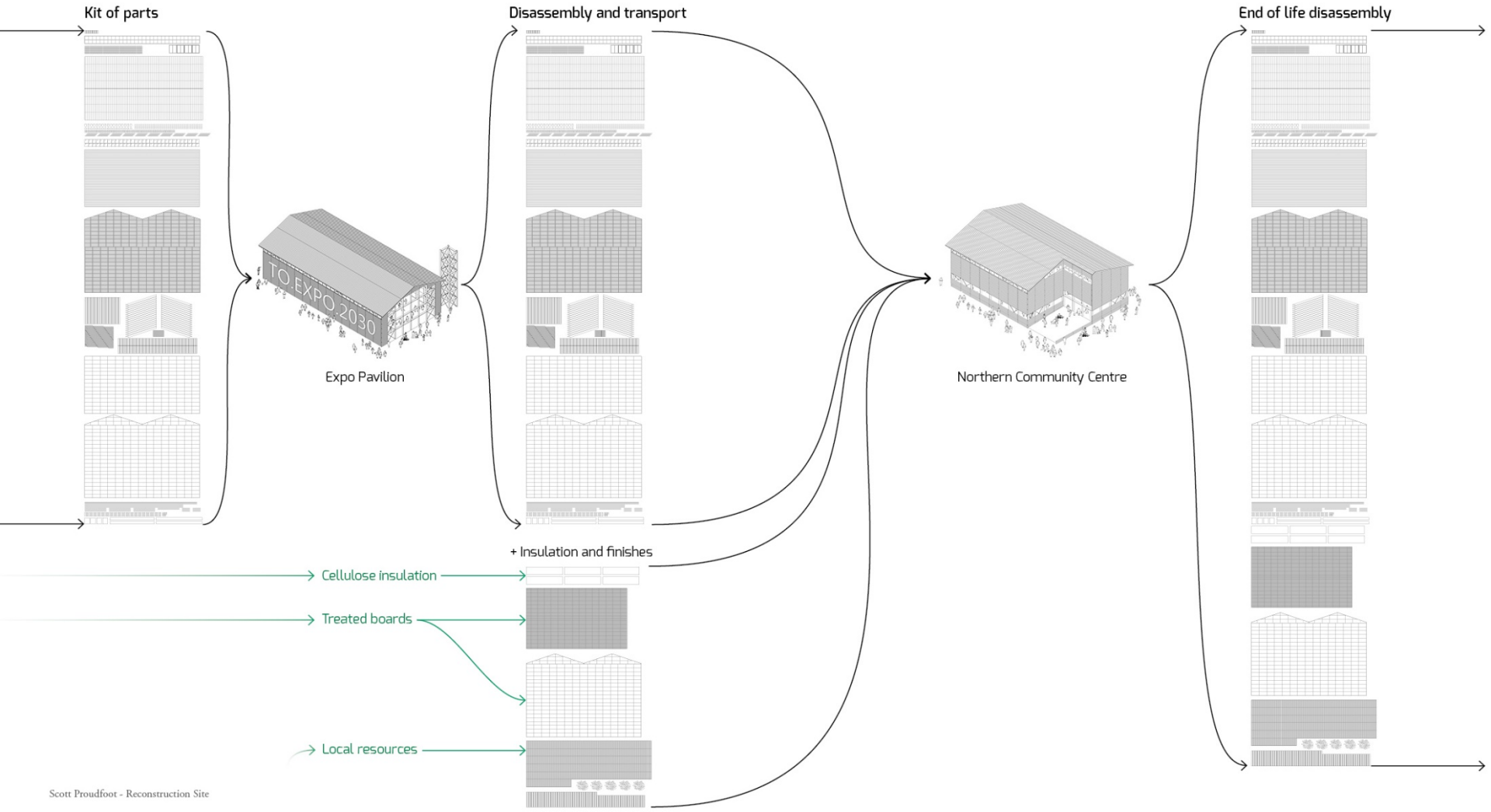
Building material flow diagram



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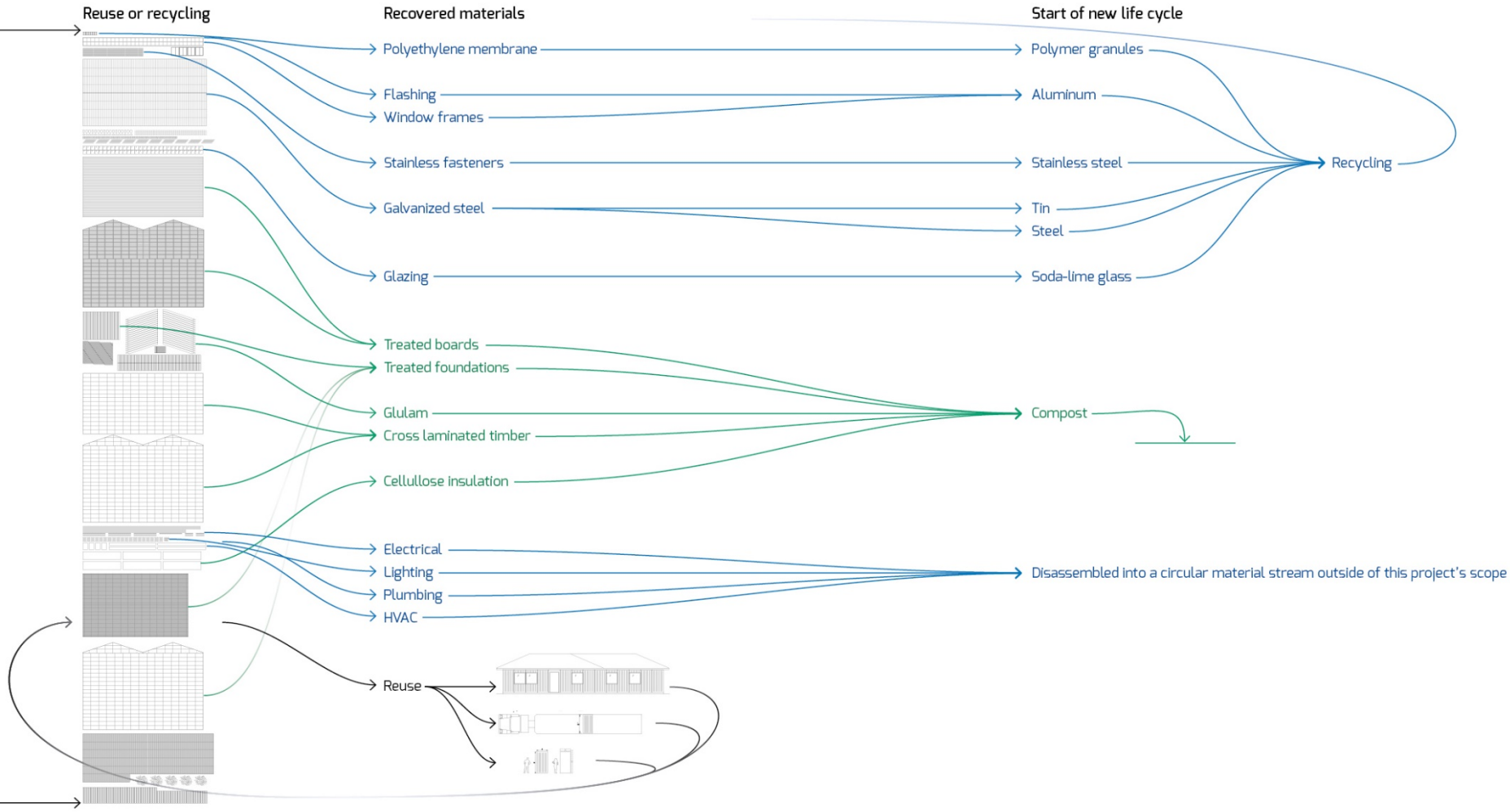

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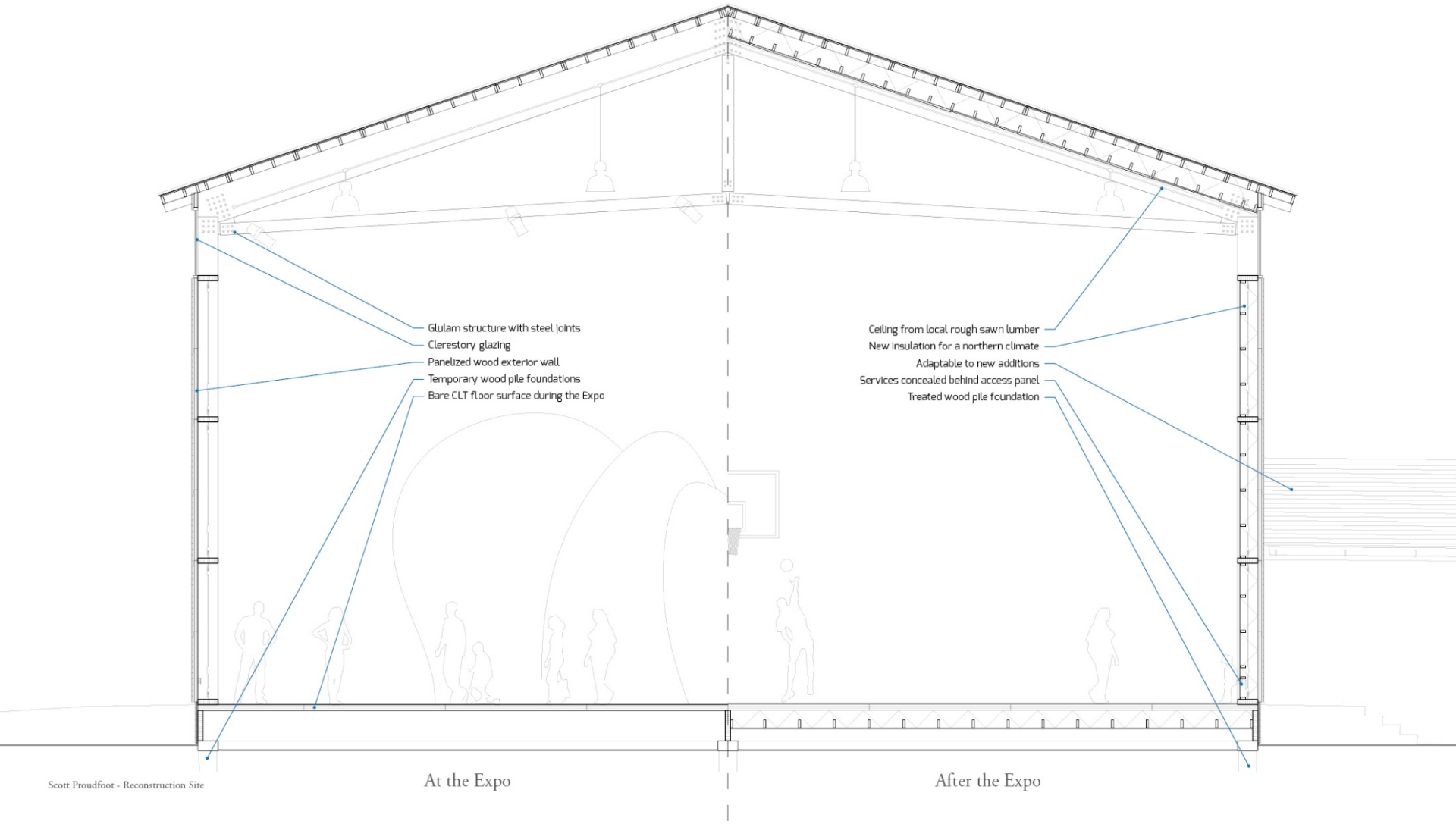
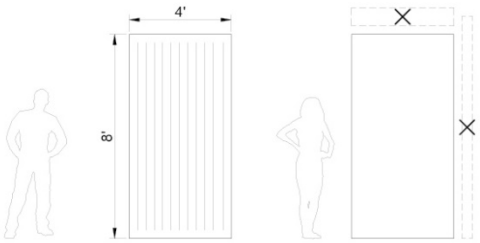
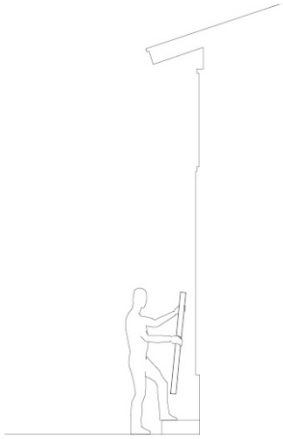
Building material flow diagram



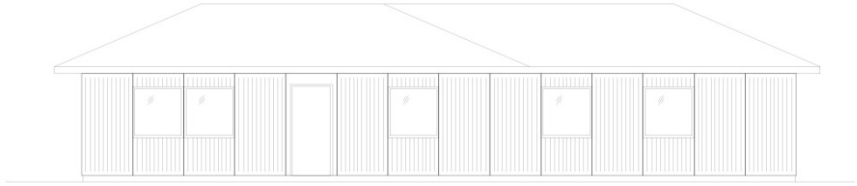
Scott Proudfoot - Reconstruction Site



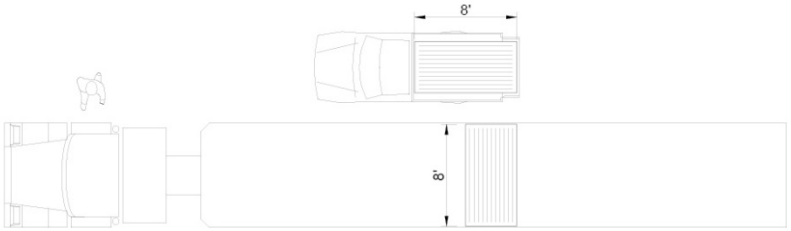
A standard sized module reduces offcuts.



Human liftable shape

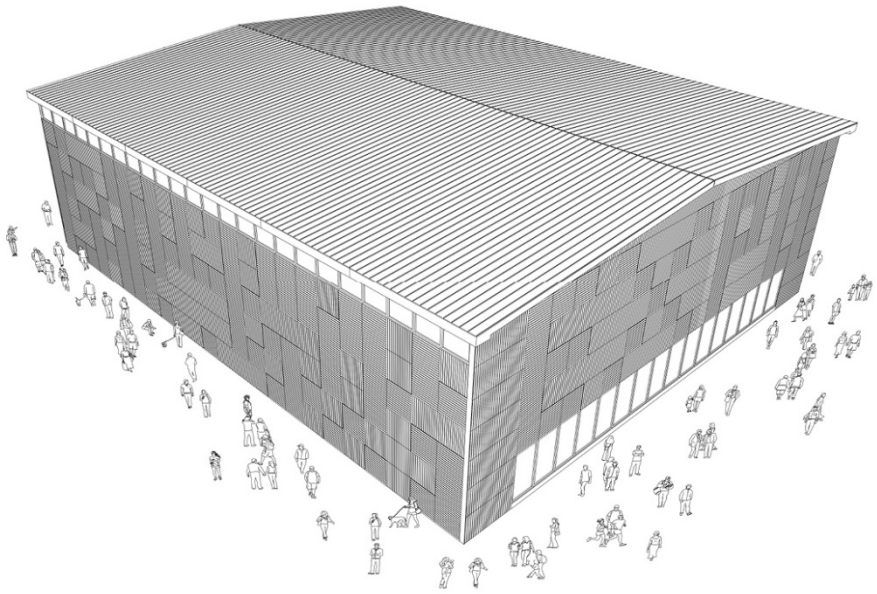


Reusable in other buildings



Standard size is easy to ship

Benefits of a generic module size



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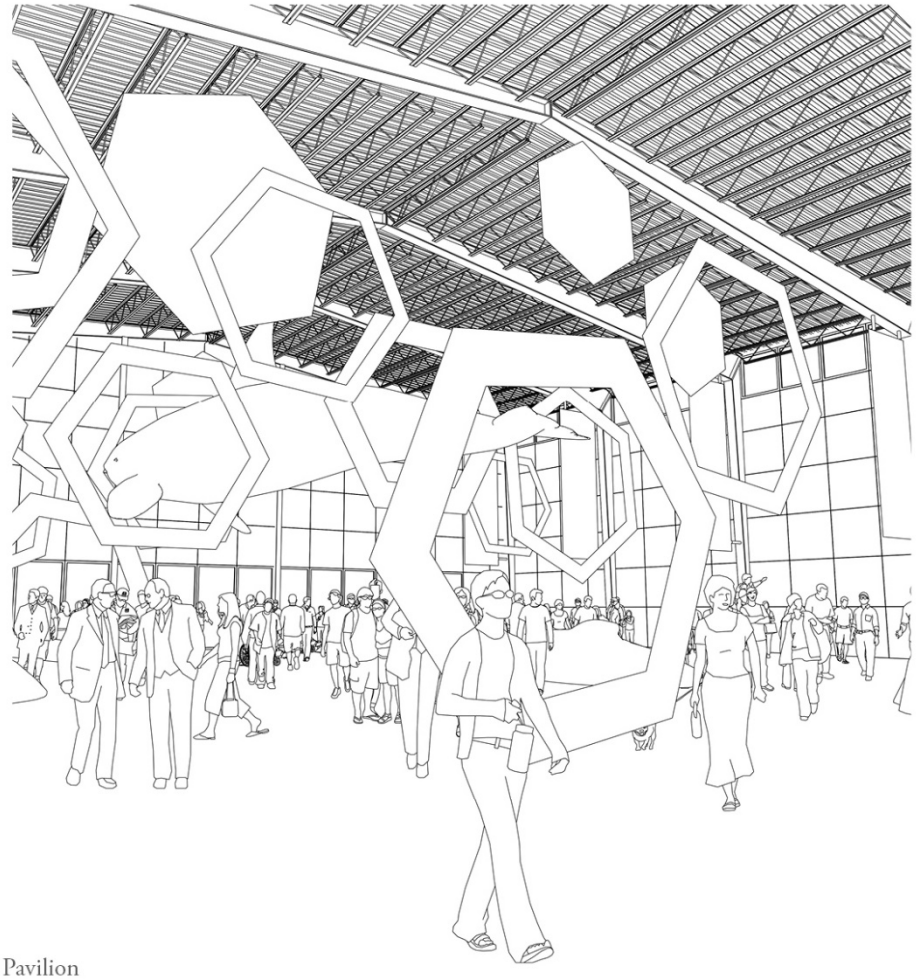
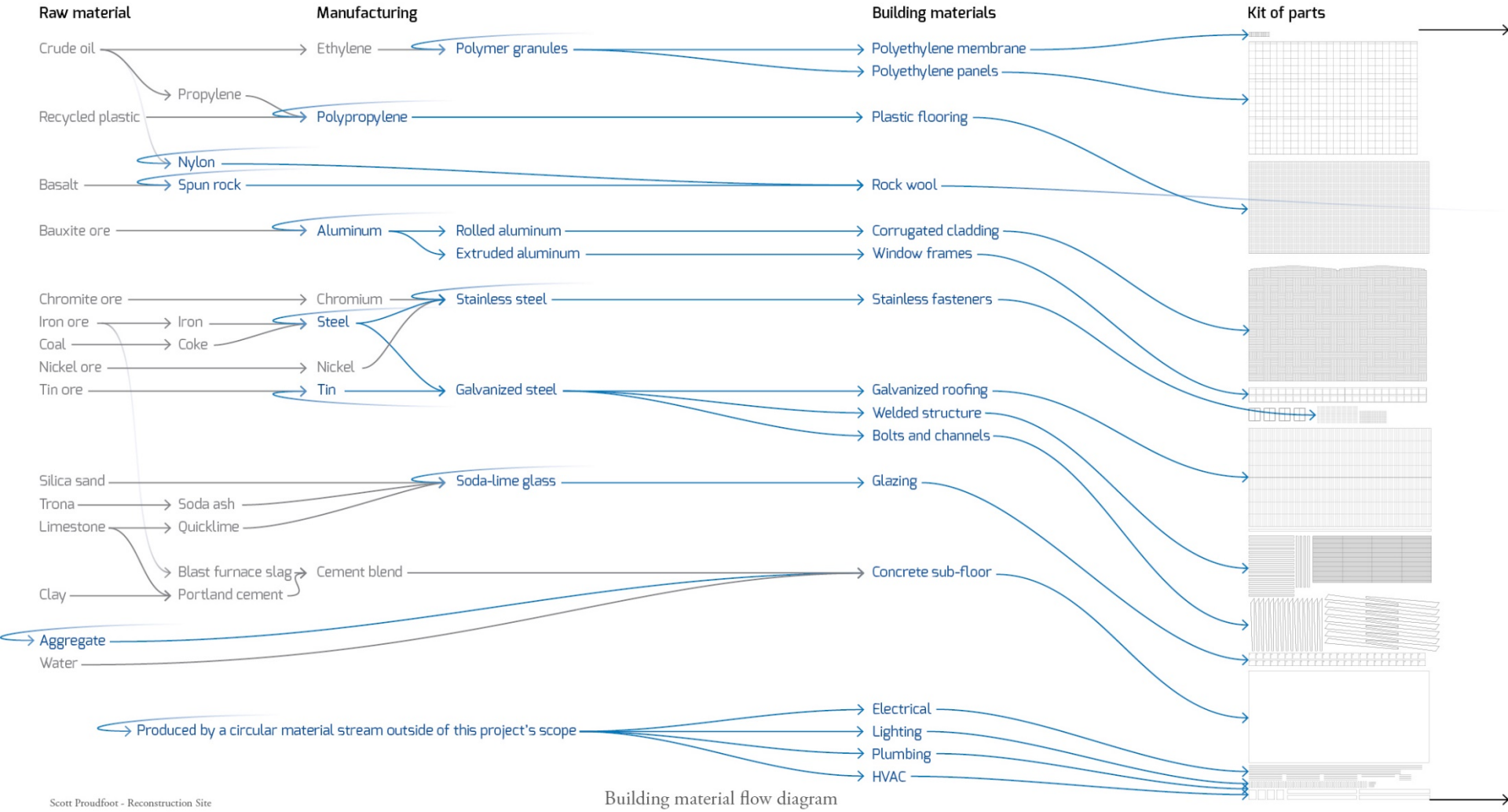


Recyclable Pavilion



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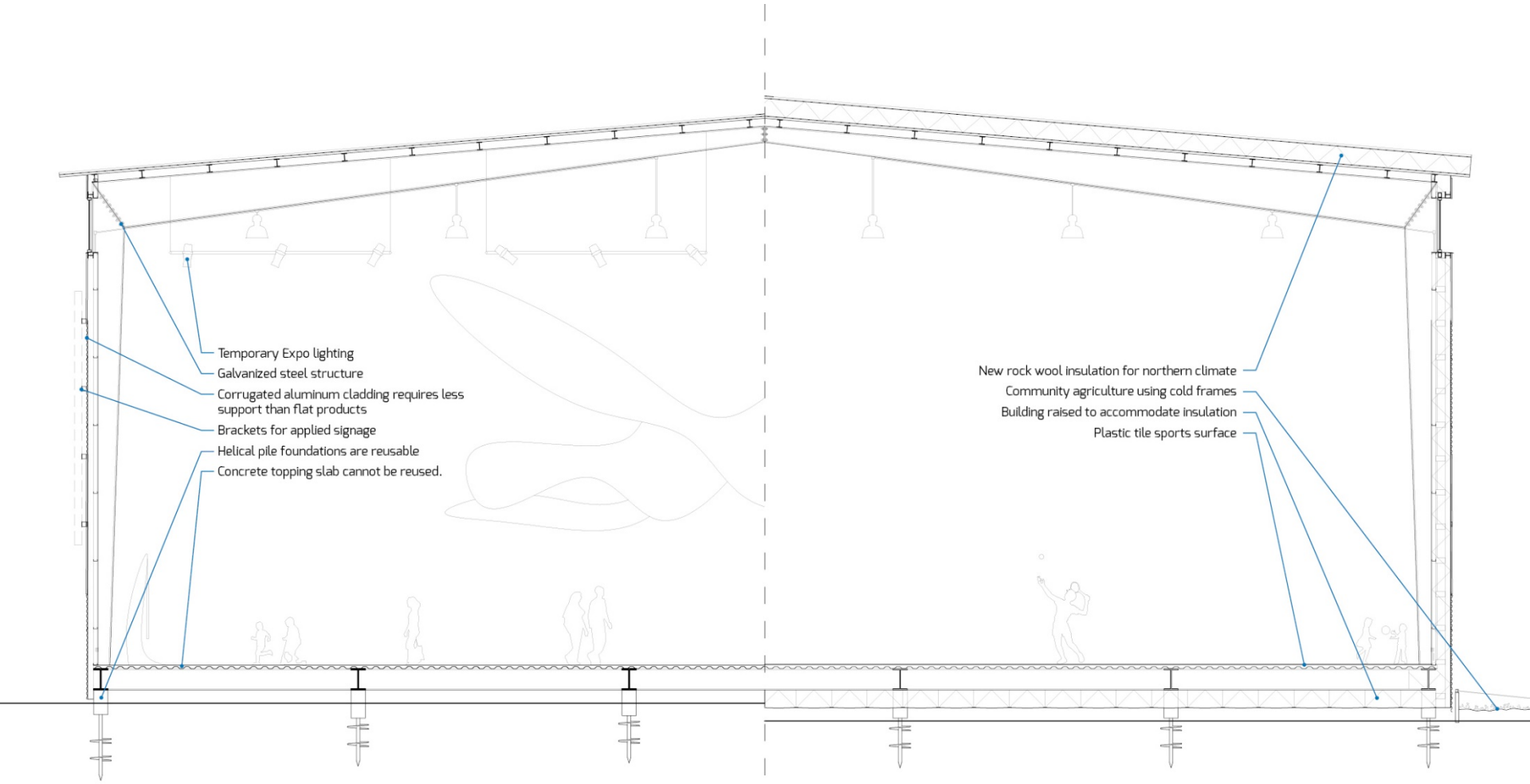
Building material flow diagram



Scott Proudfoot - Reconstruction Site

Building material flow diagram

DfD - benefits

Designing for disassembly can have the following benefits:

- Facilitate maintenance and repair, thereby reducing costs.
- Facilitate part/component re-use, thereby recovering materials and reducing costs.
- Assist material recycling, thereby avoiding disposal and handling of waste.
- Assist product testing and failure-mode/end-of-life analysis.
- Facilitate product take-back and extended producer responsibility, thereby reducing liability and assisting in regulatory compliance.

source: http://dfe-sce.nrc-cnrc.gc.ca/dfestra/dfestra7/dfestra7_2_e.html

D f DISASSEMBLY – attempt to…

Factors, such as the life span of parts/components, their standardization, maintenance requirements, and instructions for servicing and re-assembly, play a major role in designing for disassembly. In general, designers should attempt to:

- Use detachable joints such as snap, screw or bayonet instead of welded, glued or soldered connections.
- Use standardized joints so that the product can be dismantled with a few universal tools, e.g., one type and size of screw.
- Position joints so that the product does not need to be turned or moved for dismantling.
- Indicate on the product how it should be opened non-destructively, e.g., where and how to apply leverage with a screwdriver to open snap connections.
- Put parts that are likely to wear out at the same time in close proximity so they can be easily replaced simultaneously.
- Indicate on the product which parts must be cleaned or maintained in a specific way, e.g., colour-coded lubricating points.

DfD- evaluate ease of disassembly

Evaluate the ease of disassembly. Consider assigning a weighting and scoring system to the list. *(based upon an industrial model – adapt to architecture…)*

What are the bonding and fastening methods of parts and components?

- insert moulding
- cohesion
- adhesion
- mechanical fastening
- friction fitting

What are the additional operations required for disassembly?

- fracturing
- drilling
- ungluing
- heating
- lubricating

What are the tools required for disassembly?

- special tool
- simple tool
- by hand

What is the tool motion required for disassembly?

- complex
- turning
- straight line

What is the level of difficulty for disassembly?

- technician needed
- assistant needed
- deformation required
- hold-down required
- heavy
- small
- resistant
- difficult access
- difficult to grasp
- difficult to view

Table I DFD design rules

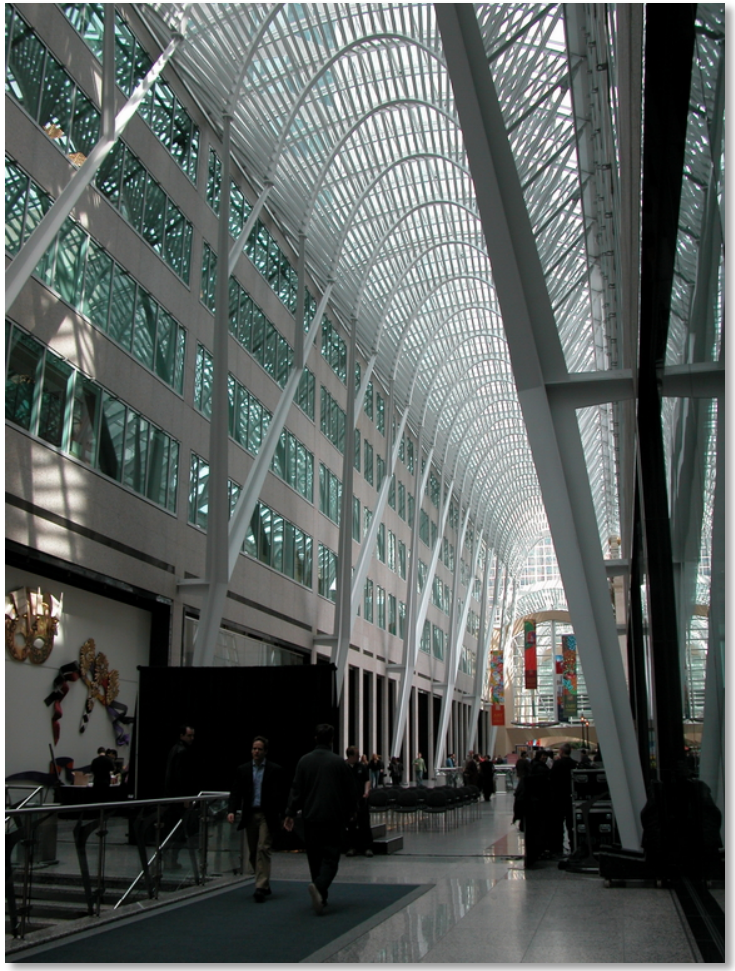
Factors affecting the disassembly process	Guides to improve disassembly
Product structure	Create a modular design
	Minimise the component count
	Optimise component standardisation
	Minimise product variants
Materials	Minimise the use of different materials
	Use recyclable materials
	Eliminate toxic or hazardous materials
Fasteners, joints and connections	Minimise the number of joints and connections
	Make joints visible and accessible, eliminate hidden joints
	Use joints that are easy to disassemble
	Mark non-obvious joints
	Use fasteners rather than adhesives
Characteristics of components for disassembly	Good accessibility
	Low weight
	Robust, minimise fragile parts
	Non hazardous
	Preferably unpainted
Disassembly conditions	Design for automated disassembly
	Eliminate the need for specialised disassembly procedures
	DFD with simple and standard tools

disassembling architecture

Utah School of Architecture – reinforced concrete

?

Is one of these inherently easier or better to disassemble?



BCE Place – structural steel

Deconstructing Christchurch

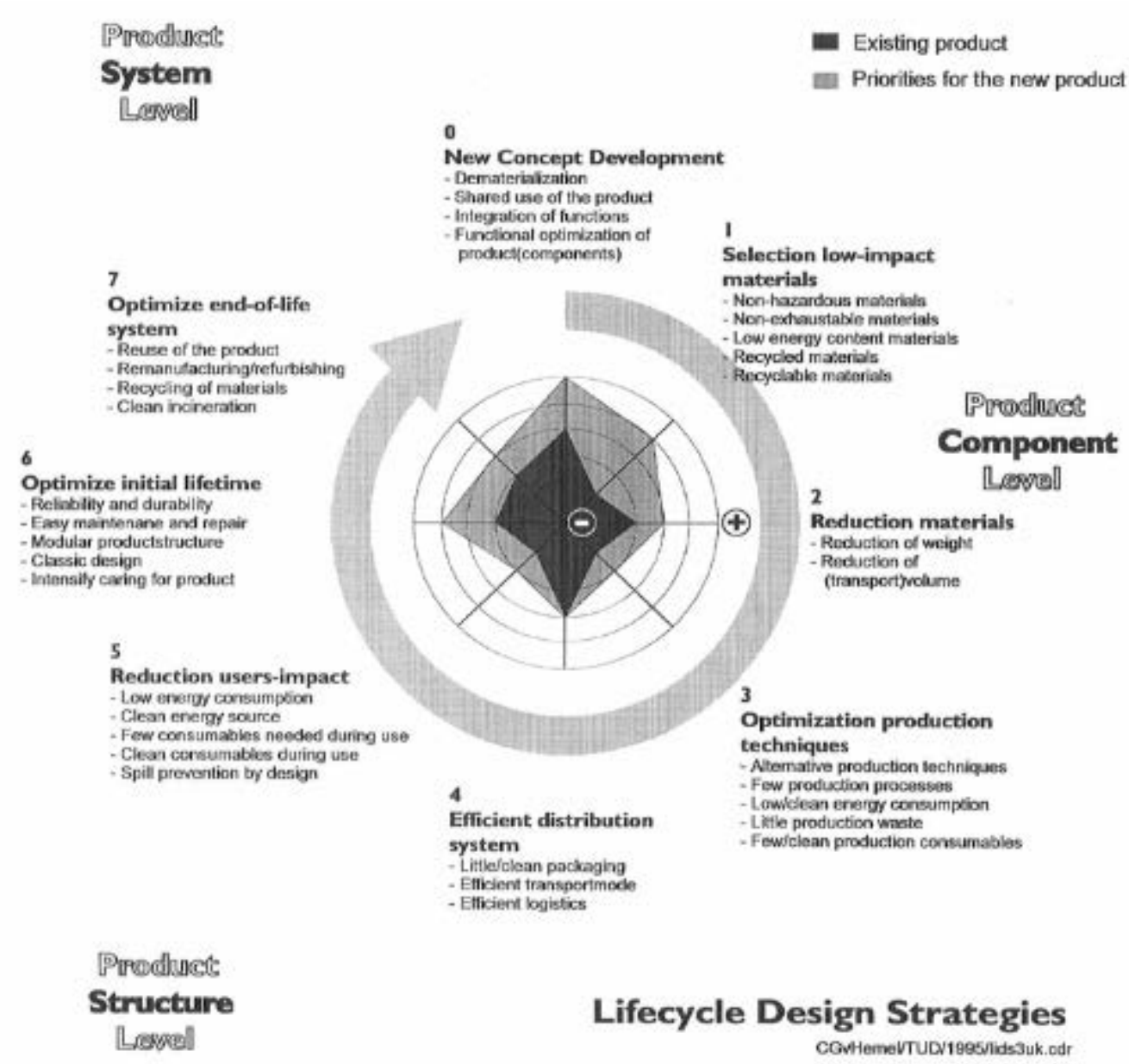
The sheet steel industry is proactively promoting their product as being simpler to reuse | recycle than the alternate – wood frame.

And although this steel framed building might be easy to disassemble and reuse…

It won’t be when it is destined to be sprayed with “Shot-crete”…

Even though precast concrete systems might be easy to *assemble*, careful examination is required to see if their disassembled parts are easily reused, retooled or recycled/upcycled.

lifecycle design strategies



factor 10 house

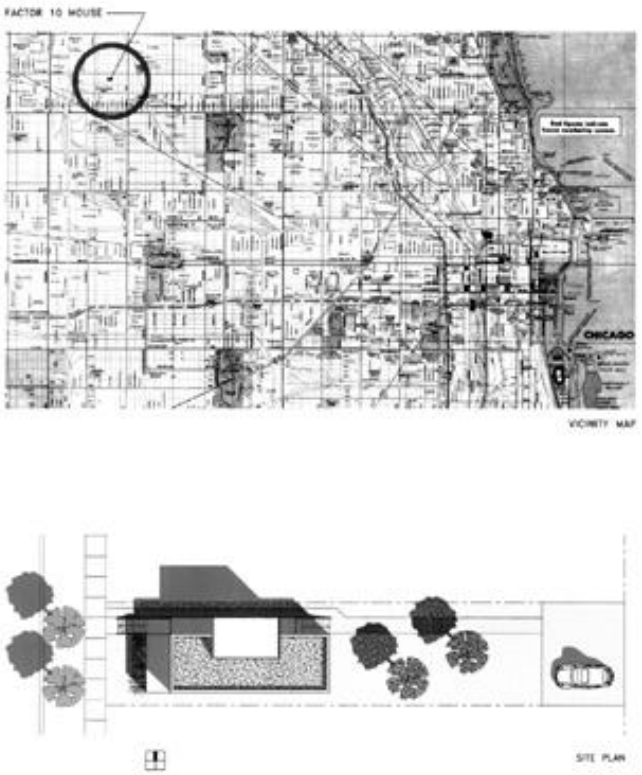
source: hopes.uoregon.edu/system/files?file=design_for_deconstruction.pdf

Overview
Location: Chicago, IL
Building type(s): Single-family residential
New construction:
1,830 sq. feet (170 sq. meters)
Project scope: 2-story building
Urban setting
Completed August 2003

F10's design is a straightforward response to four primary considerations: a narrow City site with adjacent buildings, a a modular design, an open 1,234-ft2 floor plan plus a 605-ft2 conditioned, unfinished basement, and a solar chimney incorporated into the stairwell.

Factor 10 House

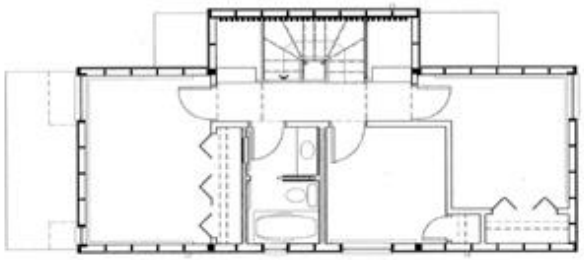
source: http://www.eere.energy.gov/buildings/database/site.cfm?ProjectID=271



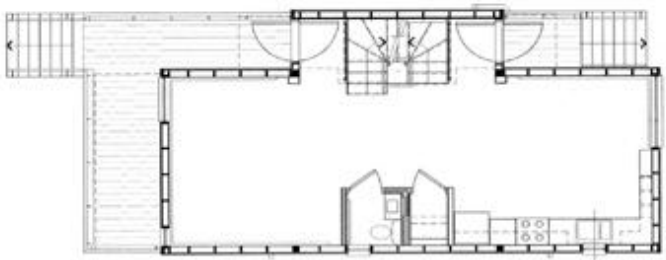
F10 strives to reduce life-cycle environmental impacts by a factor of 10 compared to the average home built in America today.

Esherick Homsey Dodge & Davis Architects
Chicago, IL
http://ehdd.com

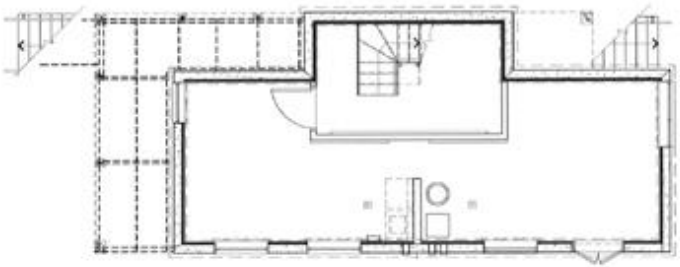
Factor 10 House



SECOND FLOOR PLAN



FIRST FLOOR PLAN



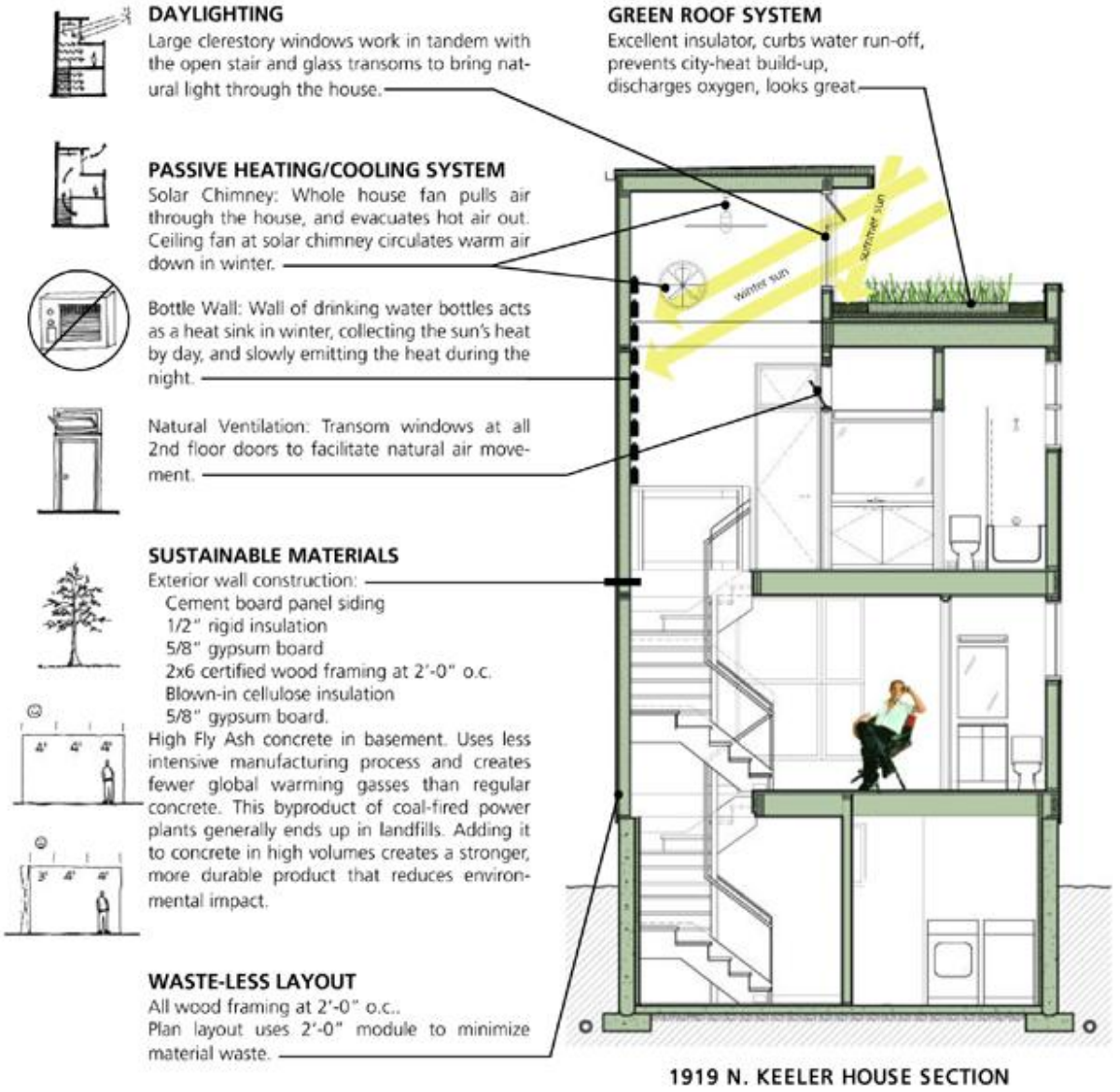
BASEMENT PLAN

The modular design works within industry's dimensional constraints, minimizing waste and allowing off-site assembly. The open floor plan enhances cross ventilation, and the window placement maximizes reflected light into the interior of the home while reducing glare.

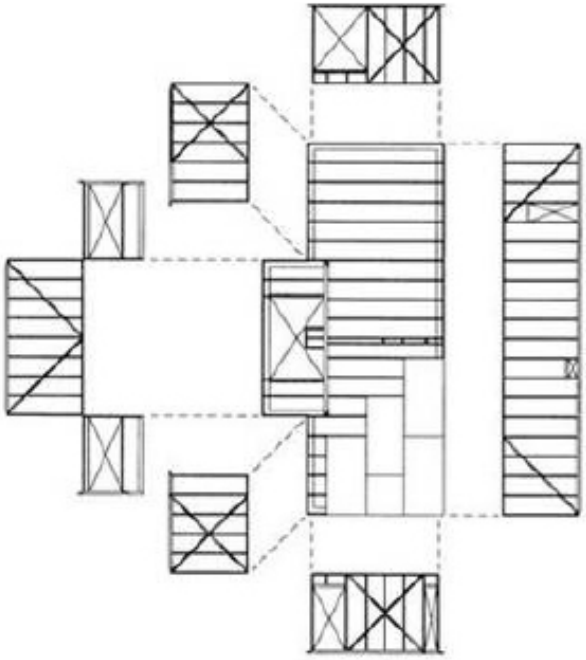
Factor 10 House

The 125’ x 25’ lot is oriented east-west. It includes a rear alley and is surrounded by single-family, detached residential buildings. F10 should be socially and visually integrated into the community. F10 is intentionally small to allow for future growth on the lot and to keep the building’s site coverage low. All setbacks were within zoning guidelines; the front setback was consistent with other homes on the street. F10 was raised 4’ above grade with a basement in order to raise the porch and steps to fit in with the other houses and foster community interaction on the street. F10’s form and mass are consistent with neighboring dwellings.

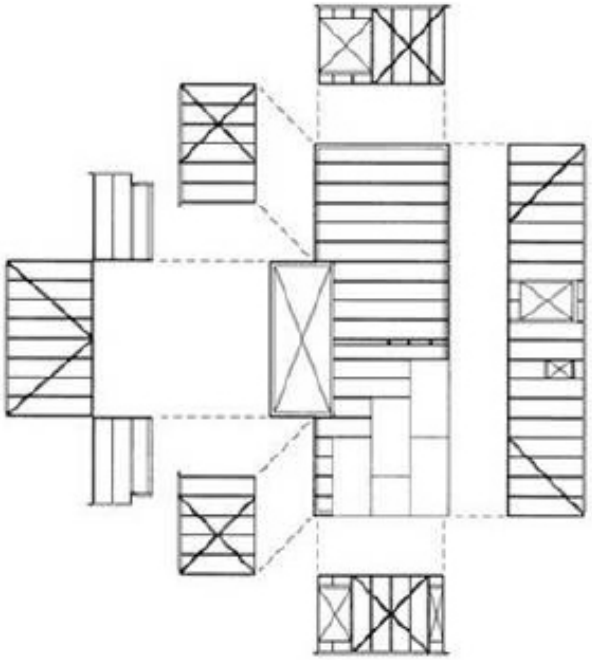
Factor 10 House



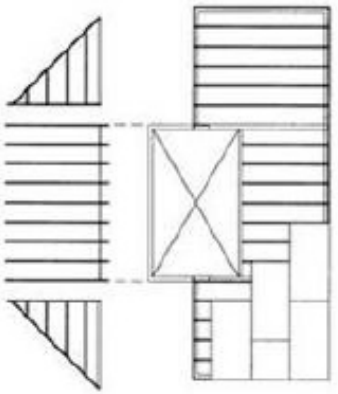
1919 N. KEELER HOUSE SECTION



1 framing

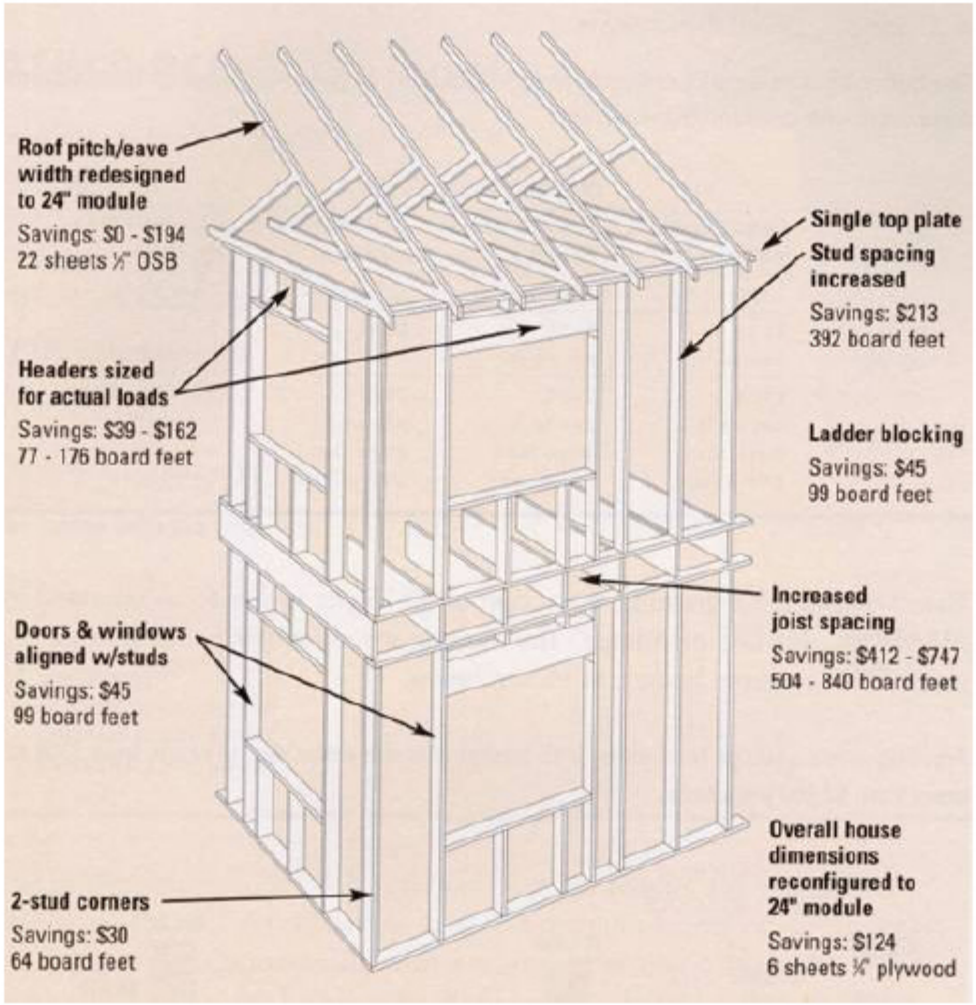


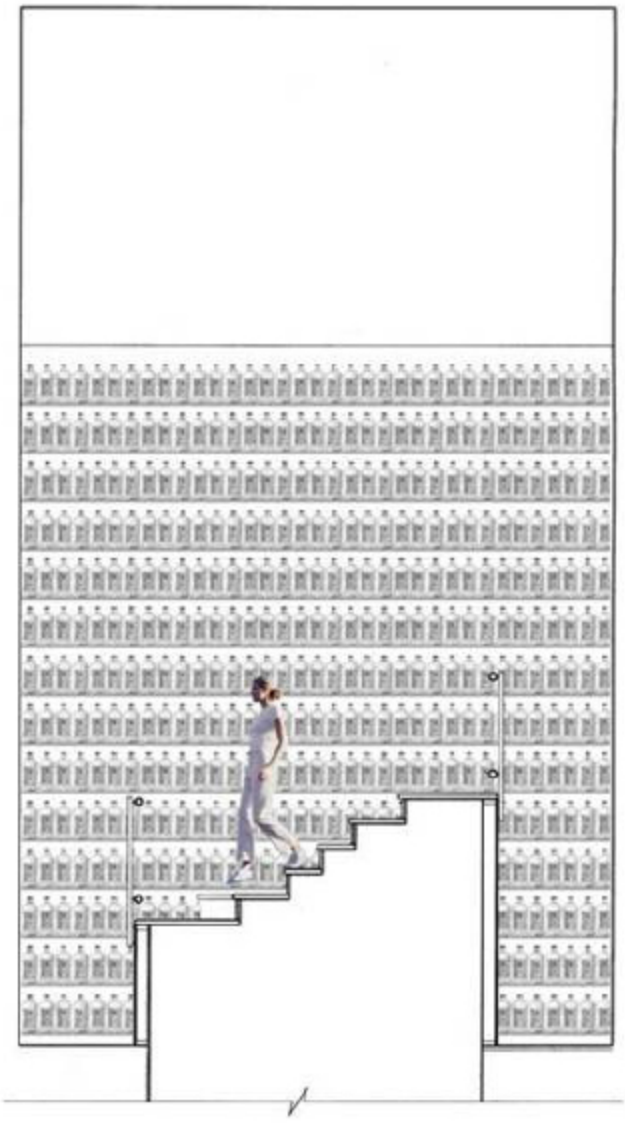
2 framing



3 framing

Efficient Wood Use in Residential Construction, NRDC, Edminster



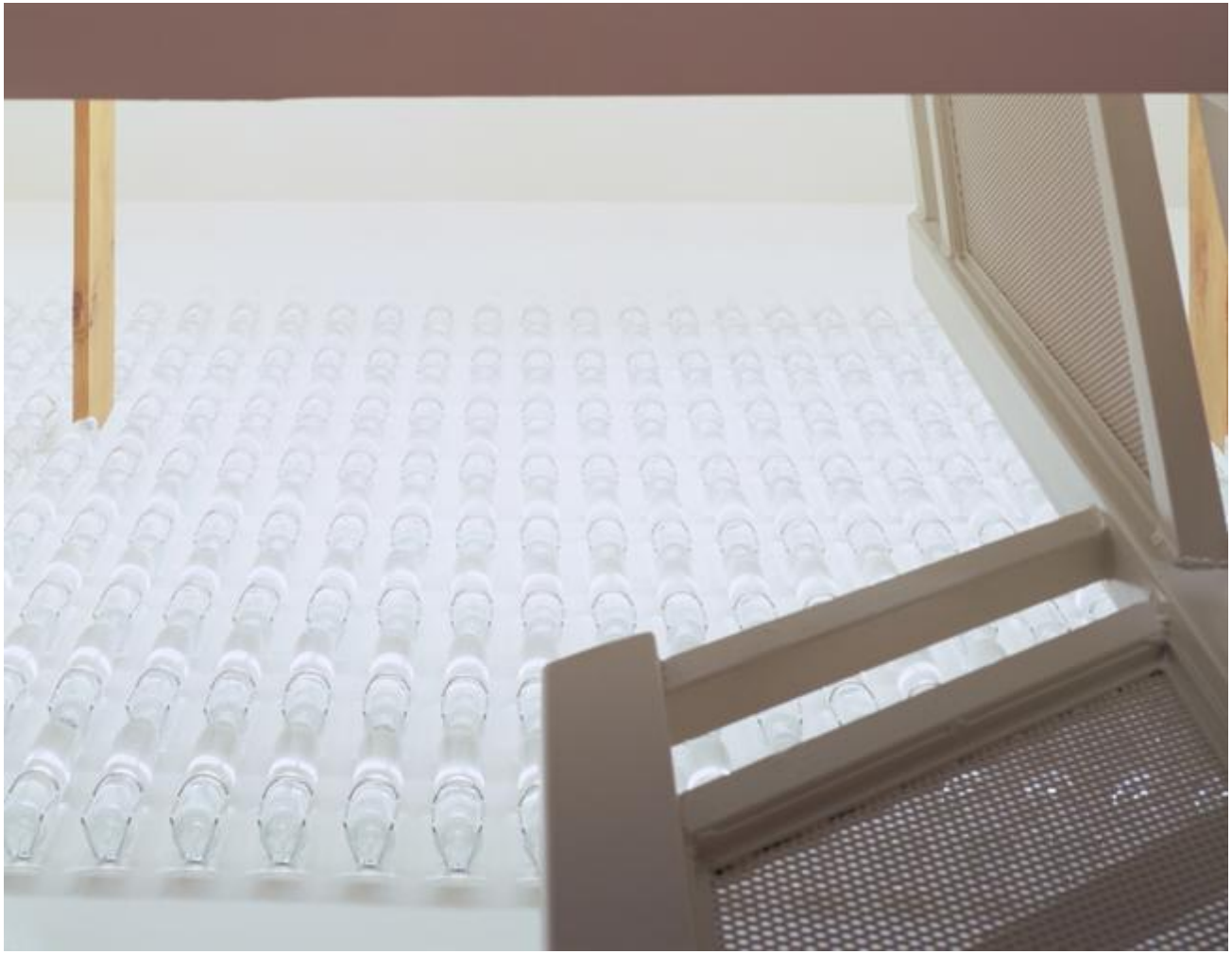


F10 HOUSE | CHICAGO, ILLINOIS

EHDD ARCHITECTURE

Factor 10 House

Also paramount to F10 was the minimization of stormwater runoff. The area of the lower roof (400 ft2) is planted with sedum, which retains stormwater and absorbs heat.



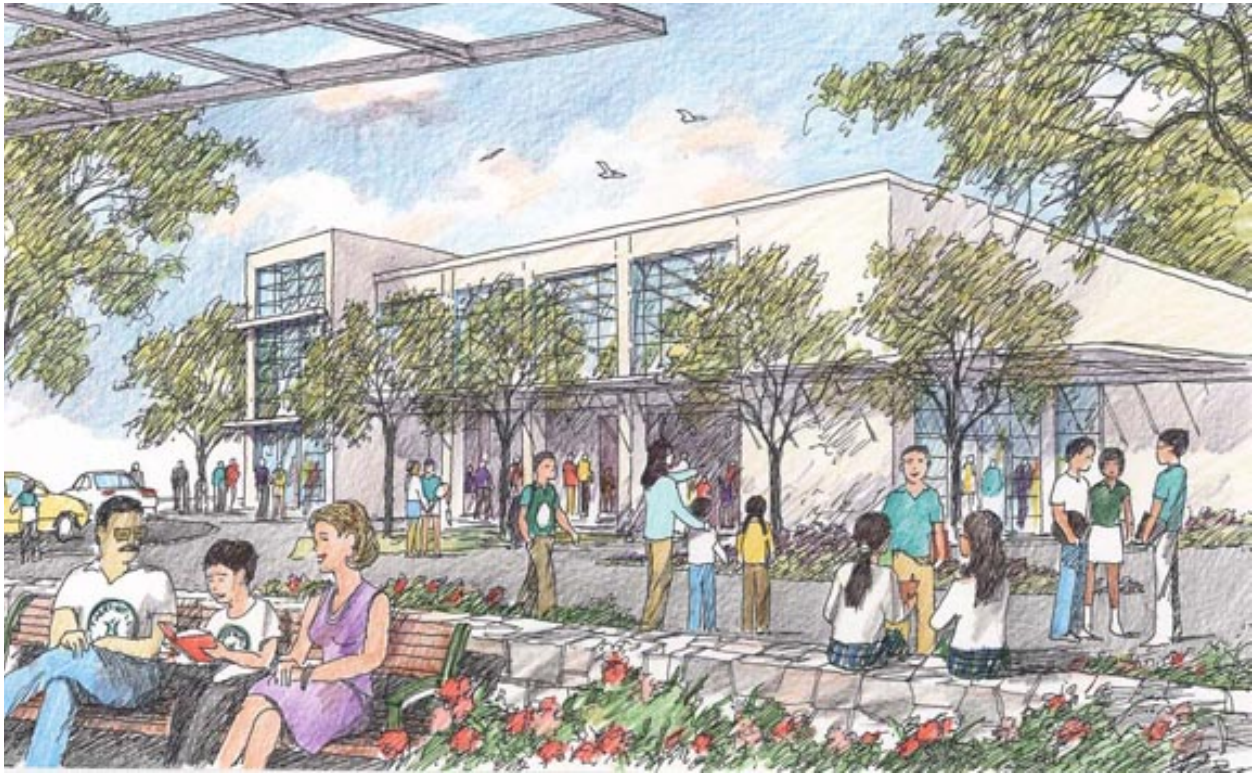
The wall of water bottles, shown here (looking up), acts as a heat sink in the solar chimney. Augmented by a whole-house fan, the shaft will pull warm air up and out of the house in the summer, and push warm air down in the winter.

Energy

F10's building envelope is super-insulated to handle the severe Chicago climate. It utilizes a vertical shaft with south-facing operable clerestory glazing to reduce primary energy consumption. The solar chimney brings light into the center of the house and supplements the daylighting. The chimney also collects heat in its upper strata in the winter for distribution throughout the house. In addition, a wall of water bottles on the north wall (facing south) acts as a heat sink, storing a small amount of heat to be given off later in the evening when ambient temperatures begin to drop.

chartwell school

source: hopes.uoregon.edu/system/files?file=design_for_deconstruction.pdf



DfD Project:

Hamer Centre +
EHDD Architecture

The Hamer Center is engaged with local governments, housing agencies, environmental organizations, and architects in an international initiative to develop principles and practices of “Design for Building Disassembly” (DfD). This initiative includes discussions with Canadian counterparts to make design for building disassembly part of mainstream architectural practice. Building DfD is design that uses methods and materials of design and construction to allow buildings to be flexible, adaptable and dismantleable at all stages of their lives. This includes formal design, and design processes, and also re-examining materials selection and connection details in light of facilitating materials recovery and continued life of the materials.

source: http://www.hamercenter.psu.edu/gallery/project_3_index.htm

Chartwell School

Chartwell School Multi-Use Building

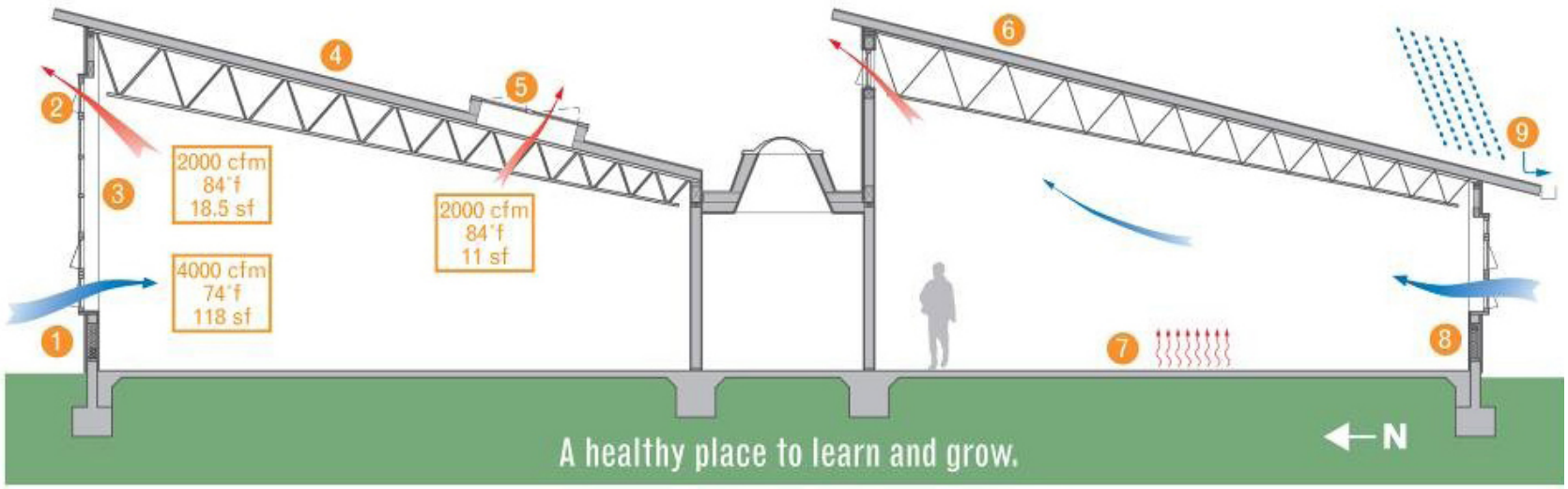
EHDD ARCHITECTURE

Chartwell School

Chartwell School Site Plan

EHDD ARCHITECTURE

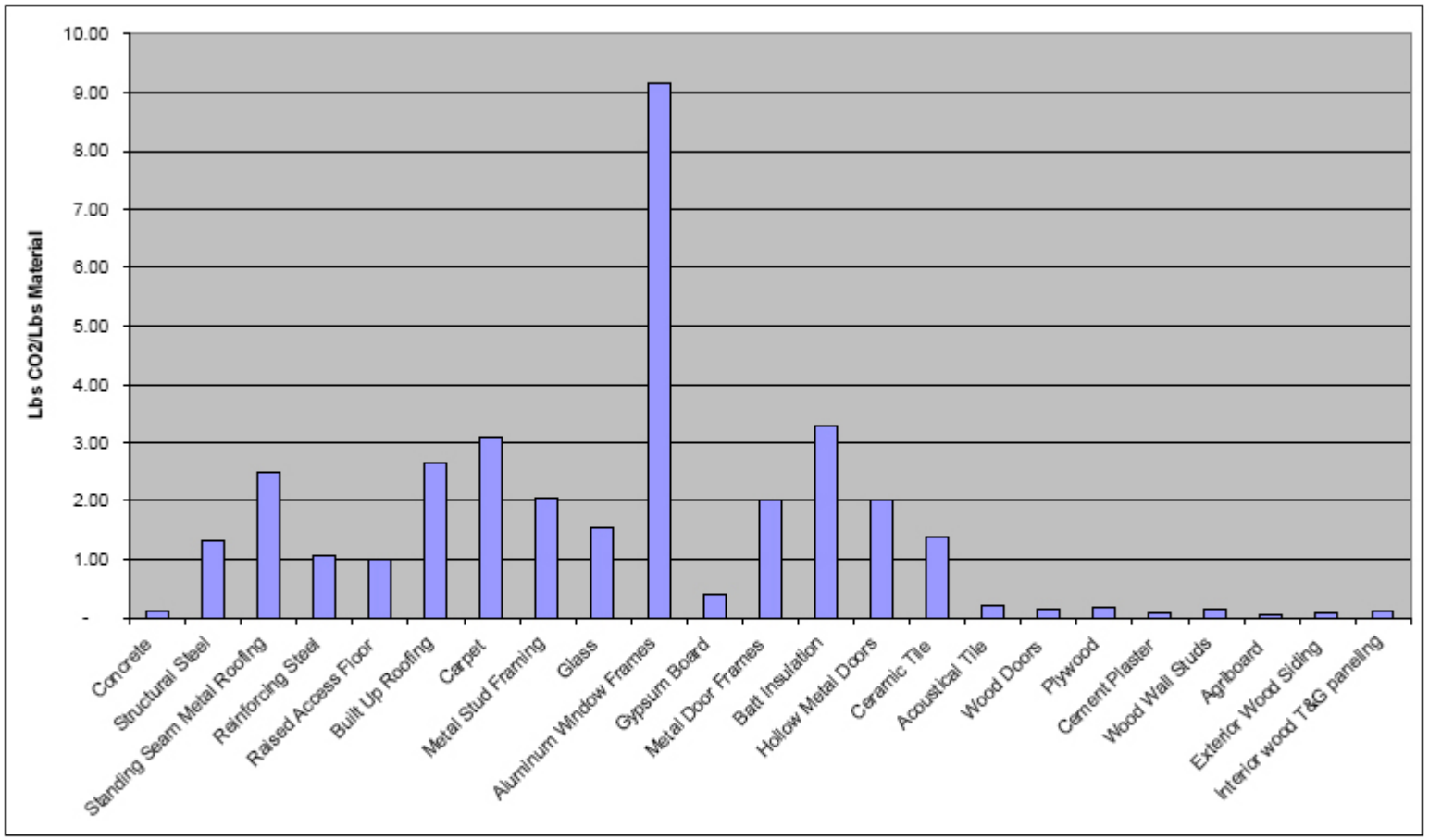
Chartwell School



Classroom Framing Section

EHDD ARCHITECTURE

Chartwell School

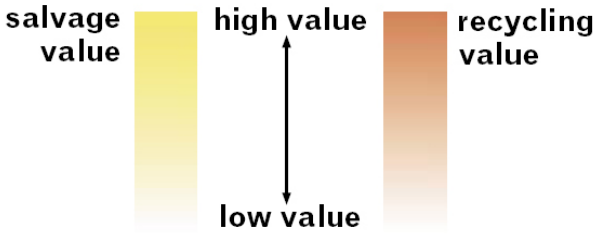


Materials Embodied Carbon Emissions

EHDD ARCHITECTURE

Chartwell School

Design for Recovery:



SPEC SECTION	COMPONENT	EXPECTED LIFESPAN *	EASE OF RECOVERY AS DETAILED	SALVAGE OR RECYCLING?	VALUE AFTER RECOVERY	QUANTITY OF MATERIALS	WEIGHT PER UNIT	ACTUAL WEIGHT OF MATERIALS	EMBODIED CO_2/TON PER UNIT	TOTAL EMBODIED CO_2	SALVAGED MATERIALS AVAILABLE?
3300	Concrete Slab on Grade	100	easy	recycling	low	538 cy	2.025 tons/cy	1085 tons	0.15	163 tons	yes (aggregate and fly ash)
3320	Concrete Site Paving	50	medium	salvage	low	413 cy	2.025 tons/ cy	836 tons	0.15	125 tons	yes (aggregate and fly ash)
5100	Reinforcing Steel	100	easy	recycling	medium	28,443 lf	.88 lbs/ sf of concrete	9.5 tons	1.05	10 tons	no
6120	Agriboard	100	easy	salvage	medium	16372 sf	13 lbs/sf (8" panel)	106 tons	0 **	0	no
6170	Wood - Wall Studs	100	medium	salvage	medium	21,000 LF (or Board Feet)	27 pcf (Fir)	23.6 tons	0	0	yes
6200	Exterior Wood Siding	50	easy	salvage	high	2900 board feet or 241.5 cf	26 pcf (Redwood)	3.14 tons	0	0	yes
6200	Interior wood T&G paneling	100	easy	salvage	high	1167 board feet = 63.6 cf	26 pcf (redwood)	0.83 tons	0	0	yes
6410	Plywood for Casework	50	medium	salvage	medium	892,069 cu. In	.022 lbs/cu in	9.8 tons	0	0	no
7210	Batt Insulation	50	medium	recycling	low	15,000 sf (wall) 4,500 sf (roof)	.28 psf (R-19)	3.1 tons	1.5	4.7 tons	no
7412	Standing Seam Metal Roofing	25	easy	recycling	medium	11660 sf 8745 lf	2.2 lbs / lf	9.6 tons	1.05	10.1 tons	no
8212	Flush Wood Doors	50	easy	salvage	low	12 doors (3'x7') 252 sf	5.3 lbs/sf	.67 tons	0	0	yes
8800	Glass	50	medium	recycling	low	7870 sf	3.28 psf	12.9 tons	1.3	16.8	no
9220	Cement Plaster	50	hard	NA	NA	9800 sf	12 psf	58.8 tons	0.2	11.8 tons	no
9250	Gypsum Board	50	medium	recycling	low	38,500 sf	2 lbs/sf	38.5 tons	0.2	7.7 tons	no
9300	Ceramic Tile	75	medium	salvage	low	1300 sf	2.5 psf	1.63 tons	1.4	2.3 tons	yes
9648	Bamboo Flooring	50	medium	salvage	high	4,609 sf	2.04 psf	4.7 tons	0	0	no
9688	Sheet Carpet	25	easy	recycling	low	11,896 sf	120 oz/yrd	14.9 tons	3.1	46 tons	no

* assuming adequate maintenance of weather envelope ** wood and other agricultural products sequester carbon

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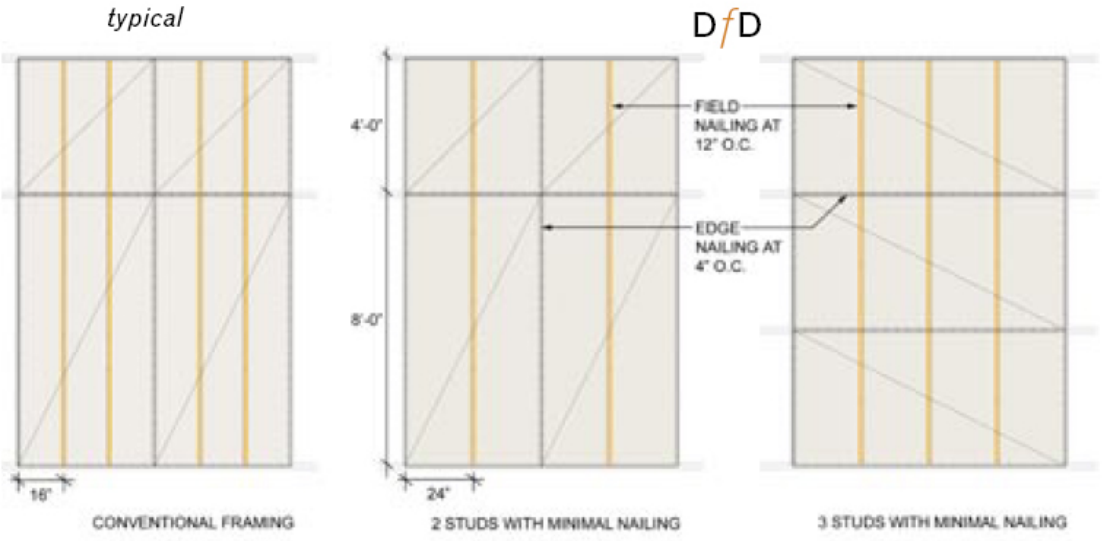
EFFICIENT FRAMING

Efficient framing design utilizes larger framing members spaced at 24"o.c. instead of 16" o.c. This achieves not only an initial reduction in material use but eases disassembly as well.



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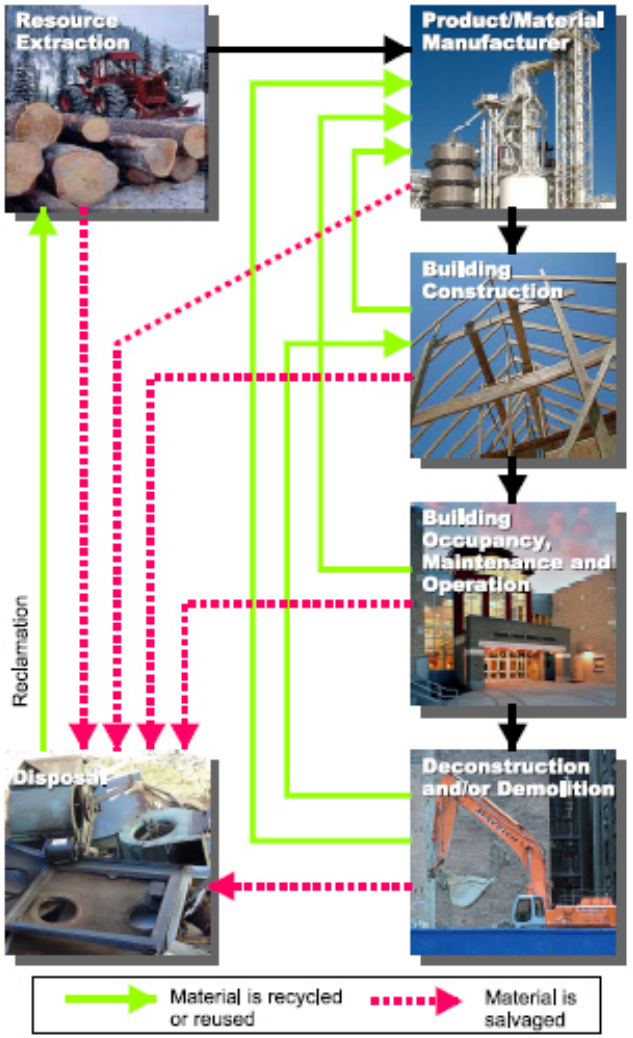
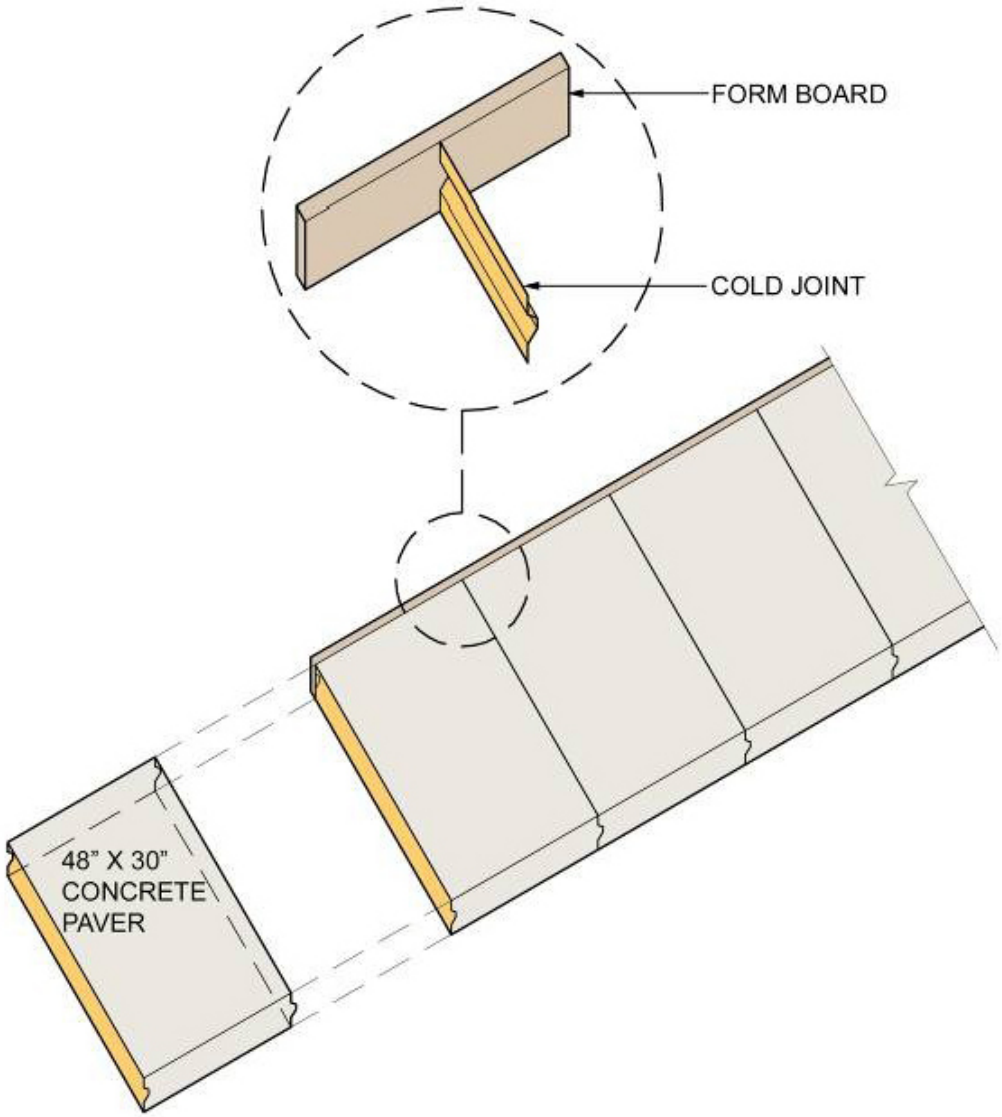


Figure 26 – Life-Cycle of Building Materials

source:
http://www.chps.net/



Concrete Reuse?

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Roof Construction

EHDD ARCHITECTURE

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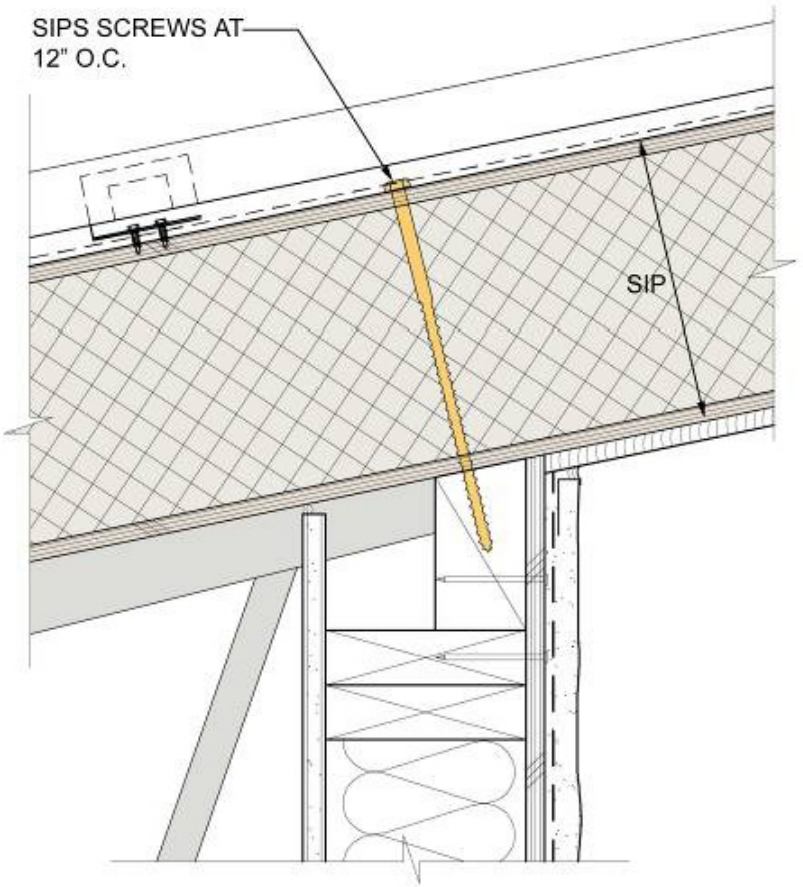
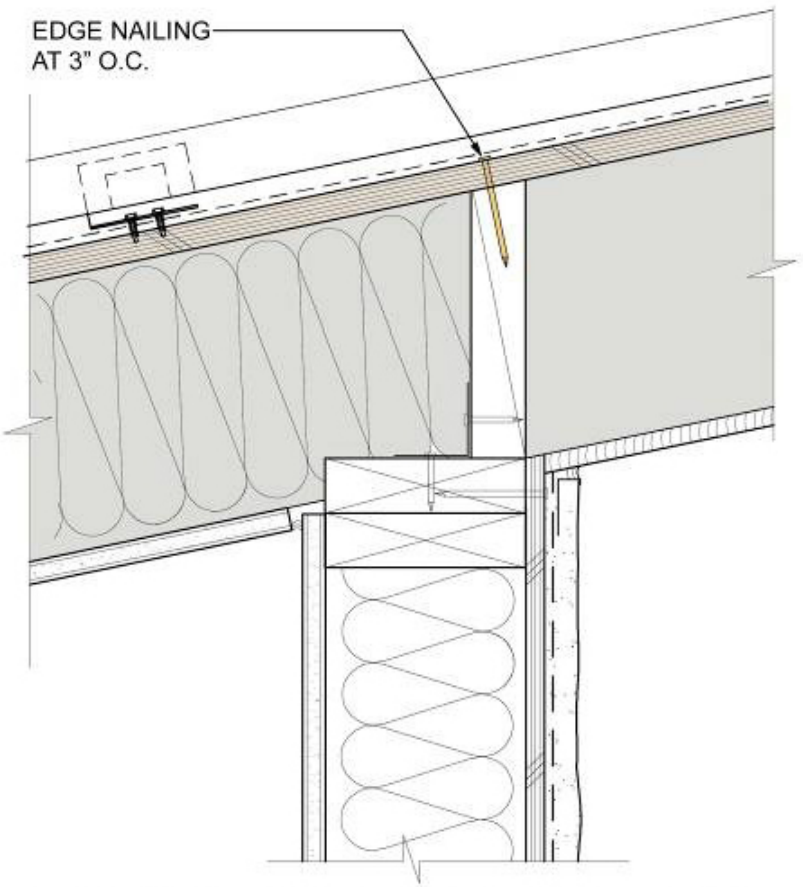
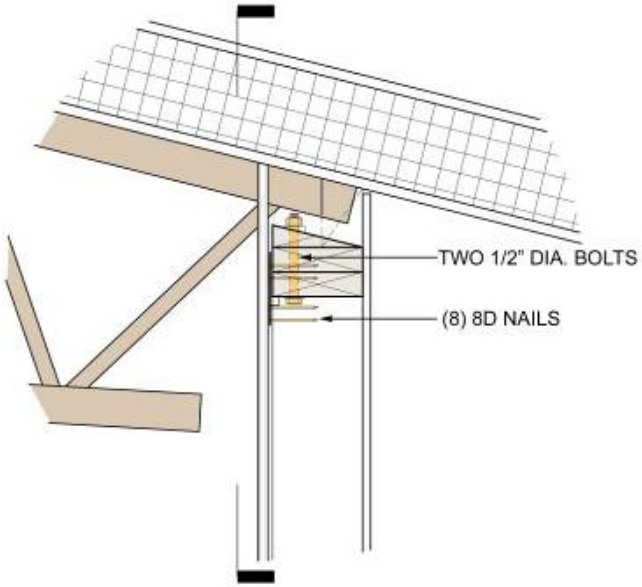
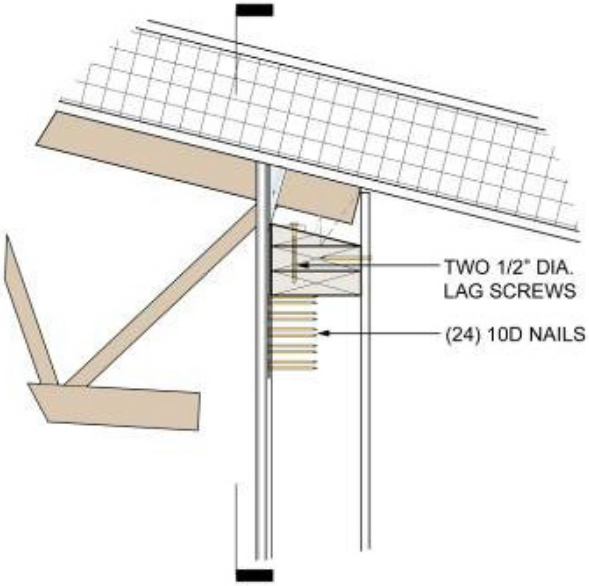


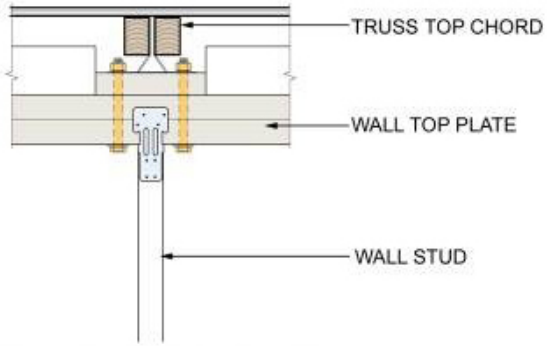
STRUCTURAL INSULATED PANELS (SIP) W/
SIP SCREWS OVER COMPOSITE TRUSSES



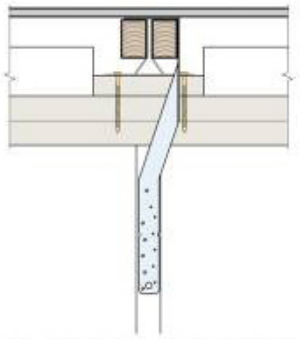
PLYWOOD SHEATHING W/ EDGE NAILS OVER
WOOD JOISTS AND INSULATION







TWO BOLTS PER TRUSS ALLOWS FOR
LESS NAILING AT EACH STUD



TYPICAL DESIGN REQUIRES
MORE NAILING

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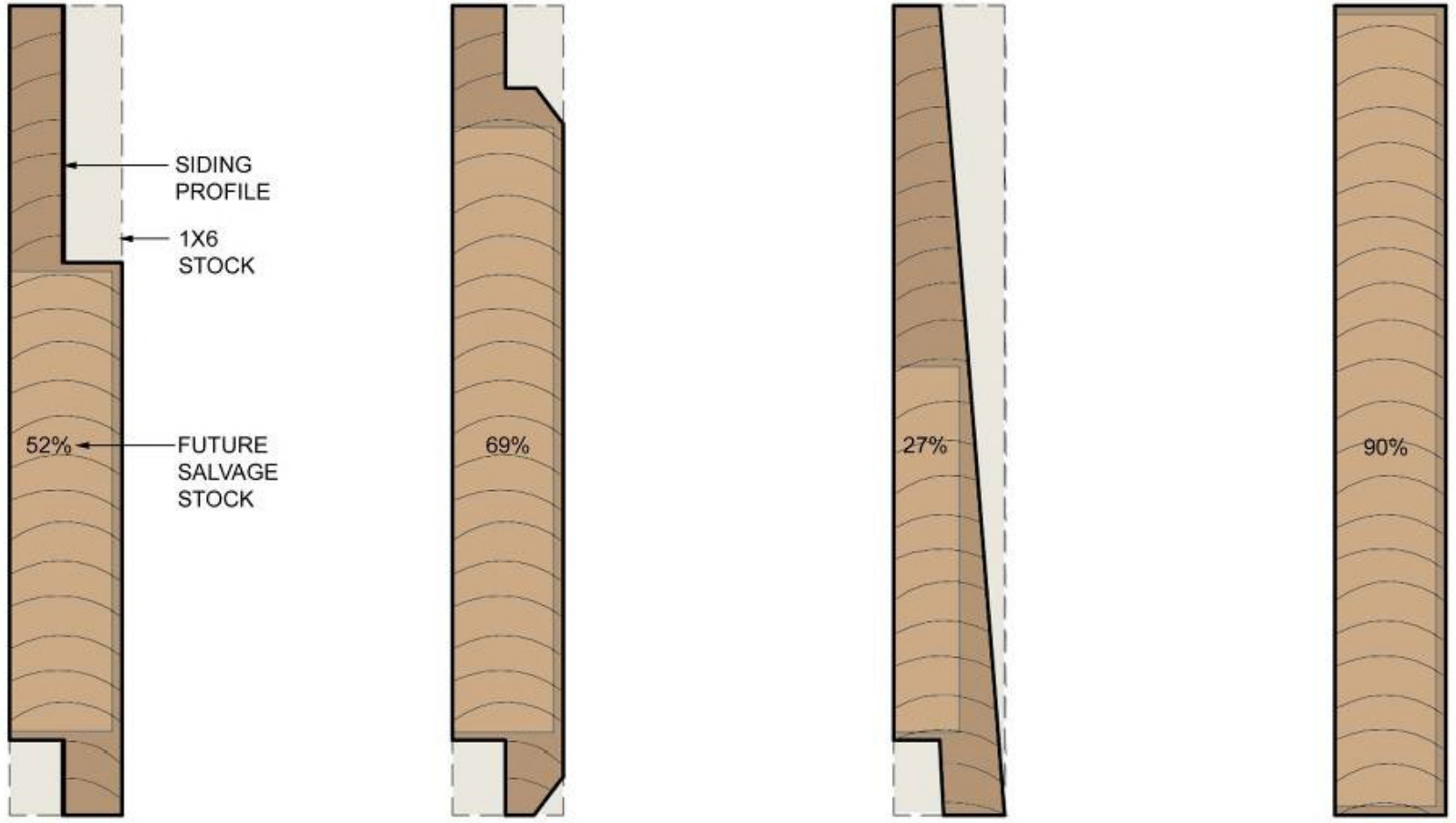
Truss Connection



SIDING PROFILES

Efficiency of Various Siding Options

EHDD ARCHITECTURE

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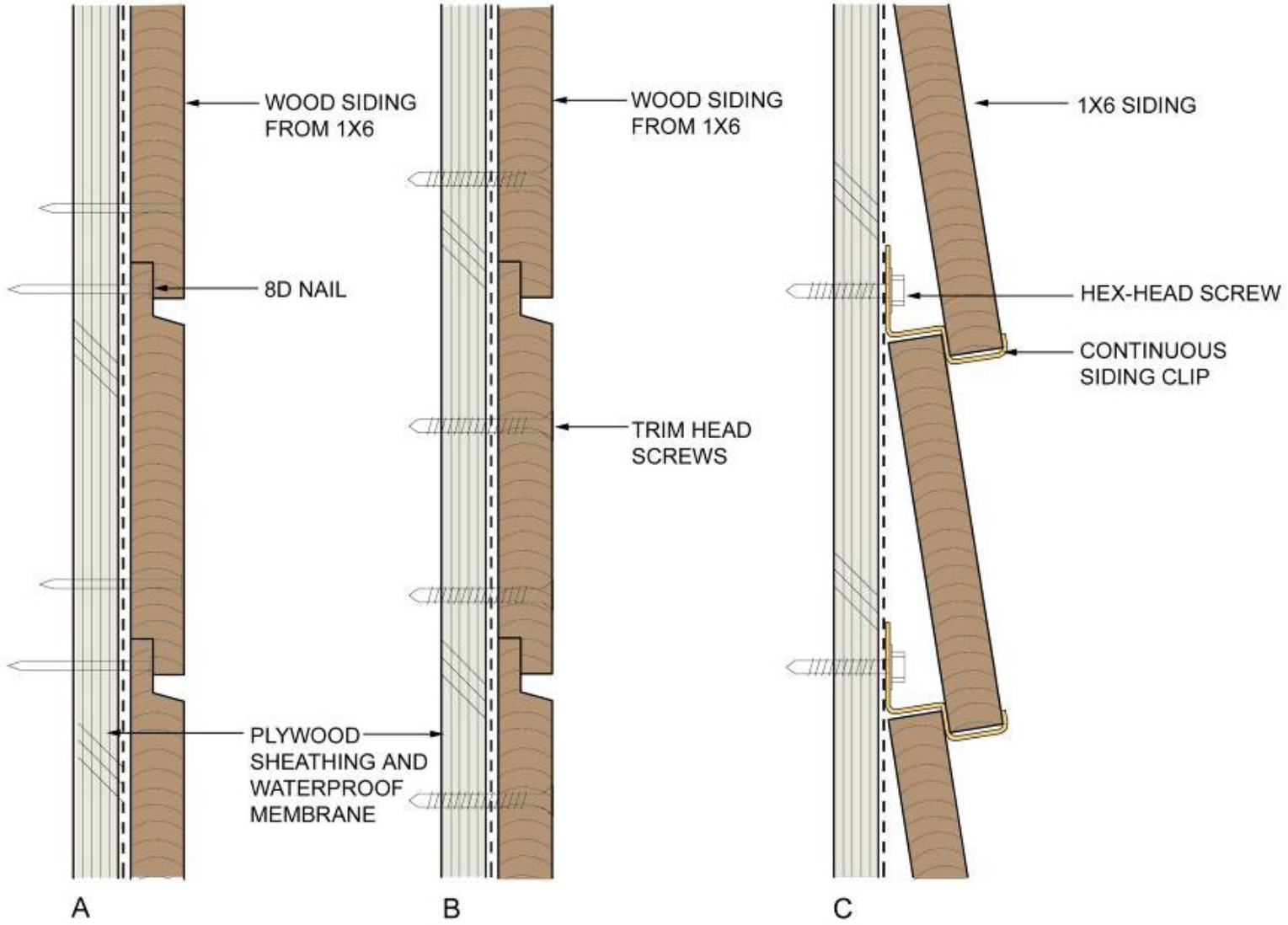

Removable Siding Options

Removable Siding Options

EHDD ARCHITECTURE

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Removable Siding Options

ENDD ARCHITECTURE

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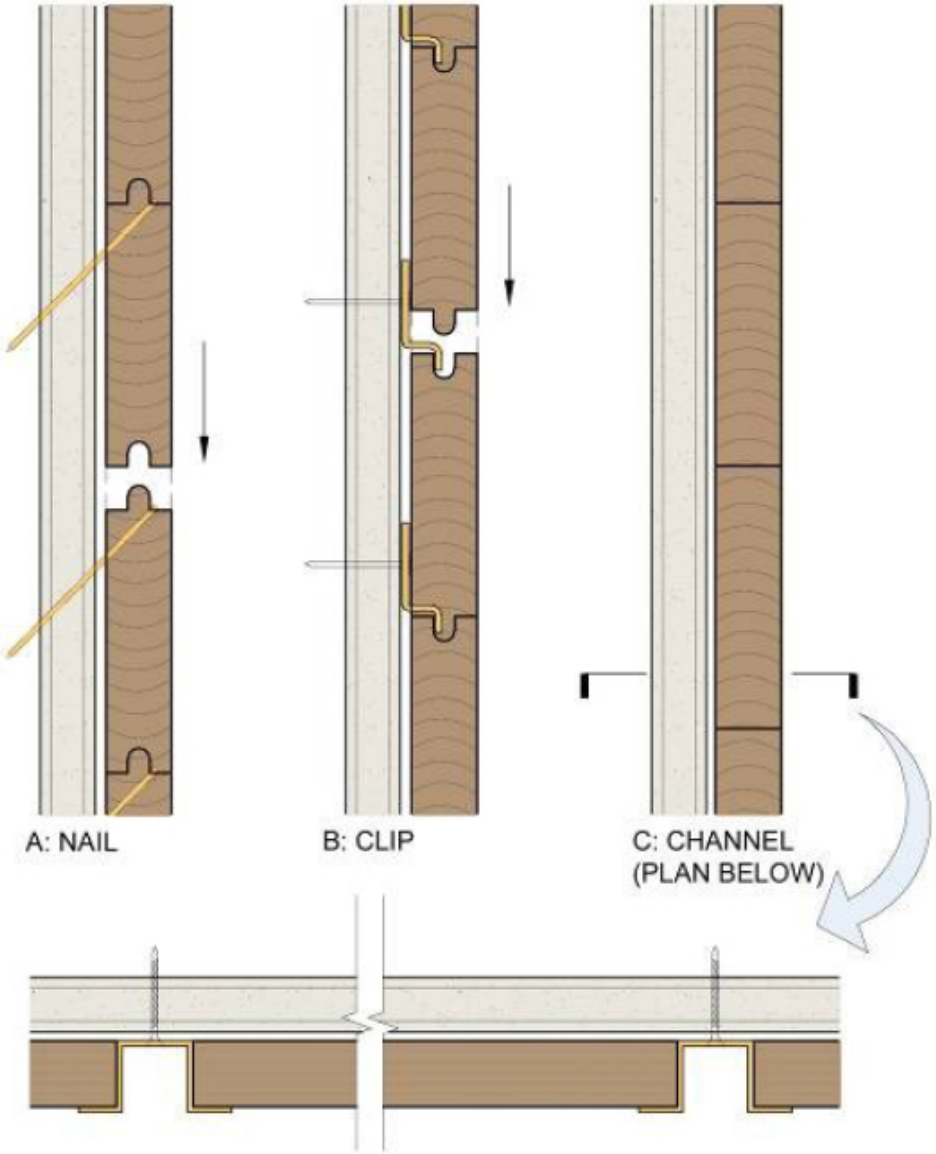

Removable Interior Wood Paneling

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Removable Interior Paneling

EHDD ARCHITECTURE

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Removable Interior Paneling

EHDD ARCHITECTURE

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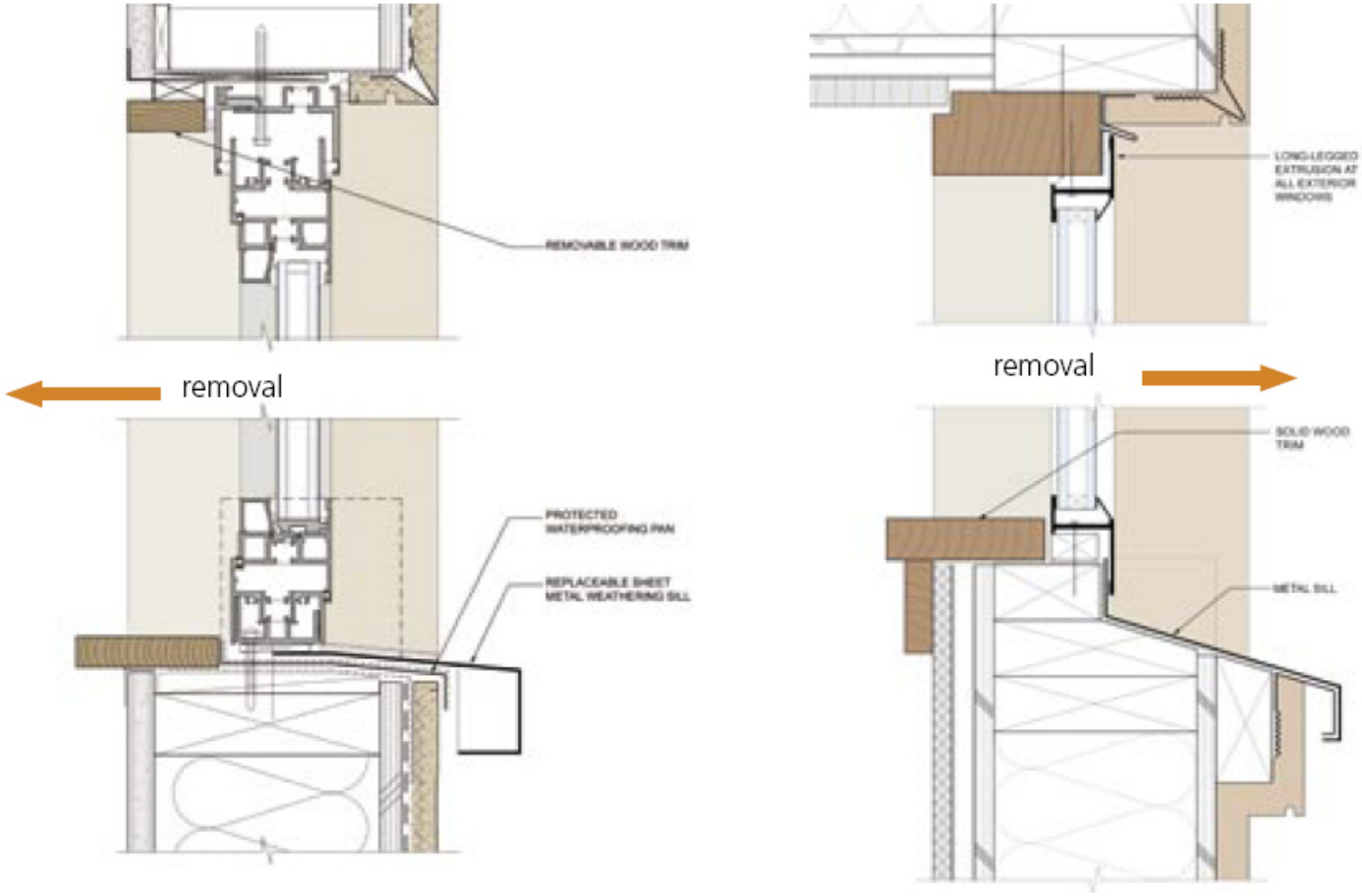
WINDOW DETAILING

Windows are replaced on average every 25 years. Designing openings so that windows can be removed without damaging exterior cladding or interior finishes will reduce renovation costs and construction waste over time.



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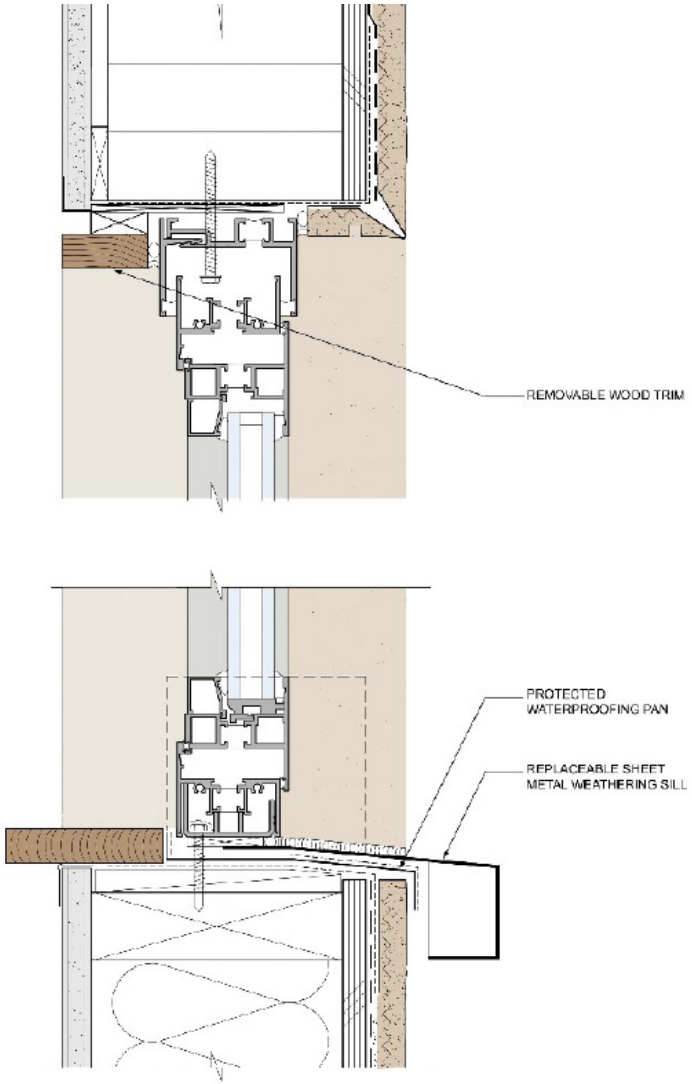
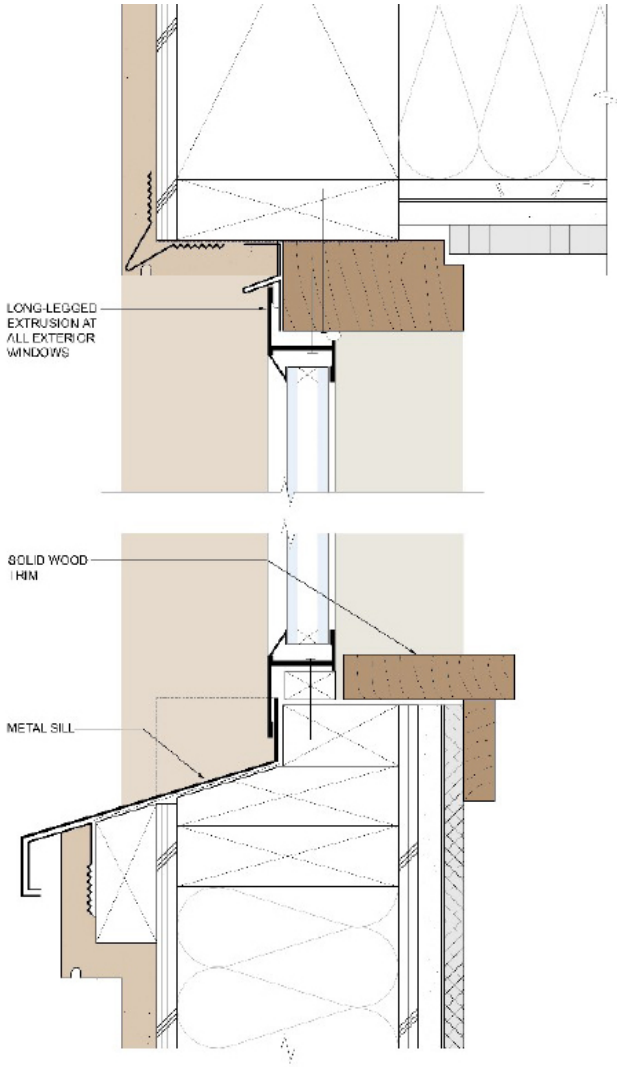


REMOVABLE WINDOW : DETAIL A



REMOVABLE WINDOW : DETAIL B

Removable Window Details

EHDD ARCHITECTURE

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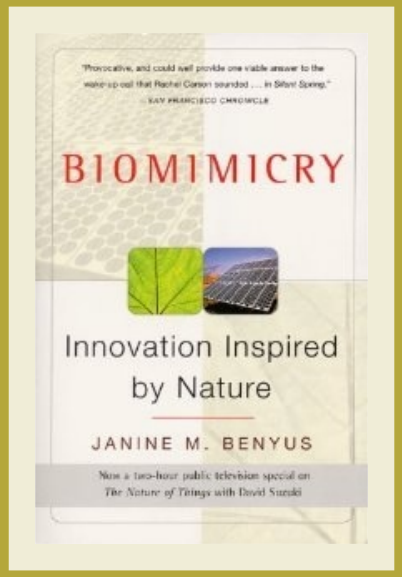
What is Biomimicry?

A design discipline that seeks sustainable solutions by emulating nature's time-tested patterns and strategies.

Core Idea: Nature has already solved many of the problems we are grappling with: energy, food production, climate control, non-toxic chemistry, transportation, packaging, and more.

Brings disciplines together who historically don't interact (e.g., biologists, engineers, designers, economists)

"The biomimics are discovering what works in the natural world and more important, what lasts. After 3.8 billion years of research and development, failures are fossils, and what surrounds us is the secret to survival."

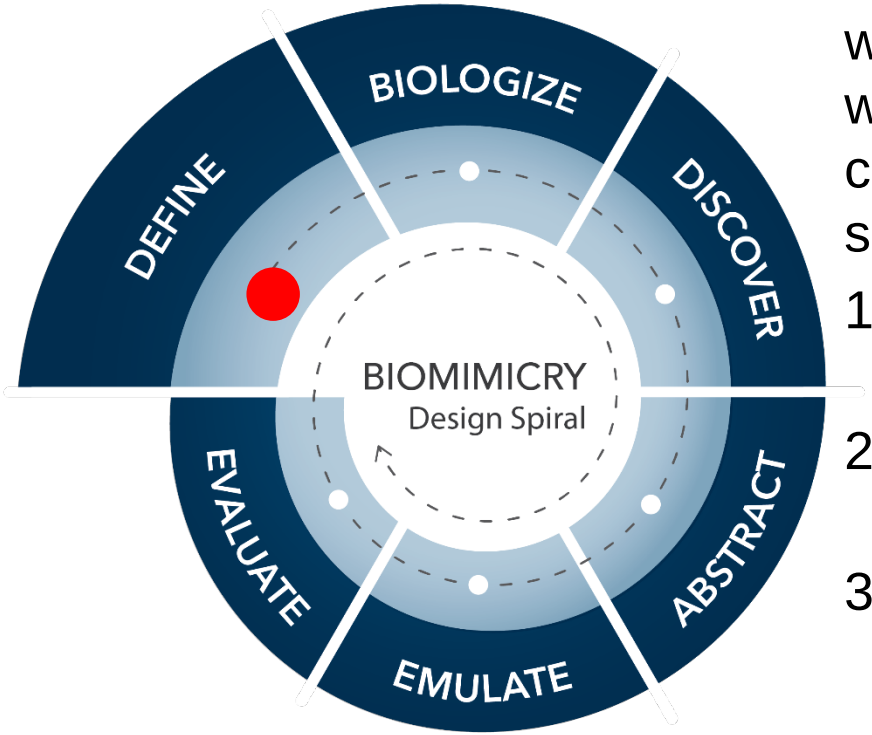


Janine Benyus

Biomimicry: Innovation Inspired by Nature

Several excellent videos of her talks on TED and YouTube web sites

Define the Challenge



Clearly articulate the impact you want your design to have in the world and the criteria and constraints that will determine success.

1. State the challenge as a question.
2. Make sure you are considering context.
3. Take a systems view and look for potential leverage points.

https://toolbox.biomimicry.org/methods/define/

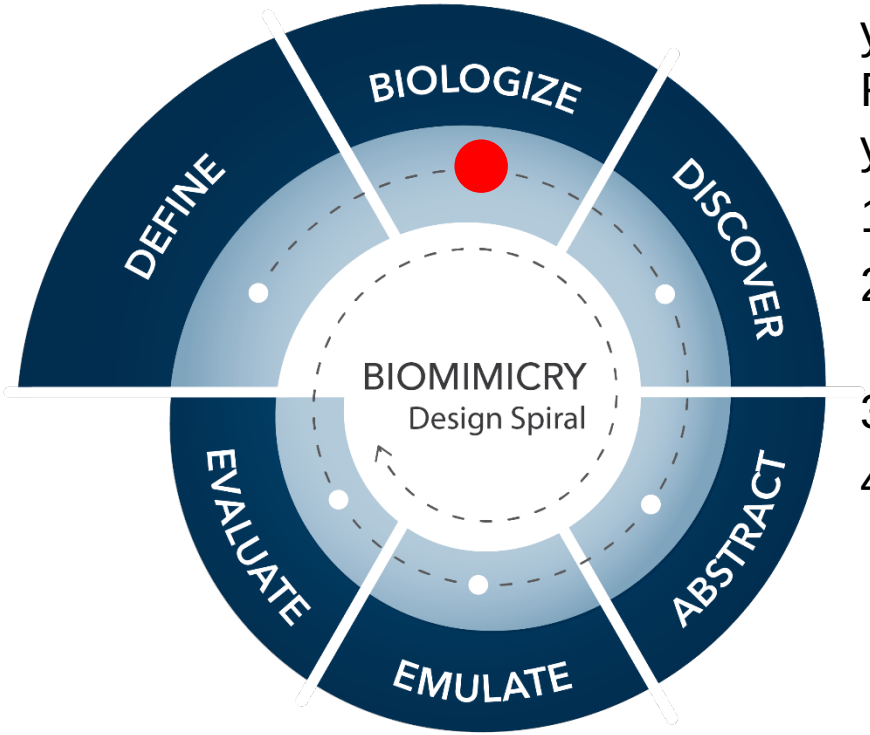
Define the Challenge

Sample design questions

A good design question is neither too broad nor too narrow. Consider these examples.

Too Broad	Just Right	Too Narrow
How might we end hunger?	**How might we connect institutional food surpluses to those in need?**	How might we design an app to help food pantries get more donations?
Hunger is a huge multifaceted problem and this statement doesn't target a specific area of intervention.	*This statement provides enough specificity while remaining open to a variety of possible solutions.*	*This statement presupposes too many details about the solution (an app) and doesn't leave enough room for innovation.*
How can we make cycling safer?	**How might we make urban cyclists more visible to drivers at night?**	How can we make better lights for cyclists?
What aspects of cycling? This is too broad.	*This statement provides enough specificity (urban, night time visibility) while remaining open to a variety of possible solutions.*	*How do we know lights are the best solution? This statement doesn't leave enough room for creative problem solving.*

Biologize Function & Context



https://toolbox.biomimicry.org/methods/biologize/

Analyze the essential functions and context your design solution must address. Reframe them in biological terms, so that you can "ask nature" for advice.

1. Ask "How does nature?" questions.
2. Think about analogous life functions and contexts in nature.
3. Consider multiple possibilities.
4. Flip the question.

   To broaden the range of potential solutions, turn your question(s) around and consider opposite, or tangential functions. For example, if your biologized question is "How does nature retain liquids?", you could also ask "How does nature repel liquids?"

Biologize Function & Context

Design Question:
How might we keep buildings cool in the summer?

Biologized Question:
How does nature regulate temperature in hot climates?

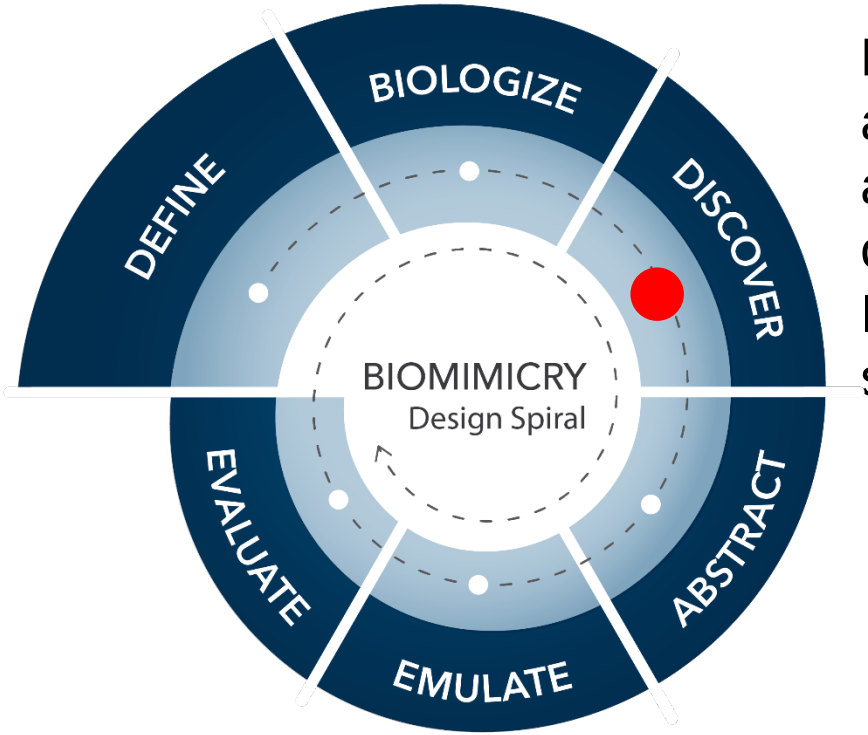
Design Question:
How might we reduce stormwater runoff and flooding in cities?

Biologized Question:
How does nature manage excess water?

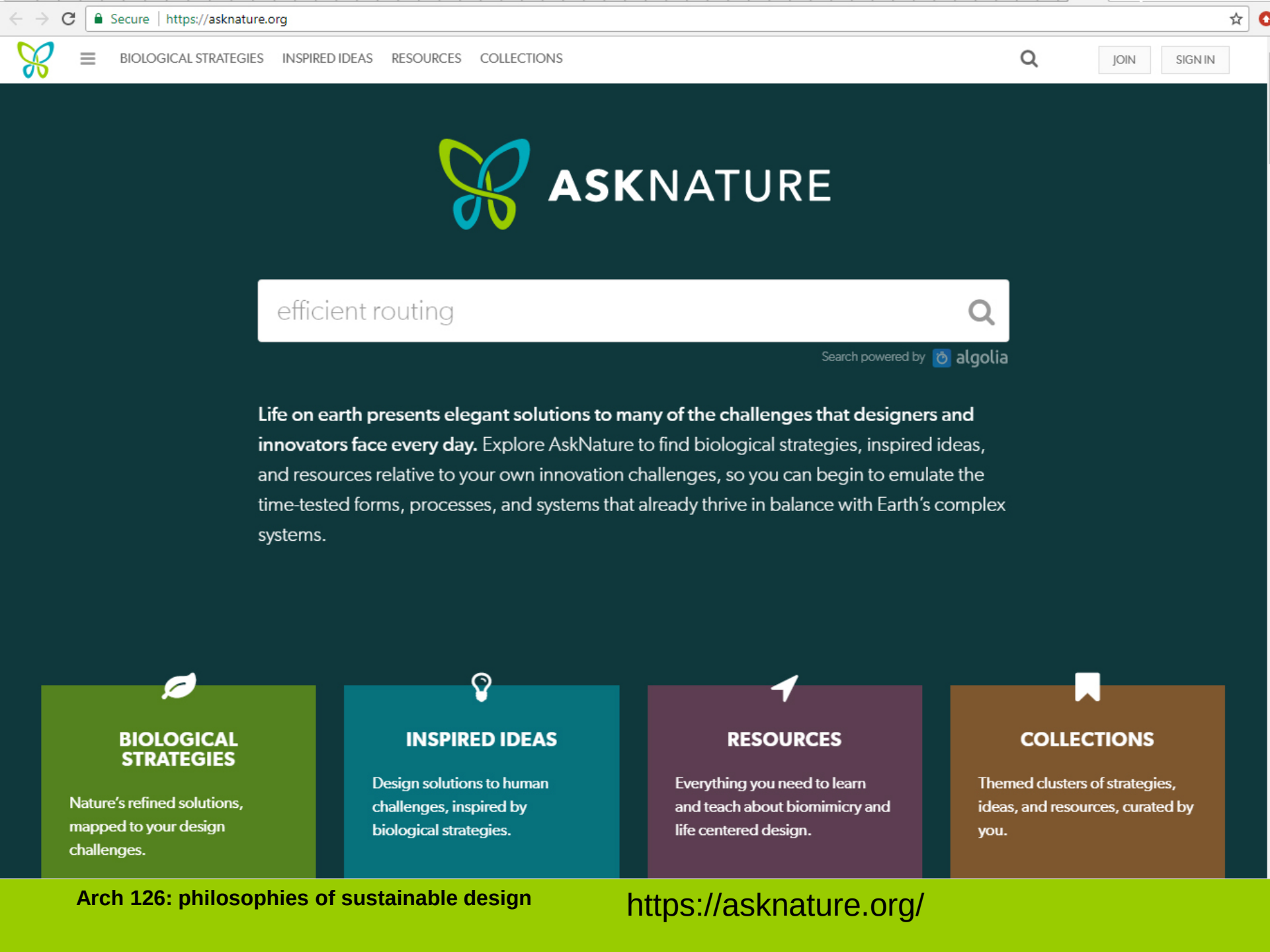
Design Question:
How might we reduce the use of toxic substances in paints?

Biologized Question:
How does nature create color?

DISCOVER



Look for natural models (organisms and ecosystems) that need to address the same functions and context as your design solution. Identify the strategies used that support their survival and success.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BIOLOGICAL STRATEGIES
INSPIRED IDEAS
RESOURCES
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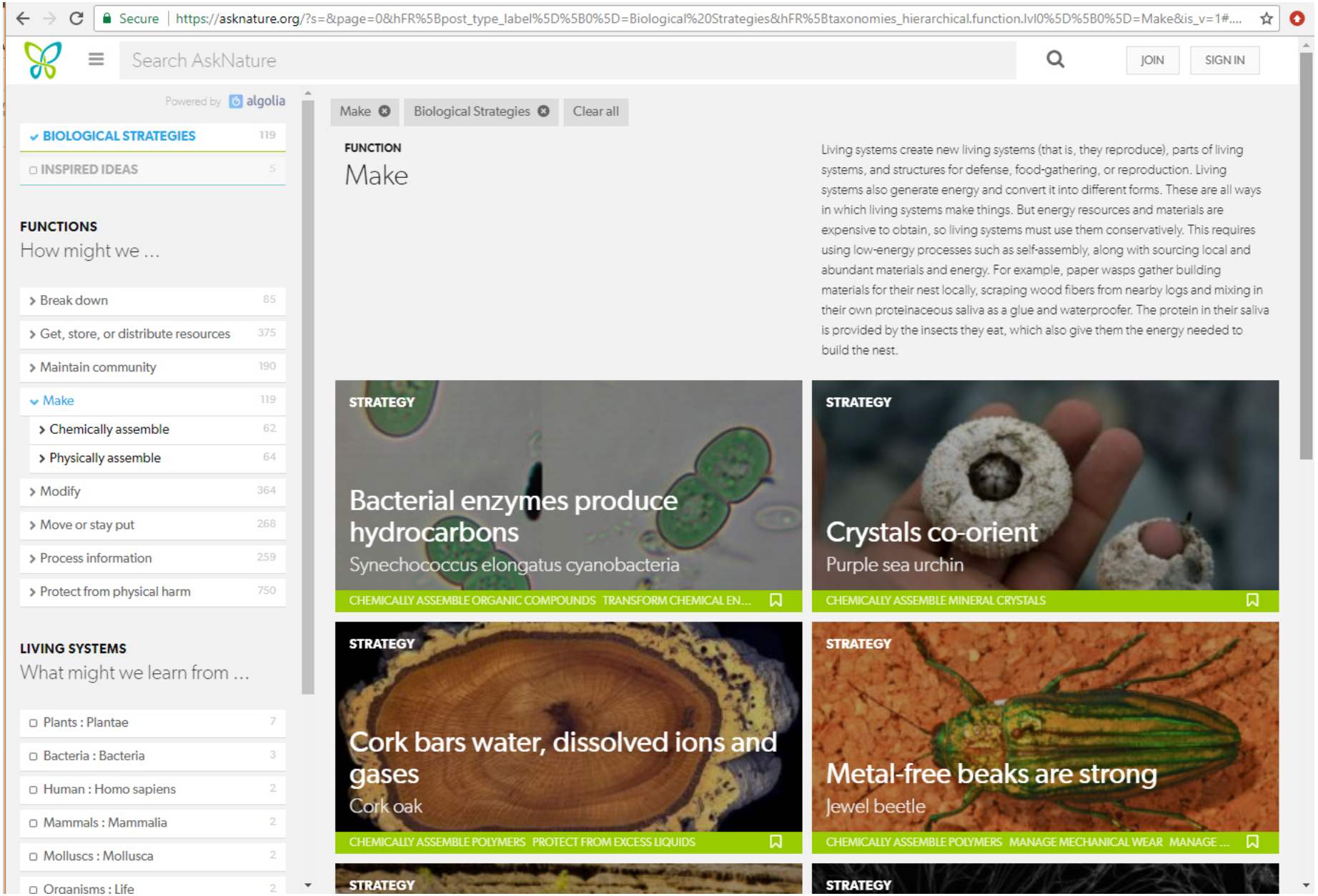
Life on earth presents elegant solutions to many of the challenges that designers and innovators face every day. Explore AskNature to find biological strategies, inspired ideas, and resources relative to your own innovation challenges, so you can begin to emulate the time-tested forms, processes, and systems that already thrive in balance with Earth's complex systems.
BIOLOGICAL STRATEGIES
Nature's refined solutions, mapped to your design challenges.
INSPIRED IDEAS
Design solutions to human challenges, inspired by biological strategies.
RESOURCES
Everything you need to learn and teach about biomimicry and life centered design.
COLLECTIONS
Themed clusters of strategies, ideas, and resources, curated by you.

Biomimicry Taxonomy

What is the biomimicry taxonomy?

- Break down (87)
- Get, store, or distribute resources (412)
- Maintain community (306)
- Maintain physical integrity (923)
  - Manage structural forces (232)
    - Chemical wear (2)
    - Compression (55)
      - Bones self-heal: vertebrates
      - Hole structure strengthens bone: horse
      - Lightweighting: Scots pine
      - Fibers keep tall spikes upright: titan arum
      - Leaves given structural support: giant water-lily
      - Nest cells support heavy weights: bees and wasps
      - Structural composition provides strength in changing conditions: plants
      - Rod-like reinforcements provide strength: plants
      - Reinforced fibers provide strength: plants
      - Lignified parenchyma cells provide strength: plants
      - Sclereid cells prevent soft tissue collapse: plants
      - Collenchyma cells provide strength, flexibility: plants
      - Thickness stabilizes tall trees: baobob
      - Fluid protects eggs: birds
      - Intricate silica architecture survives forces: diatoms


Secure | https://asknature.org/?s=&page=0&hFR%5Bpost_type_label%5D%5B0%5D=Biological%20Strategies&hFR%5Btaxonomies_hierarchical.function.lvl0%5D%5B0%5D=Make&is_v=1#....
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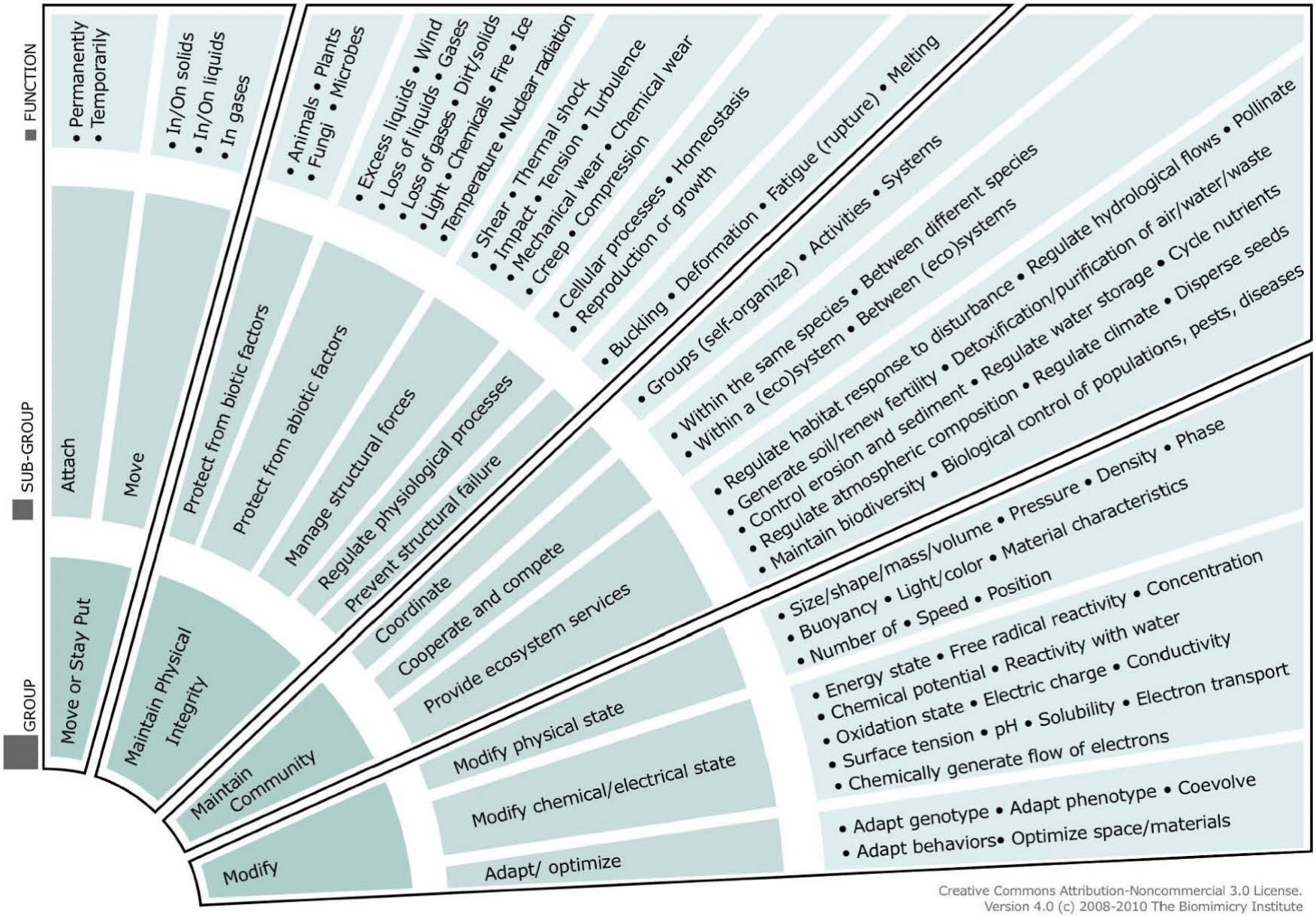
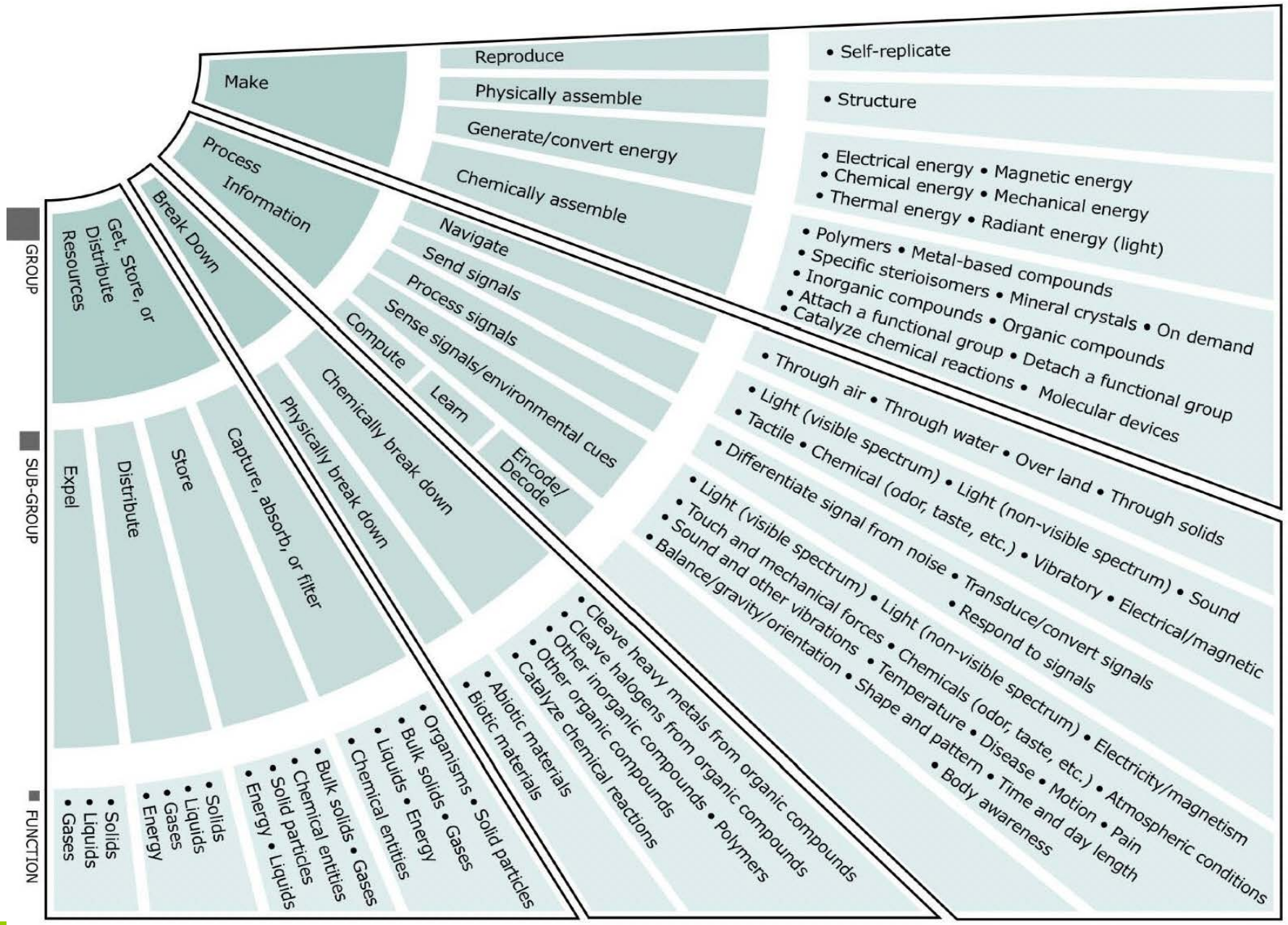
BIOLOGICAL STRATEGIES 119
INSPIRED IDEAS 5
FUNCTIONS
How might we ...
Break down 85
Get, store, or distribute resources 375
Maintain community 190
Make 119
Chemically assemble 62
Physically assemble 64
Modify 364
Move or stay put 268
Process information 259
Protect from physical harm 750
LIVING SYSTEMS
What might we learn from ...
Plants : Plantae 7
Bacteria : Bacteria 3
Human : Homo sapiens 2
Mammals : Mammalia 2
Molluscs : Mollusca 2
Organisms : Life 2
Make
Biological Strategies
Clear all
FUNCTION
Make
Living systems create new living systems (that is, they reproduce), parts of living systems, and structures for defense, food-gathering, or reproduction. Living systems also generate energy and convert it into different forms. These are all ways in which living systems make things. But energy resources and materials are expensive to obtain, so living systems must use them conservatively. This requires using low-energy processes such as self-assembly, along with sourcing local and abundant materials and energy. For example, paper wasps gather building materials for their nest locally, scraping wood fibers from nearby logs and mixing in their own proteinaceous saliva as a glue and waterproofer. The protein in their saliva is provided by the insects they eat, which also give them the energy needed to build the nest.
STRATEGY
Bacterial enzymes produce hydrocarbons
Synechococcus elongatus cyanobacteria
CHEMICALLY ASSEMBLE ORGANIC COMPOUNDS TRANSFORM CHEMICAL EN...
STRATEGY
Crystals co-orient
Purple sea urchin
CHEMICALLY ASSEMBLE MINERAL CRYSTALS
STRATEGY
Cork bars water, dissolved ions and gases
Cork oak
CHEMICALLY ASSEMBLE POLYMERS PROTECT FROM EXCESS LIQUIDS
STRATEGY
Metal-free beaks are strong
Jewel beetle
CHEMICALLY ASSEMBLE POLYMERS MANAGE MECHANICAL WEAR MANAGE ...
STRATEGY
STRATEGY

Biomimicry Taxonomy





Biomimicry Taxonomy

1. Find the verb:

   Move away from any predetermined ideas of what you want to design, and *think more about what you want your design to do*. Try to pull out single functional words in the form of verbs. The questions you might pose through the Search or Browse options might be:

   How would Nature…

   Capture rainwater?
   Store water?

2. Try a different angle.

Some organisms live in areas that don't experience any rain, yet they still get all of the water they need. So other questions to pose might be:

How would Nature…

Capture water?
Capture fog?
Absorb water?
Manage humidity?
Move water?

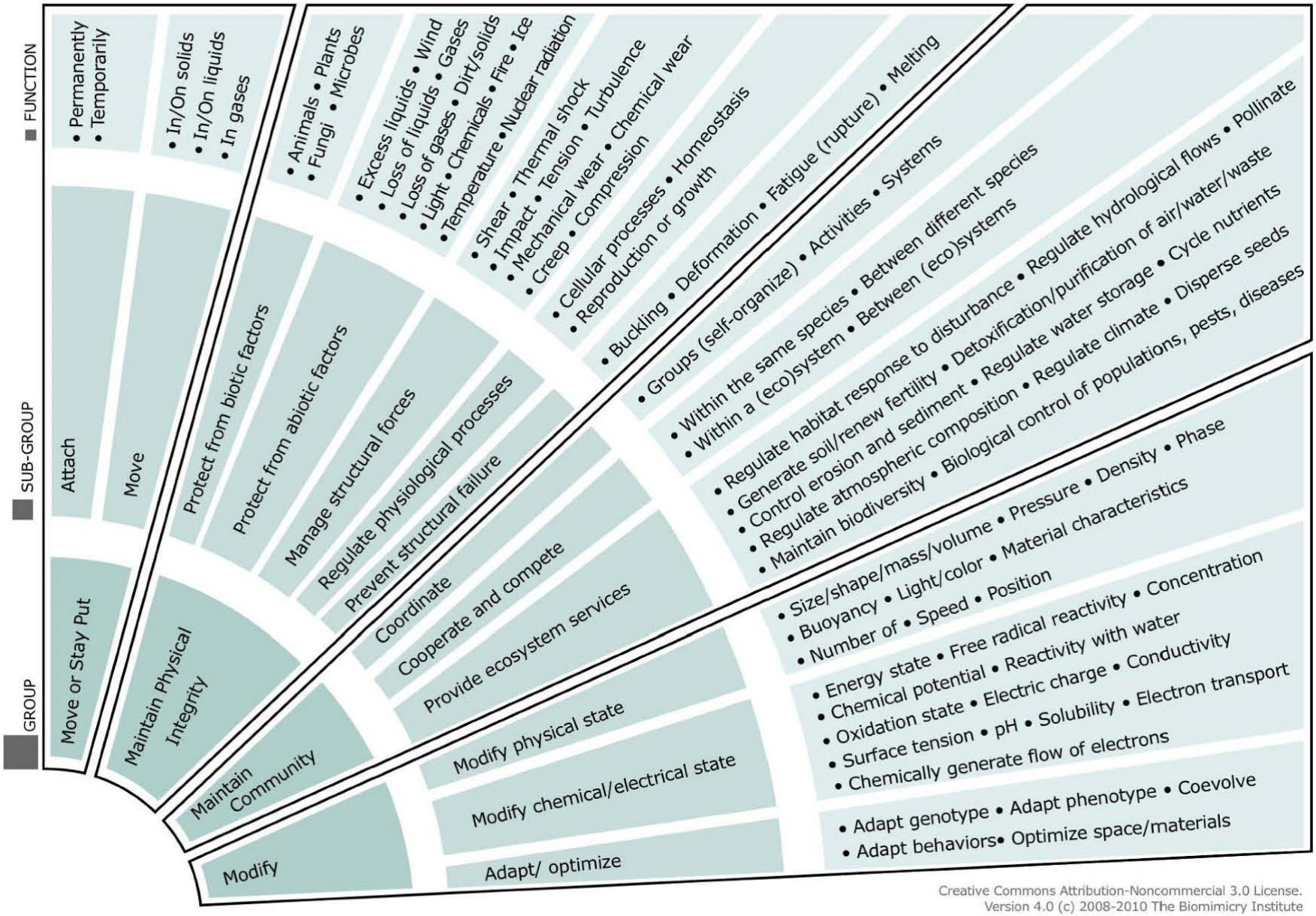
3. Turn the question around.

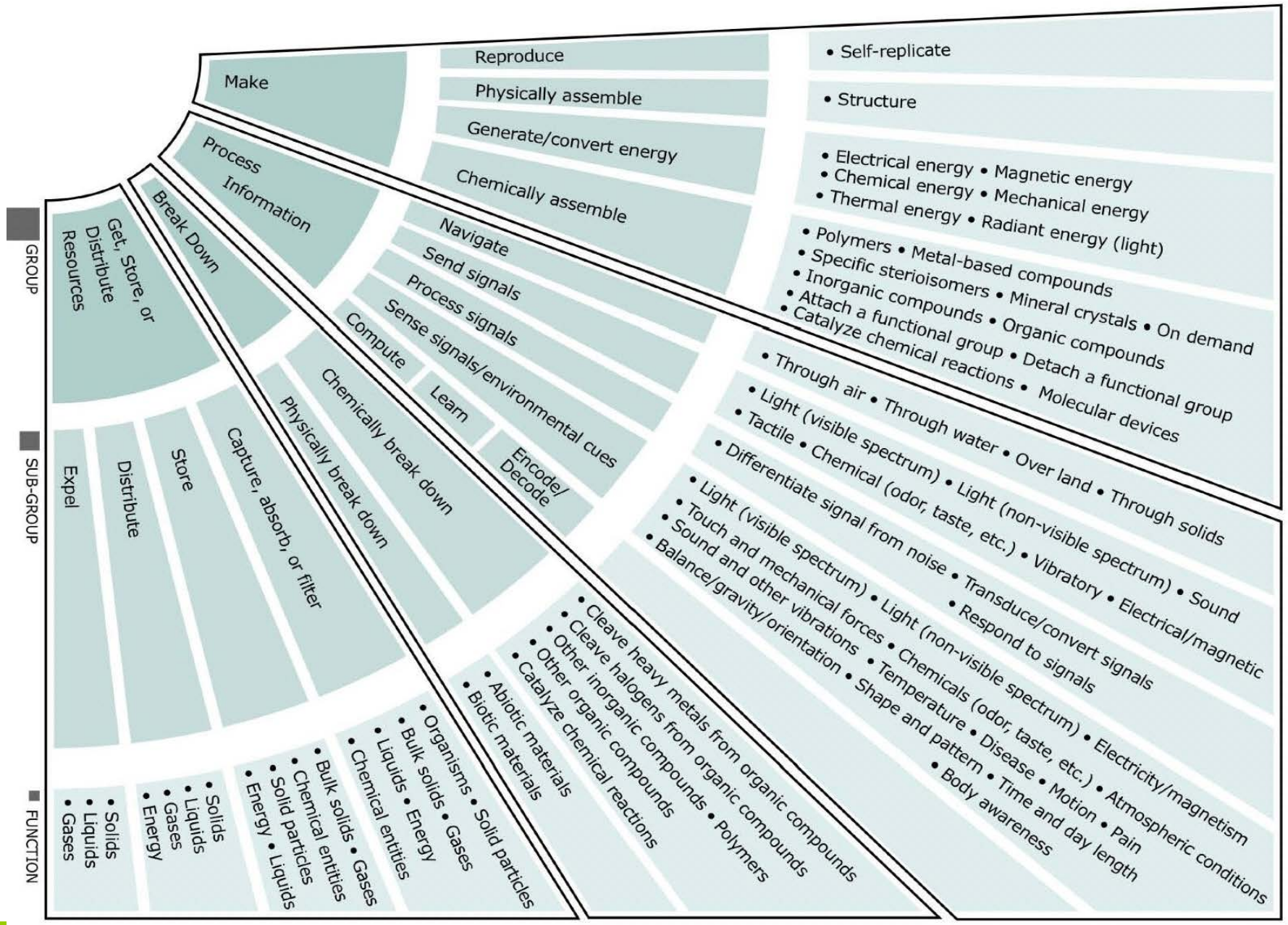
Instead of asking how Nature stores water, you might think about how Nature protects against excess water or keeps water out:

How would Nature…

Remove water?
Stay dry?

Biomimicry Taxonomy





Leaves given structural support: giant water-lily

The leaves of the Amazon water lily gain structural support via girder-like support ribs.

Biomimicry Taxonomy

- Maintain physical integrity >
- Manage structural forces >
- Compression

Biomimetic Application Ideas

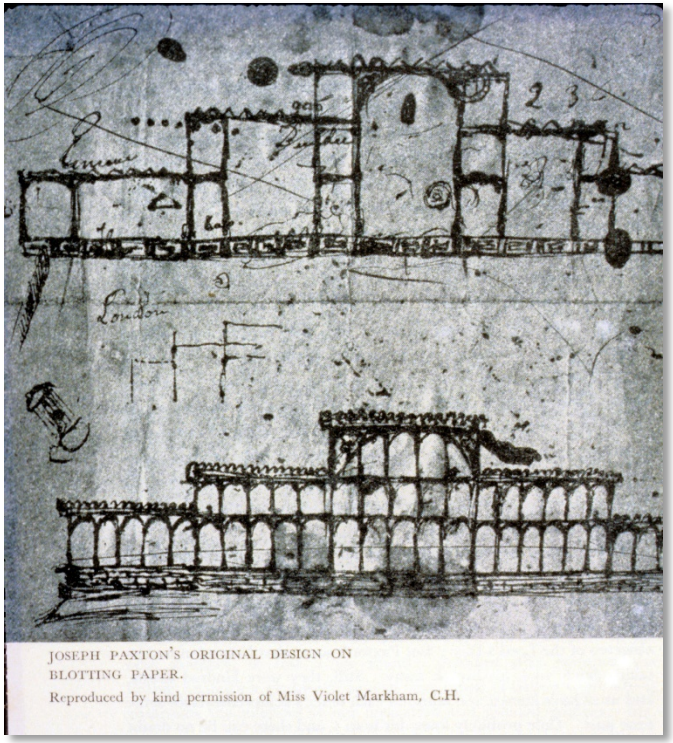
Light-weight structurally strong panels for buildings or vehicles.

> Visit strategy page

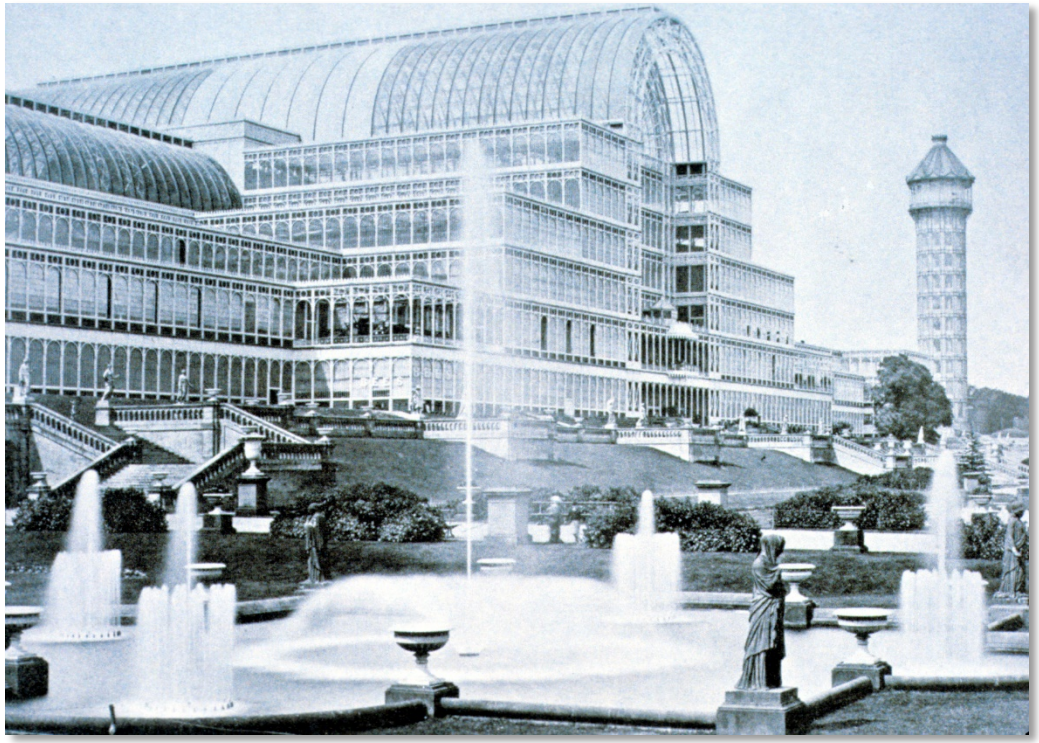
SUMMARY [Collapse all sections]

"In still or slowly-moving waters there is one easy way to collect [light]: a plant can float its leaves upon the surface. No plant does this on a more spectacular scale or more aggressively than the giant

Structural Skeleton

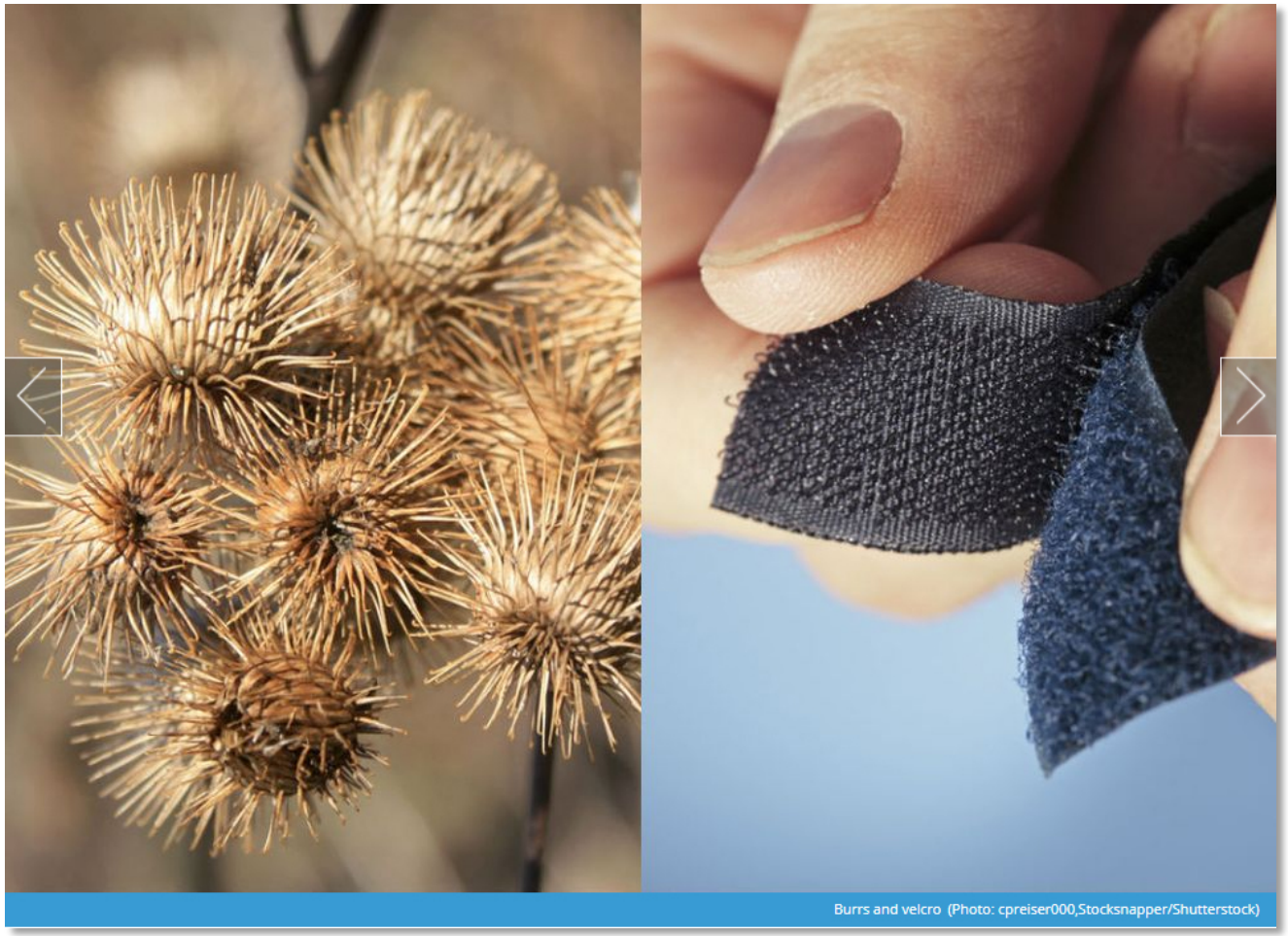


JOSEPH PAXTON'S ORIGINAL DESIGN ON BLOTTING PAPER.
Reproduced by kind permission of Miss Violet Markham, C.H.



Paxton's Crystal Palace was based on the strength of the Lily Pad and the ability of the veins of the leaf to support the thinner membranes between.

Burr = Velcro



https://www.mnn.com/earth-matters/wilderness-resources/photos/7-amazing-examples-of-biomimicry/burr-velcro

Bugs = Water Collection

Stenocara beetle and a water drop on a hydrophobic surface (Photo: Manu M Nair/Shutterstock,Brocken Inaglory/Wikimedia Commons)

https://www.mnn.com/earth-matters/wilderness-resources/photos/7-amazing-examples-of-biomimicry/bug-water-collection

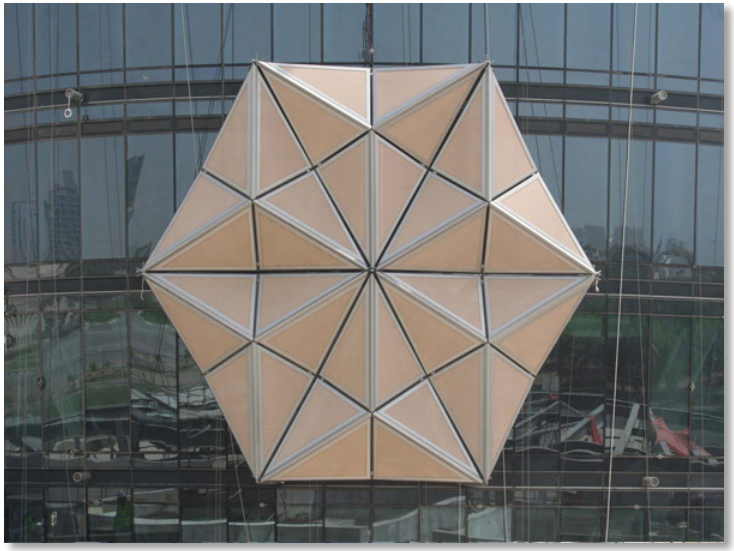
The Stenocara beetle is a master water collector. The small black bug lives in a harsh, dry desert environment and is able to survive thanks to the unique design of its shell. The Stenocara's back is covered in small, smooth bumps that serve as collection points for condensed water or fog. The entire shell is covered in a slick, Teflon-like wax and is channeled so that condensed water from morning fog is funneled into the beetle's mouth. It's brilliant in its simplicity.

Researchers at MIT have been able to build on a concept inspired by the Stenocara's shell and first described by Oxford University's Andrew Parker. They have crafted a material that collects water from the air more efficiently than existing designs. About 22 countries around the world use nets to collect water from the air, so such a boost in efficiency could have a big impact.

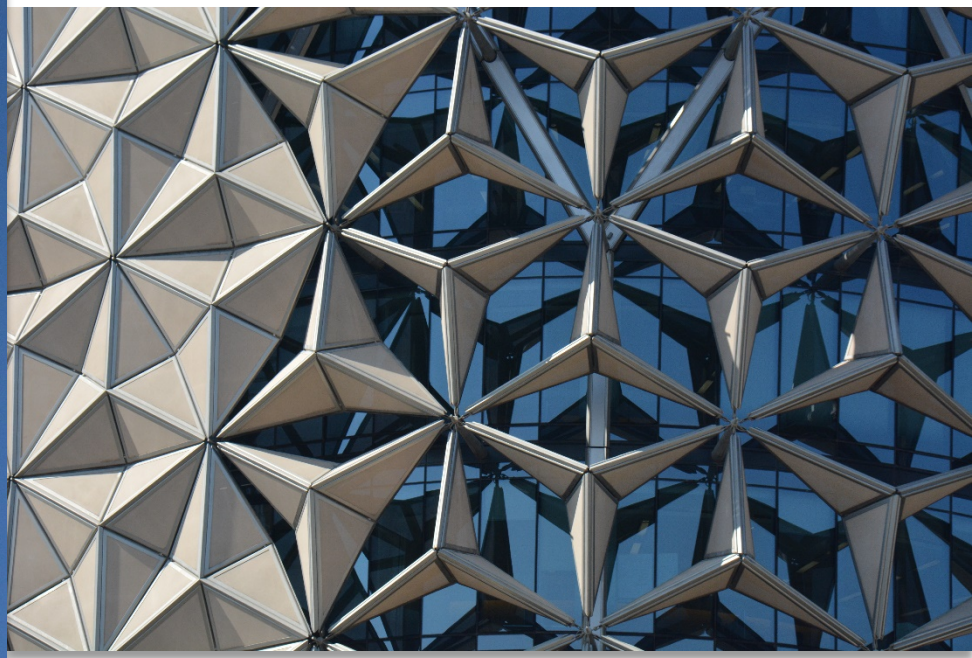
Biomimicry in Architecture

Singapore Arts Center

Shading screen over glass roof whose angles are fine tuned to the solar path as inspired by polar bear fur.



Al Bahar Towers in Abu Dhabi, by Aedas – façade opens and closes as timed to the sun.



Al Bahar Towers in Abu Dhabi, by Aedas – façade opens and closes as timed to the sun.

Photovoltaic panels that turn to track the sun, just like sunflowers.

Termite den and the Eastgate Centre (Photo: fritz16/Shutterstock; David Brazier/Wikimedia Commons)

https://www.mnn.com/earth-matters/wilderness-resources/photos/7-amazing-examples-of-biomimicry/termite-den-office-buildi

Termite den = Office building

Termite dens look otherworldly, but they are surprisingly comfortable places to live. While the temperature outside swings wildly throughout the day from lows in the 30s to highs over 100, the inside of a termite den holds steady at a comfortable (to a termite) 87 degrees.

Mick Pearce, architect of Eastgate Centre in Harare, Zimbabwe, studied the cooling chimneys and tunnels of termite dens. He applied those lessons to the 333,000 square-foot Eastgate Centre, which uses 90 percent less energy to heat and cool than traditional buildings. The building has large chimneys that naturally draw in cool air at night to lower the temperature of the floor slabs, just like termite dens. During the day, these slabs retain the coolness, greatly reducing the need for supplemental air conditioning.

BIOMIMICRY GUILD

THE INNOVATION CONSULTANCY FOR BIO-INSPIRED DESIGN

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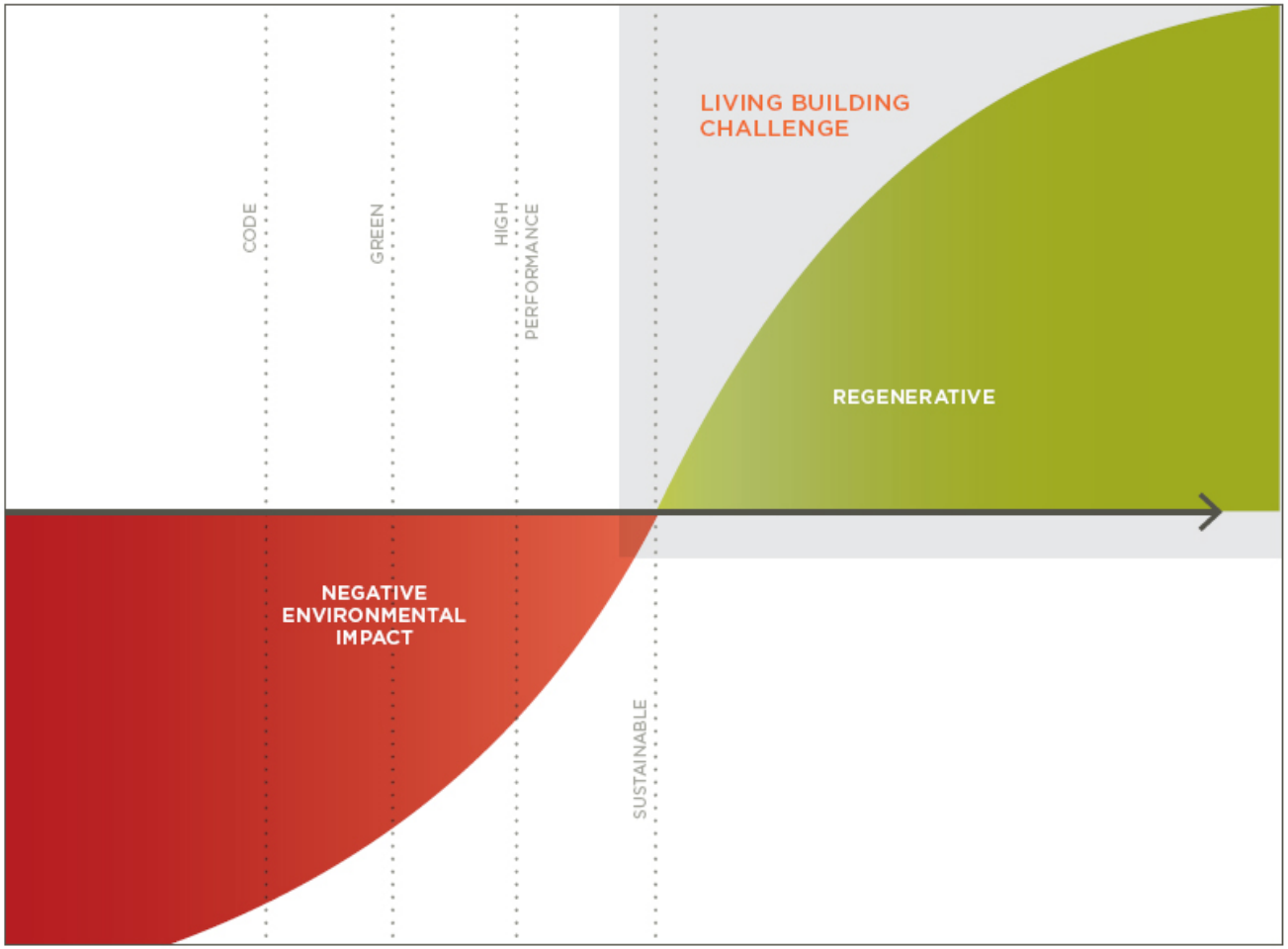
LIVING BUILDING CHALLENGE℠ 3.0

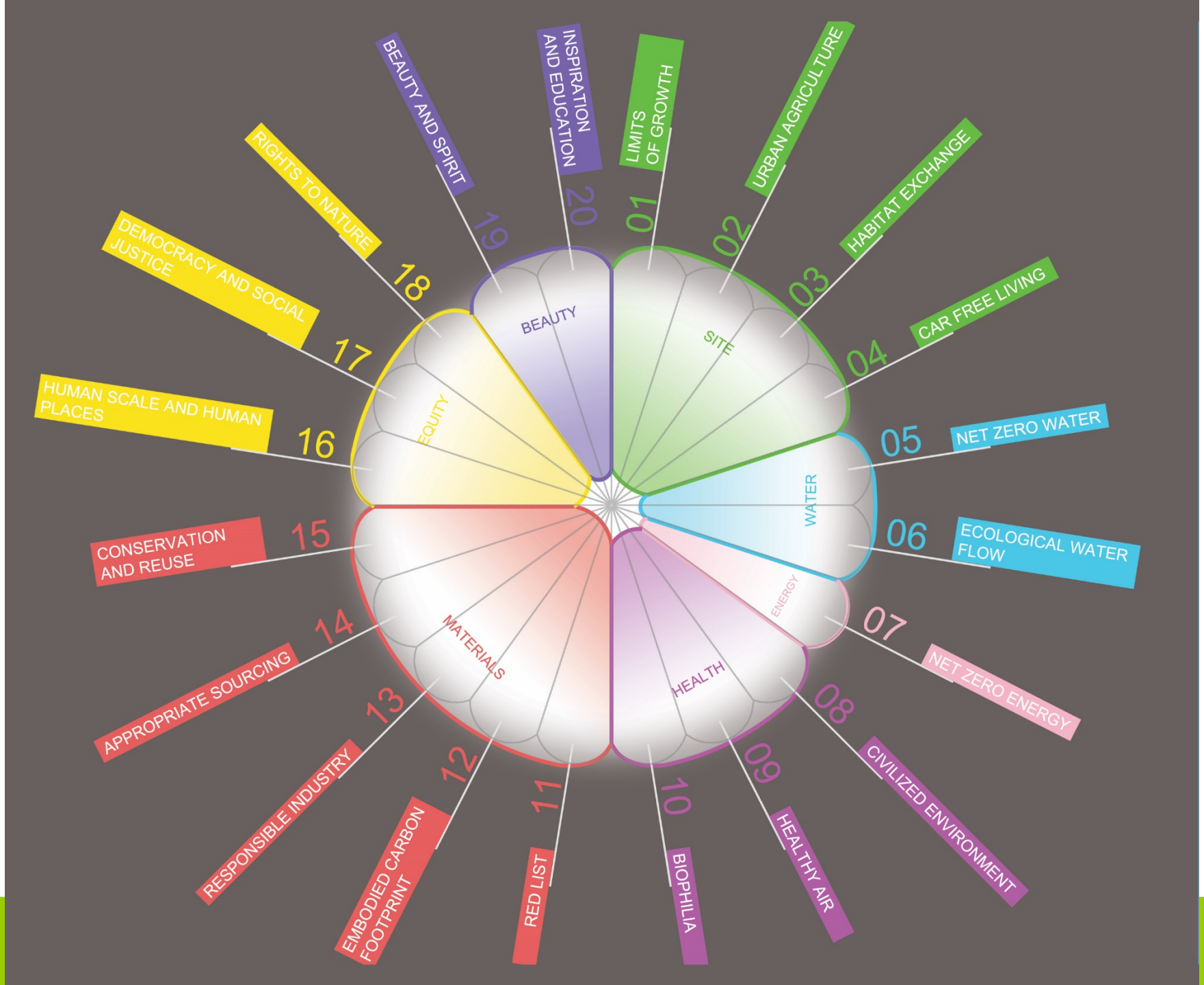
A Visionary Path to a Regenerative Future

INTERNATIONAL LIVING FUTURE INSTITUTE℠

SETTING THE IDEAL AS THE INDICATOR OF SUCCESS

THE LIVING BUILDING CHALLENGE IS A PHILOSOPHY, CERTIFICATION AND ADVOCACY TOOL FOR PROJECTS TO MOVE BEYOND MERELY BEING LESS BAD AND TO BECOME TRULY REGENERATIVE.




BEAUTY
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WATER
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MATERIALS
EQUITY
01 LIMITS OF GROWTH
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18 RIGHTS TO NATURE
19 BEAUTY AND SPIRIT
20 INSPIRATION AND EDUCATION

PROVEN PERFORMANCE RATHER THAN ANTICIPATED OUTCOMES

The Living Building Challenge is comprised of seven performance categories, or 'Petals': Place, Water, Energy, Health & Happiness, Materials, Equity and Beauty. Petals are subdivided into a total of twenty Imperatives, each of which focuses on a specific sphere of influence. This compilation of Imperatives can be applied to almost every conceivable building project, of any scale and any location—be it a new building or an existing structure.

THERE ARE TWO RULES TO BECOMING A LIVING BUILDING:

- All Imperatives are mandatory. Many of the Imperatives have temporary exceptions to acknowledge current market limitations. These are listed in the Petal Handbooks, which should be consulted for the most up-to-date rulings. Temporary exceptions will be modified or removed as the market changes. With this Standard, the Institute requires advocacy for essential improvements to the building industry.
- Living Building Challenge certification is based on actual, rather than modeled or anticipated, performance. Therefore, projects must be operational for at least twelve consecutive months prior to evaluation for the majority of our Imperative verifications. Some Imperatives can be verified after construction, through a preliminary audit.

The Hawaii Preparatory Academy Energy Lab, Kamuela, HI
Living Certification - Living Building Challenge 1.3
Photo: Matthew Millman Photography / Courtesy: Flansburgh Architects

Imperative omitted from Typology

Solutions beyond project footprint are permissible

The 20 Imperatives of the Living Building Challenge: Follow down the column associated with each Typology to see which Imperatives apply.

	LIVING BUILDING CHALLENGE			
	BUILDINGS	RENOVATIONS	LANDSCAPE + INFRASTRUCTURE	
PLACE				01. LIMITS TO GROWTH
	SCALE JUMPING		SCALE JUMPING	02. URBAN AGRICULTURE
			SCALE JUMPING	03. HABITAT EXCHANGE
				04. HUMAN POWERED LIVING
WATER			SCALE JUMPING	05. NET POSITIVE WATER
ENERGY			SCALE JUMPING	06. NET POSITIVE ENERGY
HEALTH & HAPPINESS				07. CIVILIZED ENVIRONMENT
				08. HEALTHY INTERIOR ENVIRONMENT
				09. BIOPHILIC ENVIRONMENT
MATERIALS				10. RED LIST
			SCALE JUMPING	11. EMBODIED CARBON FOOTPRINT
				12. RESPONSIBLE INDUSTRY
				13. LIVING ECONOMY SOURCING
				14. NET POSITIVE WASTE
EQUITY				15. HUMAN SCALE + HUMANE PLACES
				16. UNIVERSAL ACCESS TO NATURE & PLACE
			SCALE JUMPING	17. EQUITABLE INVESTMENT
				18. JUST ORGANIZATIONS
BEAUTY				19. BEAUTY + SPIRIT
				20. INSPIRATION + EDUCATION

LIVING BUILDING CHALLENGE™

LIVING CERTIFICATION

A project achieves Living Certification or Living Building Certification by attaining all Imperatives assigned to its Typology. All twenty Imperatives are required for Buildings, fifteen for Renovations and seventeen for Landscape and Infrastructure projects.

PETAL CERTIFICATION

While achieving Living Certification is the ultimate goal, meeting the Imperatives of multiple Petals is a significant achievement in and of itself. Petal Certification requires the achievement of at least three of the seven Petals, one of which must be either the Water, Energy or Materials Petal.

Imperative 01, Limits to Growth and Imperative 20, Inspiration and Education are required.

NET ZERO ENERGY BUILDING CERTIFICATION

NET ZERO ENERGY CERTIFICATION

The marketplace has characterized net zero energy in many different ways. The Institute has a simple definition:

One hundred percent of the building's energy needs on a net annual basis must be supplied by on-site renewable energy. No combustion is allowed.

The Net Zero Energy Building Certification program uses the structure of the Living Building Challenge 3.0 to document compliance, it requires four of the Imperatives to be achieved: 01, Limits to Growth, 06, Net Positive Energy (reduced to one hundred percent), 19, Beauty + Spirit, and 20, Inspiration + Education.

The requirement for Imperative 06, Net Positive Energy is reduced to one hundred percent, one hundred and five percent is required for Petal and Living Building Certification only.

As with Living Building and Petal Certification, NZEB certification is based on actual performance rather than modeled outcomes.

David and Lucile Packard Foundation, Los Altos, CA
Net Zero Energy Building Certification
Photo: Terry Lorrant

LIVING CERTIFICATION

A project achieves Living Certification or Living Building Certification by attaining all Imperatives assigned to its Typology.

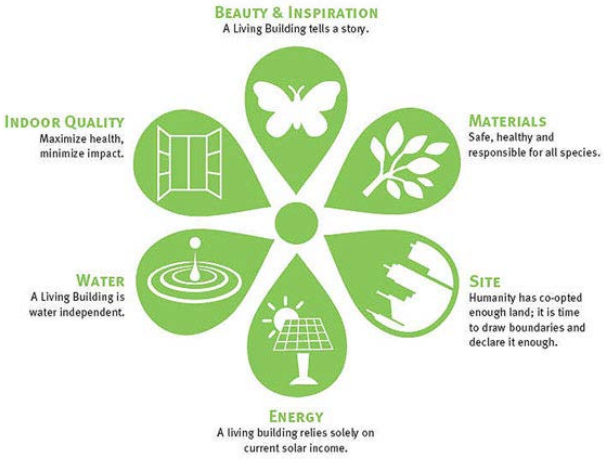
All twenty (20) Imperatives are required for Buildings, fifteen (15) for Renovations and
Seventeen (17) for Landscape and Infrastructure projects.

PETAL CERTIFICATION

While achieving Living Certification is the ultimate goal, meeting the Imperatives of multiple Petals is a significant achievement in and of itself.

Petal Certification requires the achievement of at least three of the seven Petals, one of which must be either the Water, Energy or Materials Petal.

Imperative 01, Limits to Growth and Imperative 20, Inspiration and Education are required.



PLACE

PLACE

RESTORING A HEALTHY INTERRELATIONSHIP WITH NATURE

PETAL INTENT

The intent of the Place Petal is to realign how people understand and relate to the natural environment that sustains us. The human built environment must reconnect with the deep story of place and the unique characteristics found in every community so that story can be honored, protected and enhanced. The Place Petal clearly articulates where it is acceptable for people to build, how to protect and restore a place once it has been developed, and how to encourage the creation of communities that are once again based on the pedestrian rather than the automobile. In turn, these communities need to be supported by a web of local and regional agriculture, since no truly sustainable community can rely on globally sourced food production.

The continued spread of sprawl development and the vastly increasing number of global megapolises threatens the few wild places that remain. The decentralized nature of our communities impedes our capacity to feed ourselves in a sustainable way and also increases transportation impacts and pollution. The overly dense urban centers in turn crowd out healthy natural systems, isolating culture from a sense of place. As prime land for construction diminishes, more development tends to occur in sensitive areas that are easily harmed or destroyed. Invasive species threaten ecosystems, which are already weakened by the constant pressure of existing human developments. Automobiles, often used as single occupancy vehicles, have become integral to our communities when we should depend on "people power" —walking and bicycling—as the primary mode of travel, and supplement it with shared transit.

IDEAL CONDITIONS + CURRENT LIMITATIONS

The Living Building Challenge envisions a moratorium on the seemingly never-ending growth outward, and a focus instead on compact, connected communities with healthy rather than inhumane levels of density—inherently conserving the natural resources that support human health and the farmlands that feed us, while also inviting natural systems back into the daily fabric of our lives. As previously disturbed areas are restored, the trend is reversed and nature's functions are invited back into a healthy interface with the built environment.

Human behavior and attitudes are the most significant barriers to transforming our surroundings. There is a frontier mentality that seems to encourage people to keep pursuing the next open territory and to value the untouched site more than the secondhand site. Humanity is territorial by nature, and we tend to view our impacts through a narrow lens. It is not unusual for us to encourage unhealthy solutions, so long as they are "not in my backyard" and allow us the social stature to "keep up with the Joneses." We must erase the taboo associated with certain forms of transit and abandoned industrial and commercial facilities, and we must once again give our regard to the many others that cohabit the earth with us.

SCALE JUMPING PERMITTED FOR URBAN AGRICULTURE (IMPERATIVE 02) AND HABITAT EXCHANGE (IMPERATIVE 03)

PLACE

LIMITS TO GROWTH

IMPERATIVE

01

Projects may only be built on greyfields or brownfields: previously developed[6] sites that are not classified as on or adjacent to any of the following sensitive ecological habitats[7]:

- Wetlands: maintain at least 15 meters, and up to 70 meters of separation
- Primary dunes: maintain at least 40 meters of separation
- Old-growth forest: maintain at least 60 meters of separation
- Virgin prairie: maintain at least 30 meters of separation
- Prime farmland
- Within the 100-year flood plain

Project teams must document site conditions prior to the start of work. On-site landscape must be designed so that as it matures and evolves it increasingly emulates the functionality of indigenous ecosystems with regard to density, biodiversity, plant succession, water use, and nutrient needs. It shall also provide wildlife and avian habitat appropriate to the project's transect through the use of native and naturalized plants and topsoil. No petrochemical fertilizers or pesticides can be used for the operation and maintenance of the on-site landscape.

6 Sites that qualify must have been altered from a greenfield prior to December 31, 2007.
7 Refer to the Place Petal Handbook for clarifications and exceptions. There are cases when building on a greenfield or a sensitive ecological habitat is allowed based on project type, Transect or other conditions.

PLACE

URBAN AGRICULTURE

IMPERATIVE

02

The project must integrate opportunities for agriculture appropriate to its scale and density using the Floor Area Ratio (FAR) as a basis for calculation. The table below outlines the mandatory agricultural requirements for all projects. Single-family homes must also demonstrate the capacity to store at least a two-week supply of food.[8]

PERCENT OF PROJECT AREA FOR FOOD PRODUCTION

Project F.A.R.	Minimum Percent Required
< 0.05	80%
0.05 - 0.09	50%
0.10 - 0.24	35%
0.25 - 0.49	30%
0.5 - 0.74	25%
0.75 - 0.99	20%
1.0 - 1.49	15%
1.5 - 1.99	10%
2.0 - 2.99	5%
> 3.0	1%

8 Refer to the Place Petal Handbook for clarifications such as acceptable urban agriculture practices, area calculation information as well as exceptions by Transect.

PLACE

HABITAT EXCHANGE

IMPERATIVE

03

For each hectare of development, an equal amount of land away from the project site must be set aside in perpetuity through the Institute's Living Future Habitat Exchange Program[9] or an approved Land Trust organization.[10] The minimum offset amount is 0.4 hectare.

HABITAT
LIVING FUTURE EXCHANGE

9 ILFI now operates a Habitat Exchange Program in cooperation with conservation organizations. For more information visit **www.living-future.org/exchange.**

10 Refer to the Place Petal Handbook for clarifications such as information about Land Trusts as well as exceptions.

PLACE

HUMAN POWERED LIVING

IMPERATIVE

04

Each new project should contribute toward the creation of walkable, pedestrian-oriented communities and must not lower the density of the existing site. Teams must evaluate the potential for a project to enhance the ability of a community to support a human powered lifestyle, and provide a mobility plan that addresses the interior and exterior of the project and demonstrates at a minimum the following:

ALL PROJECTS (EXCEPT SINGLE FAMILY HOMES):

- Secure, weather protected storage for human powered vehicles that provide facilities to encourage biking.[11]
- Consideration and enhancement of pedestrian routes, including weather protection on street frontages.
- Promotion of the use of stairs over elevators through interior layout and quality of stairways.
- Advocacy in the community to facilitate the uptake of human powered transportation.

PROJECTS IN TRANSECTS L4-L6 MUST ALSO PROVIDE:

- A transit subsidy for all occupants of the building (if owner occupied) or a requirement for tenant employers to provide such a subsidy.
- Showers and changing facilities that can be accessed by all occupants of the building.
- At least one electric vehicle charging station.

SINGLE FAMILY HOMES (ALL TRANSECTS):

An assessment of how the residents can reduce their transportation impact through car sharing, use of public transportation, alternative fueled vehicles, or bicycles is required.

11 Bike storage is recommended for 15% of occupants; teams should consider the occupancy type and location of the project.

WATER

WATER

CREATING DEVELOPMENTS THAT OPERATE WITHIN THE WATER BALANCE OF A GIVEN PLACE AND CLIMATE

PETAL INTENT

The intent of the Water Petal is to realign how people use water and to redefine 'waste' in the built environment, so that water is respected as a precious resource.

Scarcity of potable water is quickly becoming a serious issue as many countries around the world face severe shortages and compromised water quality. Even regions that have avoided the majority of these problems to date due to a historical presence of abundant fresh water are at risk: the impacts of climate change, highly unsustainable water use patterns, and the continued drawdown of major aquifers portend significant problems ahead.

IDEAL CONDITIONS AND CURRENT LIMITATIONS

The Living Building Challenge envisions a future whereby all developments are configured based on the carrying capacity of the site: harvesting sufficient water to meet the needs of a given population while respecting the natural hydrology of the land, the water needs of the ecosystem the site inhabits, and those of its neighbors. Indeed, water can be used and purified and then used again—and the cycle repeats.

Currently, such practices are often illegal due to health, land use and building code regulations (or because of the undemocratic ownership of water rights) that arose precisely because people were not properly safeguarding the quality of their water. Therefore, reaching the ideal for water use means challenging outdated attitudes and technology with decentralized site- or district-level solutions that are appropriately scaled, elegant and efficient.

SCALE JUMPING PERMITTED FOR NET POSITIVE WATER (IMPERATIVE 05)

WATER

NET POSITIVE WATER

IMPERATIVE

05

Project water use and release must work in harmony with the natural water flows of the site and its surroundings. One hundred percent of the project's water needs must be supplied by captured precipitation or other natural closed loop water systems,[12] and/or by re-cycling used project water, and must be purified as needed without the use of chemicals.

All stormwater and water discharge, including grey and black water, must be treated onsite and managed either through re-use, a closed loop system, or infiltration. Excess stormwater can be released onto adjacent sites under certain conditions.

12 Refer to the Water Petal Handbook for clarifications and exceptions, such as allowances for a municipal potable water use connection if required by local heath regulations.

ENERGY

Rooftop Solar Array at The Bullitt Center
Seattle, WA
Photo: Benjamin Benschneider

ENERGY

RELYING ONLY ON CURRENT SOLAR INCOME

PETAL INTENT

The intent of the Energy Petal is to signal a new age of design, wherein the built environment relies solely on renewable forms of energy and operates year round in a safe, pollution-free manner. In addition, it aims to prioritize reductions and optimization before technological solutions are applied to eliminate wasteful spending—of energy, resources, and dollars. The majority of energy generated today is from highly polluting and often politically destabilizing sources including coal, gas, oil and nuclear power. Large-scale hydro, while inherently cleaner, results in widespread damage to ecosystems. Burning wood, trash or pellets releases particulates and carbon dioxide (CO_2) into the atmosphere and often strains local supplies of sustainably harvested biomass while robbing the soil of much-needed nutrient recycling. The effects of these energy sources on regional and planetary health are becoming increasingly evident through climate change, the most worrisome major global trend attributed to human activity.

IDEAL CONDITIONS AND CURRENT LIMITATIONS

The Living Building Challenge envisions a safe, reliable and decentralized power grid, powered entirely by renewable energy, supplied to incredibly efficient buildings and infrastructure without the negative externalities associated with combustion or fission.

Although there has been considerable progress made to advance renewable energy technologies, there is still a need for a greater efficiency from these systems and for new, cleaner ways to store the energy they generate. These, together with the current cost of the systems available, are the major limitations to reaching our goals.

SCALE JUMPING PERMITTED FOR NET POSITIVE ENERGY (IMPERATIVE 06)

NETZERO ENERGY BUILDING CERTIFICATION

ENERGY

NET POSITIVE ENERGY

IMPERATIVE

06

One hundred and five percent of the project's energy needs must be supplied by on-site renewable energy on a net annual basis, without the use of on-site combustion.[13] Projects must provide on-site energy storage for resiliency.[14]

13 Refer to the Energy Petal Handbook for a list of renewable energy systems, clarifications and exceptions.

14 Projects must demonstrate that sufficient back-up battery power be installed for emergency lighting (at least 10 percent of lighting load) and refrigeration use for up to one week for greater resiliency.

Solar array at The Hawaii Preparatory Academy Energy Lab, Kamuela, HI
Living Certification - Living Building Challenge 1.3
Photo: Matthew Millman Photography / Courtesy: Flansburgh Architects

HEALTH & HAPPINESS

HEALTH & HAPPINESS

CREATING ENVIRONMENTS THAT OPTIMIZE PHYSICAL AND PSYCHOLOGICAL HEALTH AND WELL BEING

PETAL INTENT

The intent of the Health and Happiness Petal is to focus on the most important environmental conditions that must be present to create robust, healthy spaces, rather than to address all of the potential ways that an interior environment could be compromised.

Many developments provide substandard conditions for health and productivity and human potential is greatly diminished in these places. By focusing attention on the major pathways of health we create environments designed to optimize our well-being.

IDEAL CONDITIONS AND CURRENT LIMITATIONS

The Living Building Challenge envisions a nourishing, highly productive and healthy built environment. However, even best available solutions require acceptance and engagement by the project occupants and project owner. It is difficult to ensure that developments will remain healthy over time, since environmental conditions such as air quality, thermal control, and visual comfort can easily be compromised in numerous ways. It can also be complicated to ensure optimal conditions due to the unpredictable nature of how people operate and maintain their indoor spaces.

HEALTH & HAPPINESS

CIVILIZED ENVIRONMENT

07

Every regularly occupied space must have operable windows that provide access to fresh air and daylight.[15]

15 Refer to the Health Petal Handbook for clarifications, exceptions and information regarding minimum requirements for windows.

HEALTH & HAPPINESS

HEALTHY INTERIOR ENVIRONMENT

IMPERATIVE

08

To promote good indoor air quality, a project must create a Healthy Interior Environment Plan that explains how the project will achieve an exemplary indoor environment including the following:

- Compliance with the current version of ASHRAE 62, or international equivalent
- Smoking must be prohibited within the project boundary
- Results from an Indoor Air Quality test before and nine months after occupancy[16]
- Compliance with the CDPH Standard Method v1.1-2010 (or international equivalent) for all interior building products that have the potential to emit Volatile Organic Compounds[17]
- Dedicated exhaust systems for kitchens, bathrooms, and janitorial areas
- An entry approach that reduces particulates tracked in through shoes[18]
- An outline of a cleaning protocol that uses cleaning products that comply with the EPA Design for the Environment label (or international equivalent[19])

16 Testing protocols must be consistent with the United States Environmental Protection Agency Compendium of Methods for the Determination, or International equivalent. Refer to the Health Petal Handbook for the required Air Quality Conditions.
17 California Department of Public Health. Products not regulated by CDHP do not need to comply.
18 Refer to the Health Petal Handbook for the specifics of approved entry strategies.
19 www.epa.gov/dfe

NRDC Midwest Office, Chicago, IL
Petal Certification
Courtesy: Studio Gang Architects

HEALTH & HAPPINESS

BIOPHILIC ENVIRONMENT

The project must be designed to include elements that nurture the innate human/nature connection. Each project team must engage in a minimum of one all-day exploration of the biophilic design potential for the project. The exploration must result in a biophilic framework and plan for the project that outlines the following:[20]

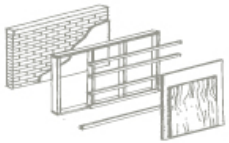
- How the project will be transformed by deliberately incorporating nature through Environmental Features, Light and Space, and Natural Shapes and Forms
- How the project will be transformed by deliberately incorporating nature's patterns through Natural Patterns and Processes and Evolved Human-Nature Relationships
- How the project will be uniquely connected to the place, climate and culture through Place-based Relationships
- The provision of sufficient and frequent human-nature interactions in both the interior and exterior of the project to connect the majority of occupants with nature directly

The plan must contain methods for tracking biophilia at each design phase. The plan should include historical, cultural, ecological, and climatic studies that thoroughly examine the site and context for the project.

20 Each of the Biophilic Design Elements outlined on Table 1-1, Page 15 of Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life by Stephen R. Kellert, Judith H. Heerwagen, and Martin L. Mador should be used as a reference.

Omega Institute, Rhinebeck, NY
Living Certification - Living Building Challenge 1.3
Photo: Farshid Assassi / Courtesy: BNIM Architects

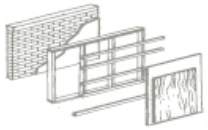
MATERIALS



UniverCity Childcare Centre
Burnaby, BC
Courtesy: space2place

MATERIALS

ENDORSING PRODUCTS THAT ARE SAFE FOR ALL SPECIES THROUGH TIME



SCALE JUMPING PERMITTED FOR EMBODIED CARBON FOOTPRINT (IMPERATIVE 11)

PETAL INTENT

The intent of the Materials Petal is to help create a materials economy that is non-toxic, ecologically regenerative, transparent and socially equitable. Throughout their life cycle, building materials are responsible for many adverse environmental issues, including personal illness, habitat and species loss, pollution, and resource depletion. The Imperatives in this section aim to remove the worst known offending materials and practices and drive business towards a truly responsible materials economy. When impacts can be reduced but not eliminated, there is an obligation not only to offset the damaging consequences associated with the construction process, but also to strive for corrections in the industry itself. At the present time it is impossible to gauge the true environmental impact and toxicity of the built environment due to a lack of product-level information, although the Living Building Challenge continues to shine a light on the need for transformative industrial practices.

IDEAL CONDITIONS + CURRENT LIMITATIONS

The Living Building Challenge envisions a future where all materials in the built environment are regenerative and have no negative impact on human and ecosystem health. The precautionary principle guides all materials decisions when impacts are unclear.

There are significant limitations to achieving the ideal for the materials realm. Product specification and purchase has far-reaching impacts, and although consumers are starting to weigh these in parallel with other more conventional attributes, such as aesthetics, function and cost, the biggest shortcoming is due to the market itself. While there are a huge number of "green" products for sale, there is also a shortage of good, publicly available data that backs up manufacturer claims and provides consumers with the ability to make conscious, informed choices. Transparency is vital; as a global community, the only way we can transform into a truly sustainable society is through open communication and honest information sharing, yet many manufacturers are wary of sharing trade secrets that afford them a competitive advantage, and make proprietary claims about specific product contents.

Declare, the Institute's ingredients label for building products, is a publicly accessible label and online database with an official connection to the Materials Petal. Not only does Declare contribute to the overt methodology for removing a temporary exception, it also provides a forum for sharing the information compiled by a project team as part of their documentation requirements for certification.

declareproducts.com

The Hawaii Preparatory Academy Energy Lab, Kamuela, HI
Living Certification - Living Building Challenge 1.3
Photo: Matthew Millman Photography / Courtesy: Flansburgh Architects

MATERIALS

RED LIST

10

There are temporary exceptions for numerous Red List items due to current limitations in the materials economy. Refer to the Materials Petal Handbook for complete and up-to-date listings.

The project cannot contain any of the following Red List materials or chemicals:[21]

- Alkylphenols
- Asbestos
- Bisphenol A (BPA)
- Cadmium
- Chlorinated Polyethylene and Chlorosulfonated Polyethlene
- Chlorobenzenes
- Chlorofluorocarbons (CFCs) and Hydrochlorofluorocarbons (HCFCs)
- Chloroprene (Neoprene)
- Chromium VI
- Chlorinated Polyvinyl Chloride (CPVC)
- Formaldehyde (added)
- Halogenated Flame Retardants (HFRs)
- Lead (added)
- Mercury
- Polychlorinated Biphenyls (PCBs)
- Perfluorinated Compounds (PFCs)
- Phthalates
- Polyvinyl Chloride (PVC)
- Polyvinylidene Chloride (PVDC)
- Short Chain Chlorinated Paraffins
- Wood treatments containing Creosote, Arsenic or Pentachlorophenol
- Volatile Organic Compounds (VOCs) in wet applied products[23]

21 A link to the list of CAS Registry Numbers that correspond with each Red List item is available in the Materials Petal Handbook.

22 Wet applied products (coatings, adhesives and sealants) must have VOC levels below the South Coast Air Quality Management District (SCAQMD) Rule 1168 for Adhesives and Sealants or the CARB 2007 Suggested Control Measure (SCM) for Architectural Coatings as applicable. Containers of sealants and adhesives with capacity of 16 ounces or less must comply with applicable category limits in the California Air Resources Board (CARB) Regulation for Reducing Emissions from Consumer Products.

MATERIALS

EMBODIED CARBON FOOTPRINT

IMPERATIVE

11

The project must account for the total embodied carbon (tCO_2e) impact from its construction through a one-time carbon offset in the Institute's new Living Future Carbon Exchange or an approved carbon offset provider.[23]

CARBON
LIVING FUTURE EXCHANGE

23 Refer to the Materials Petal Handbook for approved carbon offset programs, clarifications and exceptions.

Omega Institute, Rhinebeck, NY
Living Certification - Living Building Challenge 1.3
Photo: Farshid Assassi / Courtesy: BNIM Architects

MATERIALS

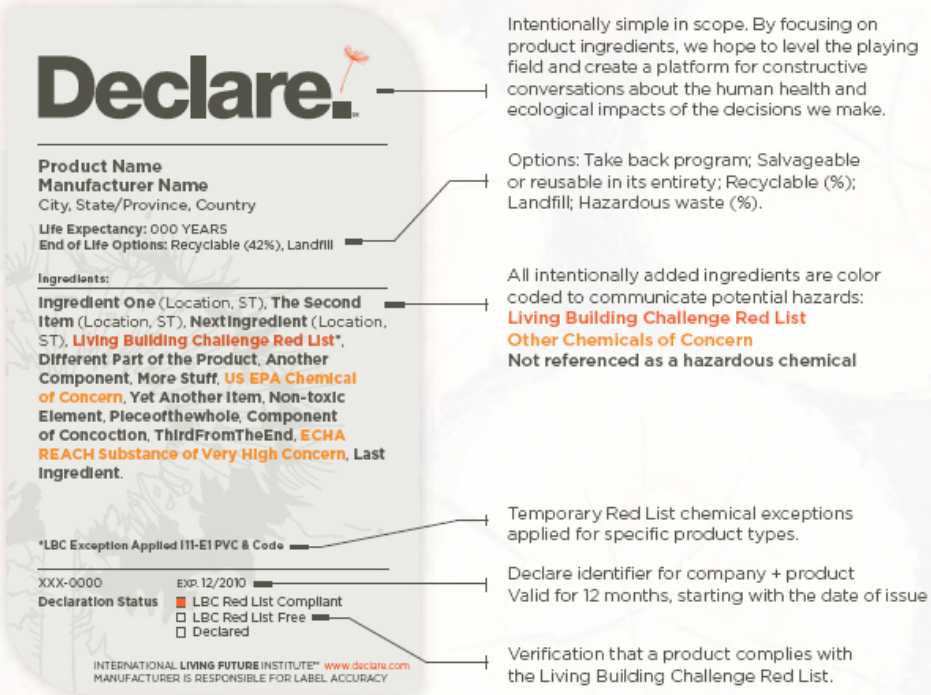
RESPONSIBLE INDUSTRY

The project must advocate for the creation and adoption of third-party certified standards for sustainable resource extraction and fair labor practices. Applicable raw materials include stone and rock, metal, minerals, and timber.

For timber, all wood must be certified to Forest Stewardship Council (FSC)[24] 100% labeling standards, from salvaged sources, or from the intentional harvest of timber onsite for the purpose of clearing the area for construction or restoring/maintaining the continued ecological function of the onsite bionetwork.

All projects must use, at a minimum, one Declare product for every 500 square meters of gross building area and must send Declare program information[25] to at least 10 manufacturers not currently using Declare.

IMAGE DEPICTS A "BLANK" LABEL PRIOR TO CUSTOMIZATION BY MANUFACTURER



24 Refer to the Materials Petal Handbook for a full list of exceptions such as an exception for wood in existing buildings undergoing renovation.
25 www.declareproducts.com

MATERIALS

LIVING ECONOMY SOURCING

IMPERATIVE

13

The project must incorporate place-based solutions and contribute to the expansion of a regional economy rooted in sustainable practices, products and services.

Manufacturer location for materials and services must adhere to the following restrictions:

- 20% or more of materials construction budget[26] must come from within 500 km of construction site.
- An additional 30% of materials construction budget must come from within 1000 km of the construction site or closer.
- An additional 25% of materials construction budget must come from within 5000 km of the construction site.
- 25% of materials may be sourced from any location.
- Consultants must come from within 2500 km of the project location.[27]

26 Materials construction budget is defined as all material costs and excludes labor, soft costs and land. Declare products and salvaged materials may be counted at twice their value. Certain natural building materials may include labor cost in their calculation. Refer to the Materials Petal Handbook for more information.

27 There is a temporary exception for specialty consultants and subcontractors, who may travel up to 5,000 km. Refer to the Materials Petal Handbook for additional exceptions.

Painters Hall
Courtesy: Pringle Creek Community

MATERIALS

NET POSITIVE WASTE

14

The project team must strive to reduce or eliminate the production of waste during design, construction, operation, and end of life in order to conserve natural resources and to find ways to integrate waste back into either an industrial loop or natural nutrient loop.[28]

All Projects must feature at least one salvaged material per 500 square meters of gross building area or be an adaptive reuse of an existing structure.

The project team must create a Material Conservation Management Plan that explains how the project optimizes materials in each of the following phases:

- Design Phase, including the consideration of appropriate durability in product specification
- Construction Phase, including product optimization and collection of wasted materials
- Operation Phase, including a collection plan for consumables and durables
- End of Life Phase, including a plan for adaptable reuse and deconstruction

During construction, the project team must divert wasted material to the following levels:

MATERIAL	MINIMUM DIVERTED/WEIGHT
Metal	99%
Paper & Cardboard	99%
Soil & Biomass	100%
Rigid foam, Carpet & Insulation	95%
All others - combined weighted average[29]	90%

For all project types, there must be dedicated infrastructure for the collection of recyclables and compostable food scraps.

A project that is located on a site with existing infrastructure must complete a pre-building audit that inventories available materials and assemblies for reuse or donation.

28 Refer to the Materials Petal Handbook for calculation details, clarifications and exceptions.
29 Hazardous materials in demolition waste, such as lead-based paint, asbestos, and polychlorinated biphenyls (PCBs), are exempt from percentage calculations.

EQUITY

The Bullitt Center, Seattle, WA
Photo: Benjamin Benschneider

EQUITY

SUPPORTING A JUST, EQUITABLE WORLD

PETAL INTENT

The intent of the Equity Petal is to transform developments to foster a true, inclusive sense of community that is just and equitable regardless of an individual's background, age, class, race, gender or sexual orientation. A society that embraces all sectors of humanity and allows the dignity of equal access and fair treatment is a civilization in the best position to make decisions that protect and restore the natural environment that sustains all of us.

There is a disturbing trend toward privatizing infrastructure and creating polarized attitudes of 'us' vs. 'them'—allowing only those of a certain economic or cultural background to participate fully in community life. Although opposite on the spectrum, enclaves for the wealthy are only one step removed from the racial and ethnic ghettos that continue to plague our neighborhoods. A subset of this trend is the notion that individuals can own access to nature itself, by privatizing admittance to waterways, beaches and other wilderness areas, cutting off most people from the few pristine environmental places that remain. Only by realizing that we are indeed all in this together can the greatest environmental and social problems be addressed.

We need to aggressively challenge the notion that property ownership somehow implies that we can do whatever we like, even externalize the negative environmental impacts of our actions onto others.

For example, consider these situations: when a polluting factory is placed next to a residential community, the environmental burdens of its operation are placed on the individuals who live in those houses. The factory is diminishing its neighbors' rights to clean air, water and soil. When a building towers over another structure, its shadow diminishes that structure's ability to generate clean and renewable energy, thereby impeding the rights to energy independence. We all deserve access to sunlight and clean air, water and soil.

We need to prioritize the concept of "citizen" above that of "consumer." Equity implies the creation of communities that provide universal access to people with disabilities, and allow people who can't afford expensive forms of transportation to fully participate in the major elements of society. Indeed, most projects in the built environment greatly outlive the original owner or developer—society inherits

continued >>

SCALE JUMPING PERMITTED

EQUITY

SUPPORTING A JUST, EQUITABLE WORLD

the legacies of bad decisions and good decisions alike. Since the act of building is a considerable environmental impact shared by all, there is an inherent responsibility to ensure that any project provides some public good and does not degrade quality of life. Finally, it is essential that we recognize the business practices and welfare of the people that we support as we design and build our developments.

JUST, the Institute's ingredients label for social justice, is a publicly accessible label and online database with an official connection to the Equity Petal. JUST provides a powerful forum for helping project teams support organizations that share the values of a responsible equitable living future.

Justorganizations.org

IDEAL CONDITIONS + CURRENT LIMITATIONS

The Living Building Challenge envisions communities that allow equitable access and treatment to all people regardless of physical abilities, age, or socioeconomic status.

Current limitations to reaching this ideal stem from ingrained cultural attitudes about the rights associated with private ownership and the varying rights of people.

It is necessary to change zoning standards in order to protect the rights of individuals who are 'downstream' of water, air and noise pollution, and who are adversely impacted due to lack of sunlight or exposure to toxins. Past attempts by zoning standards to protect people from particularly egregious pollutants resulted in sterile, single-use areas. A healthy, diverse community is one that encourages multiple functions, and is organized in a way that protects the health of people and the environment.

SCALE JUMPING PERMITTED

EQUITY

HUMAN SCALE AND HUMANE PLACES

IMPERATIVE

15

The project must be designed to create human-scaled rather than automobile-scaled places so that the experience brings out the best in humanity and promotes culture and interaction.
In context of the character of each Transect, there are specific maximum (and sometimes minimum) requirements for paved areas, street and block design, building scale and signage that contribute to livable places.

The project must follow the following design guidelines:

TRANSECT		L1	L2	L3	L4	L5	L6
Surface Cover	Maximum dimension of surface parking lot before a separation is required on all four sides e.g., building, wall, or 3 m wide (minimum) planted median or bioswale	20 m x 30 m					
	Total area of surface parking lot allowed. All other parking requirements must be handled in structured or underground parking.	20%	20%	20%	15%	5%	0%
TRANSECT		**L1**	**L2**	**L3**	**L4**	**L5**	**L6**
Streets + Intersections Only applicable if adding new streets	Maximum street width, measured either shoulder-to-shoulder or curb-to-curb	5 m		7.5 m	10 m	15 m	22.5 m
	Maximum street width before driving lanes must be separated by a pedestrian strip and planting median. Additional lanes may be included on the other side of median to a maximum of 22.5 m total width of driving area	Not applicable Development of this kind is not permitted in a Natural Habitat Preserve or Rural Agricultural Zone		15 m			
	Maximum street width before tree plantings and sidewalks are required on both sides			7.5 m			
	Minimum overall width of sidewalks and planted median			1/3 street width			
	Maximum distance between trees in furnishing zone and planted median			9 m			
	Maximum distance between circulation routes Access way must be 3 m wide minimum to qualify			45 m		60 m	
	Maximum street block size			60 m x 120 m		120 m x 120 m	
TRANSECT		**L1**	**L2**	**L3**	**L4**	**L5**	**L6**
Signage	Number of free-standing signs per development	1					
	Maximum dimensions of free-standing sign(s)	2 m x 2.5 m		2.5 m x 3 m		3.5 m x 6 m	
	Maximum elevation of sign's bottom edge above ground	2 m	3 m	6 m	9 m	12 m	12 m or roof-mounted
TRANSECT		**L1**	**L2**	**L3**	**L4**	**L5**	**L6**
	Maximum single family residence size	N/A	425 m²				
Proportion	Maximum distance between façade openings	N/A	30 m				
	Maximum footprint for any building with a single use, single owner or single tenant. Acceptable to provide additional floor area for tenant on upper/lower floor(s)	3750 m² excludes floor area of atriums, courtyards and daylight shafts					
Human Scale	Provision of places for people to gather and connect internally and/or with the neighborhood.	1	1	One every 1000 m² (10,760sf)			
	Provision of elements along the project edge which support the human scale of the larger neighborhood, such as seat walls, art, displays, or pocket parks. Single Family residences are excluded	1	1	One every 4000 m² (43,000sf)			

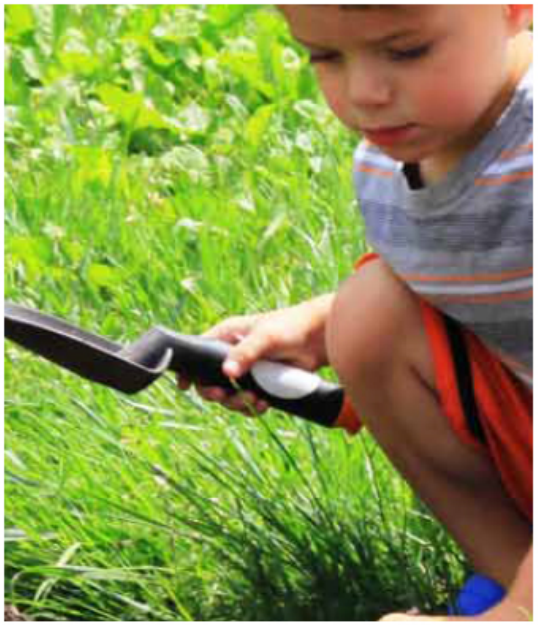
UniverCity Childcare Centre, Burnaby, BC
Photo: Martin Tessler

EQUITY

UNIVERSAL ACCESS TO NATURE & PLACE

IMPERATIVE

16



All primary transportation, roads and non-building infrastructure that are considered externally focused must be equally accessible[30] to all members of the public regardless of background, age and socioeconomic class—including the homeless—with reasonable steps taken to ensure that all people can benefit from the project's creation.

For any project (except single family residential) located in Transect L3-L6, the public realm must be provided for and enhanced through design measures and features such as street furniture, public art, gardens and benches that are accessible to all members of society.

Access for those with physical disabilities must be safeguarded through designs meeting the Americans with Disabilities Act (ADA) and Architectural Barriers Act (ABA) Accessibility Guidelines.[31]

continued >>

30 Refer to the Equity Petal Handbook for a complete list of applicable infrastructure and exceptions that address issues of safety.
31 Refer to the Equity Petal Handbook for specific exceptions, such as those for private residences and historic structures. Complete ADA and ABA Accessibility Guidelines are available online: www.access-board.gov/adaag/about

Science Education at Phipps Conservatory and Botanical Gardens, Pittsburgh, PA
Net Zero Energy Building Certification
Photo: Cory Doman

EQUITY

UNIVERSAL ACCESS TO NATURE & PLACE

IMPERATIVE

16

The project may not block access to, nor diminish the quality of, fresh air, sunlight and natural waterways for any member of society or adjacent developments. The project must also appropriately address any noise audible to the public.

- **Fresh Air:** The project must protect adjacent property from any noxious emissions that would compromise its ability to use natural ventilation. All operational emissions must be free of Red List items, persistent bioaccumulative toxicants, and known or suspect carcinogenic, mutagenic and reprotoxic chemicals.

- **Sunlight:** The project may not block sunlight to adjacent building façades and rooftops above a maximum height allotted for the Transect.[32]

  The project may not shade the roof of a development with which it shares a party wall, unless the adjoining development was built to a lesser density than acceptable for the Transect.[33]

- **Natural Waterways:** The project may not restrict access[34] to the edge of any natural waterway, except where such access can be proven to be a hazard to public safety or would severely compromise the function of the development.[35] No project may assume ownership of water contained in these bodies or compromise the quality or quantity that flows downstream. If the project's boundary is more than sixty meters long parallel to the edge of the waterway, it must incorporate and maintain an access path to the waterway from the most convenient public right-of-way.[36]

32 Detailed exceptions relating to transects are in the Equity Petal Handbook
33 This corresponds to a neighboring building that is at least two stories in L2-L3; four stories in L4; eight stories in L5; and sixteen stories in L6.
34 Public access throughway must allow approach to waterway from land for pedestrians and bicyclists, and from the water via boat. No infrastructure to support any water-based transport is required.
35 For example, a working dock or marina might need to restrict shoreline access for safety reasons. A private residence may not.
36 The easement containing the pathway must be at least three meters wide and allow entry to both pedestrians and bicyclists.

EQUITY

EQUITABLE INVESTMENT

IMPERATIVE 17

For every dollar of total project cost,[37] the development must set aside and donate half a cent or more to a charity[38] of its choosing or contribute to ILFI's Equitable Offset Program, which directly funds renewable infrastructure for charitable enterprises.[39/40]

EQUITY
LIVING FUTURE EXCHANGE

37 Project cost includes land, soft costs, hard costs and FFE.
38 The Charity must be located in the country of the project and be a registered charity or 501 c 3.
39 Projects may choose to split the offset as desired between multiple charities or ILFI's offset program.
40 Public agencies and charitable organizations are exempt from this requirement.

Global Change Institute at University of Queensland, Brisbane, Australia
Courtesy: HASSELL

EQUITY

JUST ORGANIZATIONS

IMPERATIVE **18**

The project must help create a more JUST, equitable society through the transparent disclosure of the business practices of the major organizations involved. At least one of the following project team members must have a JUST Label for their organization:

- Architect of Record
- MEP Engineer of Record
- Structural Engineer of Record
- Landscape Architect of Record
- Interior Architect of Record
- Owner/Developer

Project teams are also required to send JUST program information[41] to at least ten project consultants, sub-consultants or product suppliers as part of ongoing advocacy.

Just.

Organization Name:
Organization Type:
Headquarters:
Satellite Facilities:
Number of Employees:

Social Justice and Equity Indicators:

Diversity
- ☐☐☐ Non-Discrimination
- ☐☐☐ Gender Diversity
- ☐☐☐ Ethnic Diversity

Equity
- ☐☐☐ Full Time Employment
- ☐☐☐ Pay-Scale Equity
- ☐☐☐ Employee/Union Friendly
- ☐☐☐ Living Wage
- ☐☐☐ Gender Pay Equity
- ☐☐☐ Family Friendly

Safety
- ☐☐☐ Occupational Safety
- ☐☐☐ Hazardous Chemicals

Worker Benefit
- ☐☐☐ Worker Happiness
- ☐☐☐ Employee Health Care
- ☐☐☐ Continuing Education

Local Benefit
- ☐☐☐ Local Control
- ☐☐☐ Local Sourcing

Stewardship
- ☐☐☐ Responsible Investing
- ☐☐☐ Community Volunteering
- ☐☐☐ Positive Products
- ☐☐☐ Charitable Giving
- ☐☐☐ Animal Welfare
- ☐☐☐ Transparency

THE SOCIAL JUSTICE LABEL
SPC-001 EXP. 10/26/2014

INTERNATIONAL LIVING FUTURE INSTITUTE® justorganizations.com

An innovative social justice transparency platform through which organizations can shed light on their operations, including how they treat their employees and where they make financial and community investments.

22 Social and equity indicators.

Asking all companies and organizations to accept social responsibility and to be truly transformative and transparent by publicly declaring and showcasing their social justice and equity policies and practices through the indicator metrics.

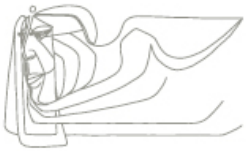
JUST label is valid for 12 months, starting with the date of issue.

JUST classification number.

41 www.justorganizations.com

The Bullitt Center, Seattle, WA
Photo: Benjamin Benschneider

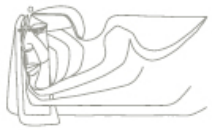
BEAUTY



VanDusen Botanical Garden
Visitor Center, Vancouver, BC
Photo: Nic Lehoux / Courtesy: Perkins+Will

BEAUTY

CELEBRATING DESIGN THAT UPLIFTS THE HUMAN SPIRIT



PETAL INTENT

The intent of the Beauty Petal is to recognize the need for beauty as a precursor to caring enough to preserve, conserve and serve the greater good. As a society, we are often surrounded by ugly and inhumane physical environments. If we do not care for our homes, streets, offices and neighborhoods, then why should we extend care outward to our farms, forests and fields? When we accept billboards, parking lots, freeways and strip malls as being aesthetically acceptable, in the same breath we accept clear-cuts, factory farms and strip mines.

IDEAL CONDITIONS AND CURRENT LIMITATIONS

The Living Building Challenge envisions designs that elevate our spirits and inspire us to be better than we currently are. Mandating beauty is, by definition, an impossible task. And yet, the level of discussion and, ultimately, the results are elevated through attempting difficult but critical tasks. In this Petal, the Imperatives are based on genuine efforts, thoughtfully applied. We do not begin to assume we can judge beauty and project our own aesthetic values on others. But we do want to understand people's objectives and know that an effort was made to enrich people's lives with each square meter of construction, on each project. This intentionality of good design and graceful execution must carry forth into a program for educating the public about the environmental qualities of their Living Building Challenge project.

There are no current limitations to this Petal other than our imaginations and what we as a society choose to value.

Green Roof at Phipps Conservatory and Botanical Gardens, Pittsburgh, PA
Net Zero Energy Building Certification
Photo: Paul G. Wiegman

BEAUTY

BEAUTY & SPIRIT

IMPERATIVE

The project must contain design features intended solely for human delight and the celebration of culture, spirit and place appropriate to its function and meaningfully integrate public art.

Omega Institute, Rhinebeck, NY
Living Certification - Living Building Challenge 1.3
Photo: Farshid Assassi / Courtesy: BNIM Architects

BEAUTY

INSPIRATION & EDUCATION

IMPERATIVE 20

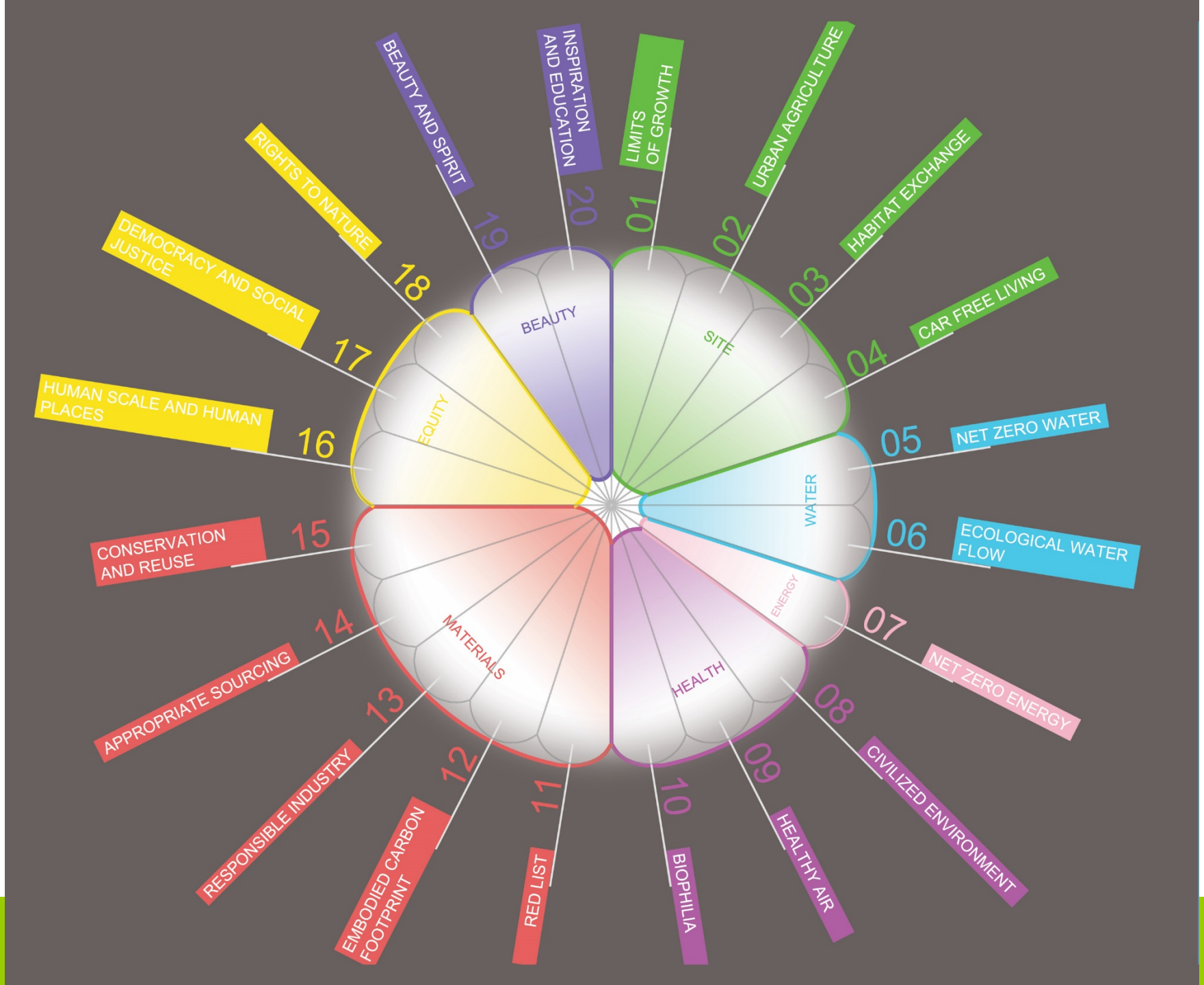
Educational materials about the operation and performance of the project must be provided to the public to share successful solutions and to motivate others to make change.

Projects must provide:[42]

- An annual open day for the public.
- An educational web site that shares information about the design, construction, and operation of the project.
- A simple brochure describing the design and environmental features of the project, as well as ways for occupants to optimize project function.
- A copy of the Operations and Maintenance Manual.
- Interpretive signage that teaches visitors and occupants about the project.
- A Living Building Case Study to be posted on the Institute website.

42 Refer to the Beauty and Inspiration Petal Handbook for additional information.

Living wall at Bertschi School, Seattle, WA
Living Certification - Living Building Challenge 2.0
Photo: Benjamin Benschneider


BEAUTY
SITE
WATER
ENERGY
HEALTH
MATERIALS
EQUITY
01 LIMITS OF GROWTH
02 URBAN AGRICULTURE
03 HABITAT EXCHANGE
04 CAR FREE LIVING
05 NET ZERO WATER
06 ECOLOGICAL WATER FLOW
07 NET ZERO ENERGY
08 CIVILIZED ENVIRONMENT
09 HEALTHY AIR
10 BIOPHILIA
11 RED LIST
12 EMBODIED CARBON FOOTPRINT
13 RESPONSIBLE INDUSTRY
14 APPROPRIATE SOURCING
15 CONSERVATION AND REUSE
16 HUMAN SCALE AND HUMAN PLACES
17 DEMOCRACY AND SOCIAL JUSTICE
18 RIGHTS TO NATURE
19 BEAUTY AND SPIRIT
20 INSPIRATION AND EDUCATION

http://www.bullittcenter.org/2015/04/01/bullitt-center-earns-living-building-certification/

Bullitt Center

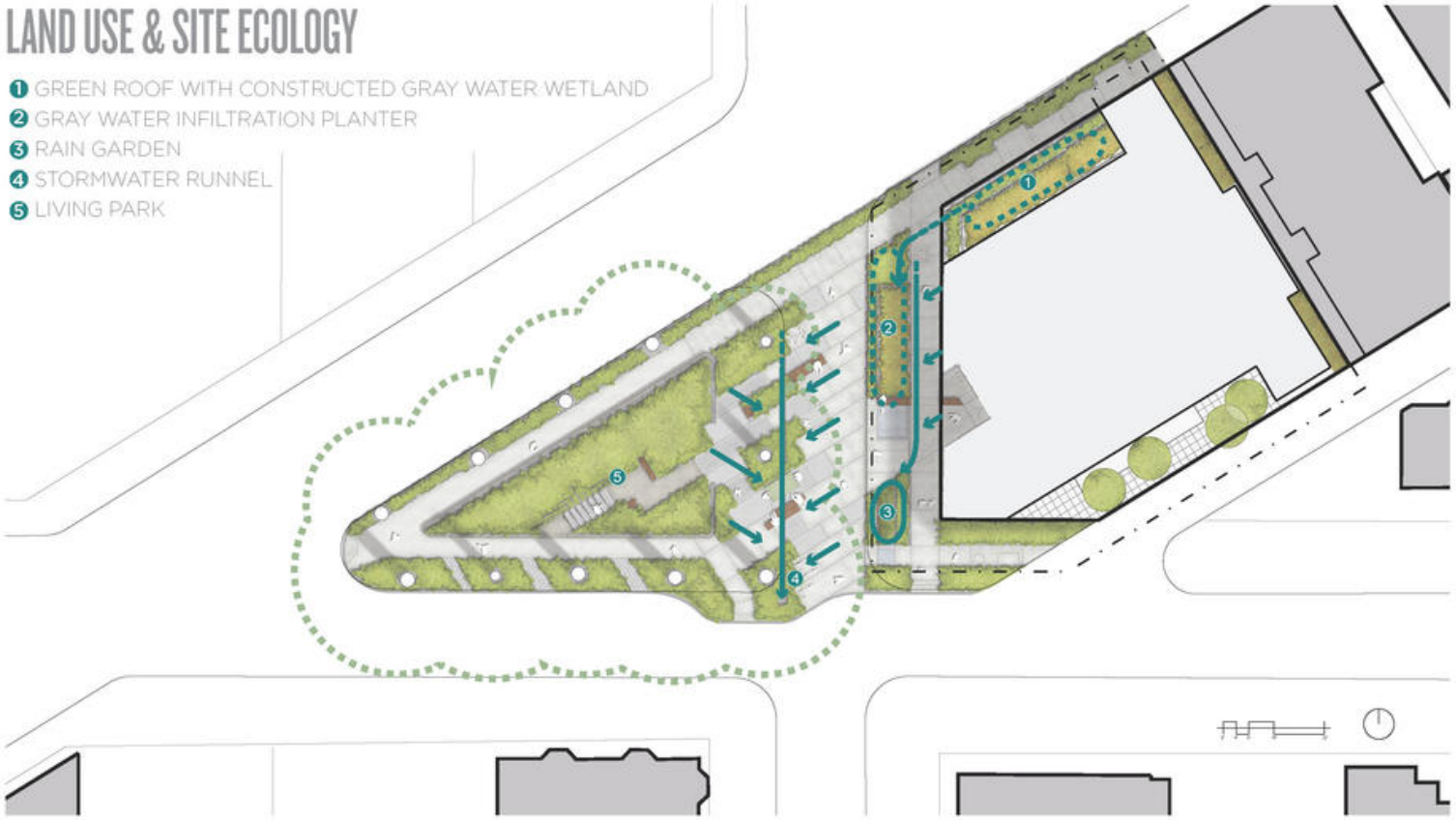
2013

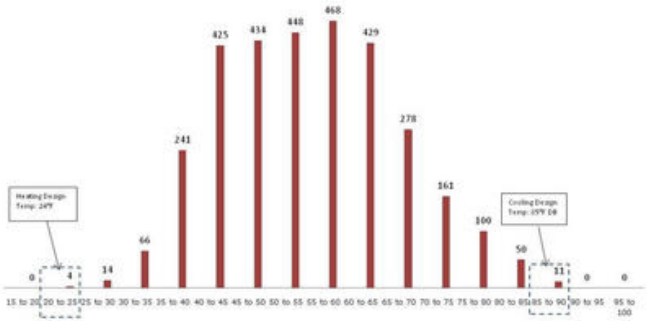
Seattle, Washington

The Miller Hull Partnership

LAND USE & SITE ECOLOGY

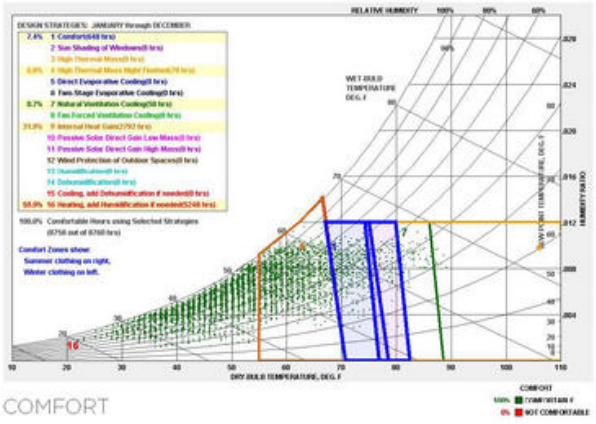
1. GREEN ROOF WITH CONSTRUCTED GRAY WATER WETLAND
2. GRAY WATER INFILTRATION PLANTER
3. RAIN GARDEN
4. STORMWATER RUNNEL
5. LIVING PARK



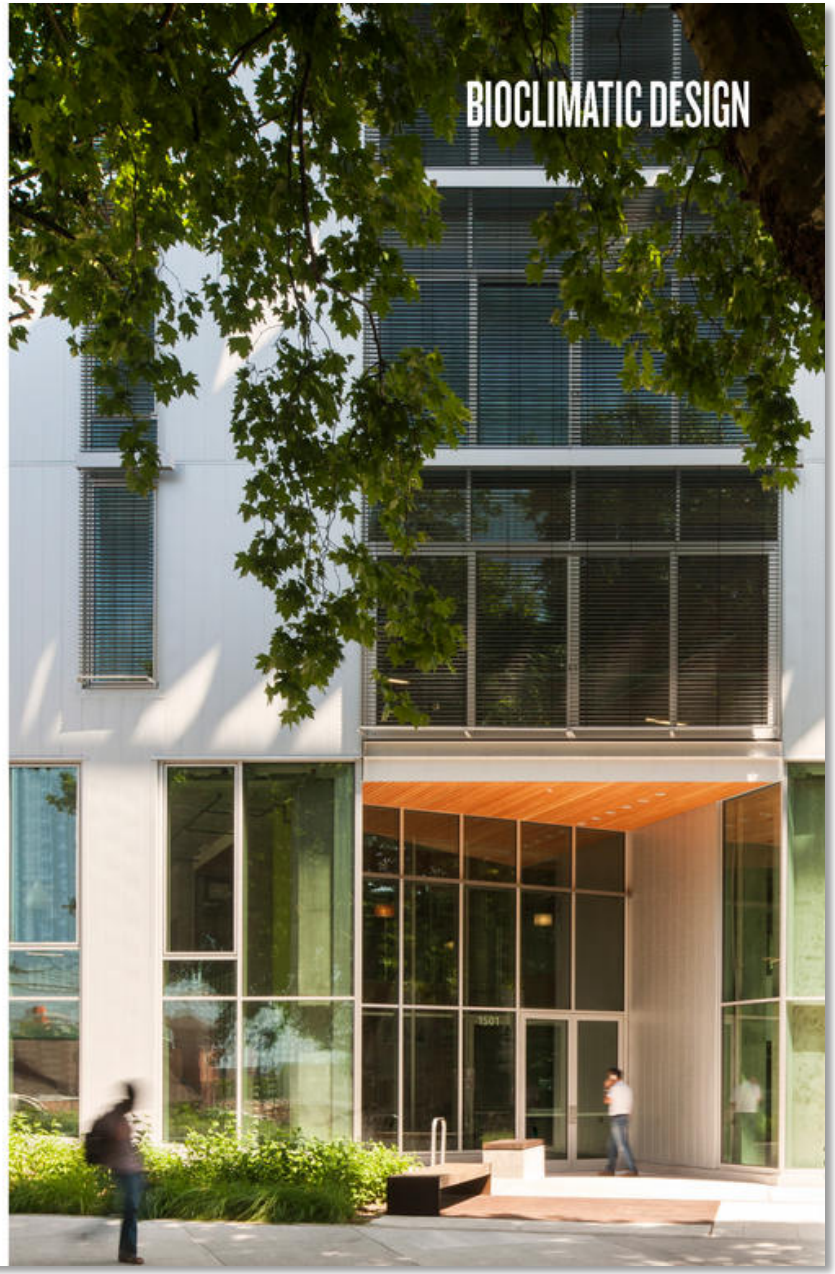


NUMBER OF HOURS AT 5-DEGREE TEMPERATURE RANGES
(full year: 6AM-6PM)

AVERAGE PRECIPITATION (rainwater collection)



COMFORT



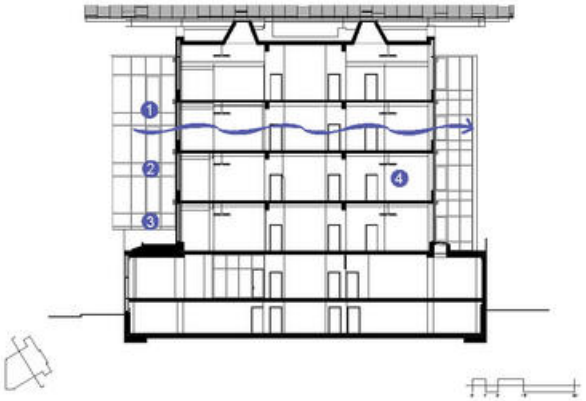
LIGHT & AIR

ENVELOPE

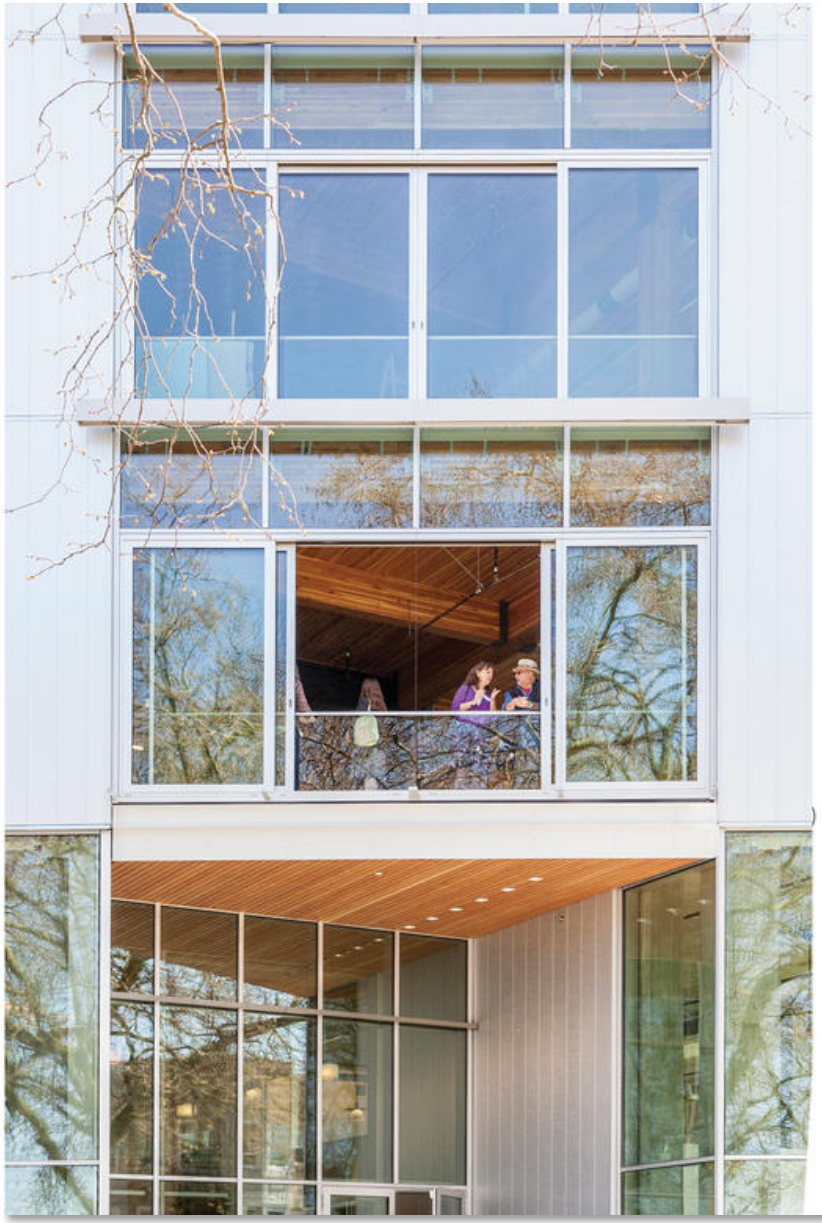
1. OPERABLE WINDOWS FOR VENTILATION & COOLING
2. TRIPLE-GLAZED HIGH PERFORMANCE WINDOWS
3. OPERABLE BLINDS MINIMIZE HEAT AND GLARE

COOLING

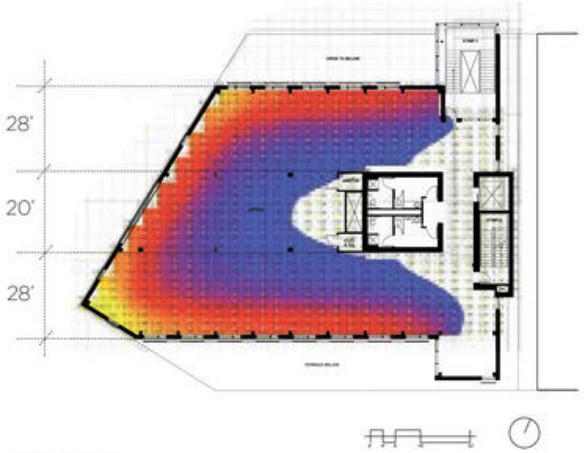
4. CEILING FANS FOR THERMAL COMFORT



West facade with exterior motorized shades on upper stories. Ground floor is shaded by the trees in the park.

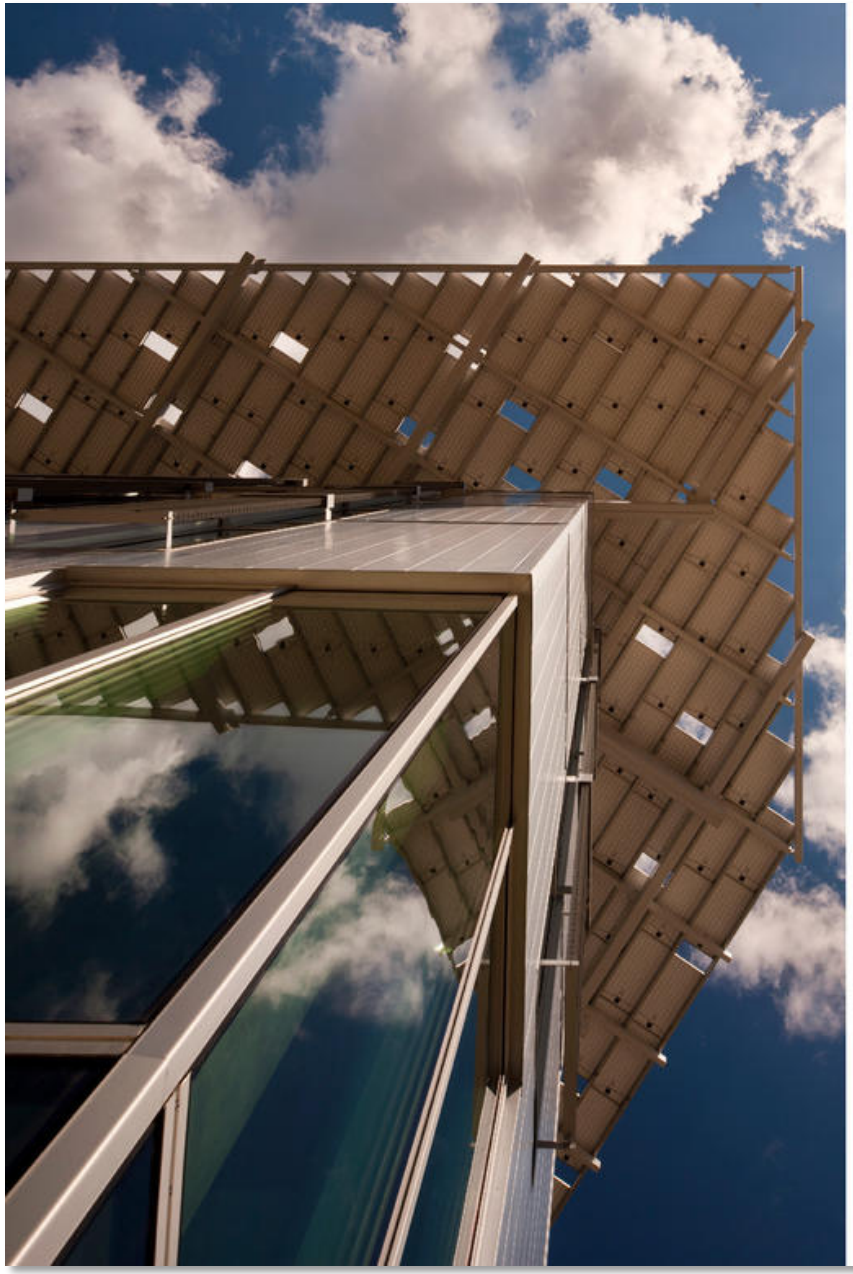


LIGHT & AIR

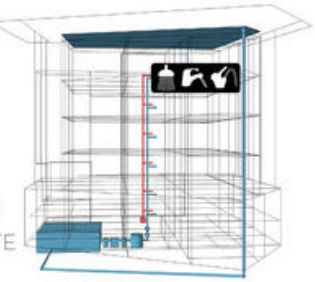


DAYLIGHT

TYPICAL FLOOR 75% DAYLIT

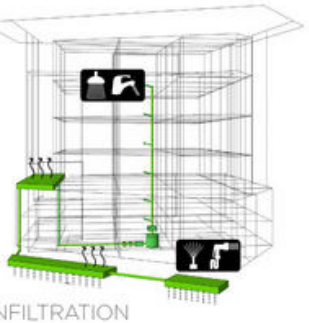


WATER CYCLE



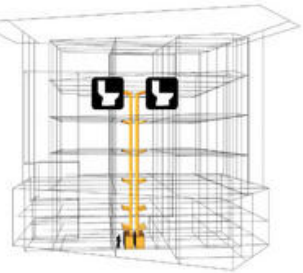
RAINWATER COLLECTION

100% DEMAND MET ON SITE
50.000 GALLON CISTERN



GREYWATER

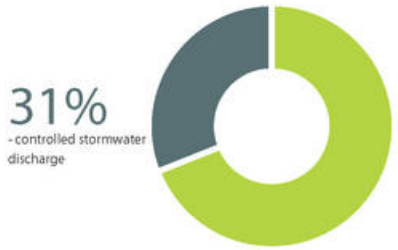
100% TREATMENT ON SITE
EVAPOTRANSPIRATION & INFILTRATION



WASTE COMPOST

100% TREATMENT ON SITE

WATER CYCLE



31%
- controlled stormwater discharge

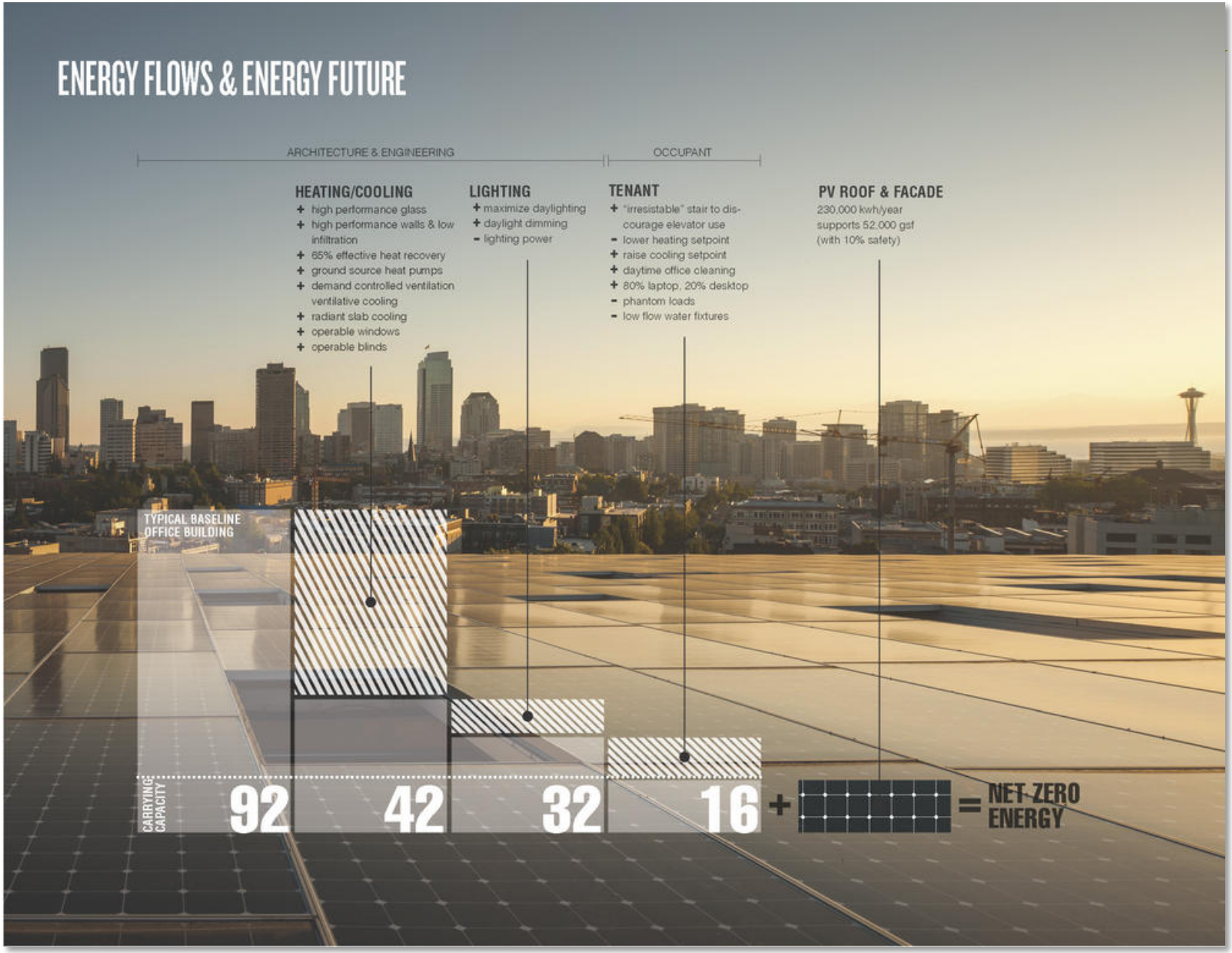
69%
- collected
- stored
- treated and used
- returned to soil and groundwater

BULLITT CENTER

39%
- stormwater runoff

61%
- evapotranspiration
- infiltration to native soils and groundwater

DOUGLAS FIR FOREST


ENERGY FLOWS & ENERGY FUTURE
ARCHITECTURE & ENGINEERING
OCCUPANT
HEATING/COOLING
+ high performance glass
+ high performance walls & low infiltration
+ 65% effective heat recovery
+ ground source heat pumps
+ demand controlled ventilation ventilative cooling
+ radiant slab cooling
+ operable windows
+ operable blinds
LIGHTING
+ maximize daylighting
+ daylight dimming
- lighting power
TENANT
+ "irresistable" stair to discourage elevator use
- lower heating setpoint
+ raise cooling setpoint
+ daytime office cleaning
+ 80% laptop, 20% desktop
- phantom loads
- low flow water fixtures
PV ROOF & FACADE
230,000 kwh/year
supports 52,000 gsf
(with 10% safety)
TYPICAL BASELINE OFFICE BUILDING
CARRYING CAPACITY
92
42
32
16
+
=
NET-ZERO ENERGY

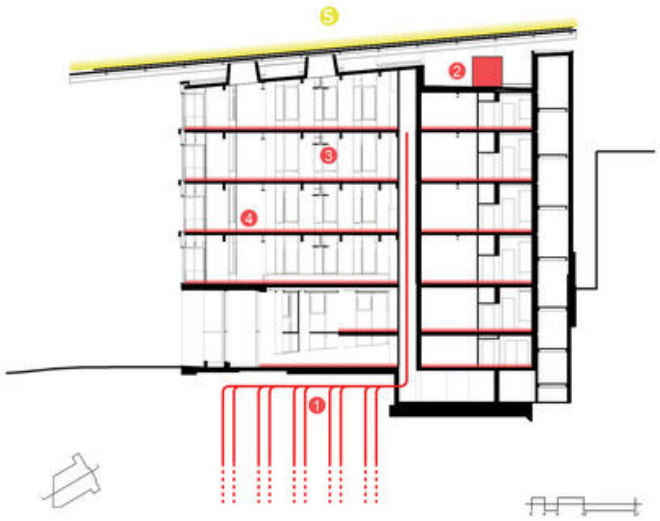
ENERGY FLOWS & ENERGY FUTURE

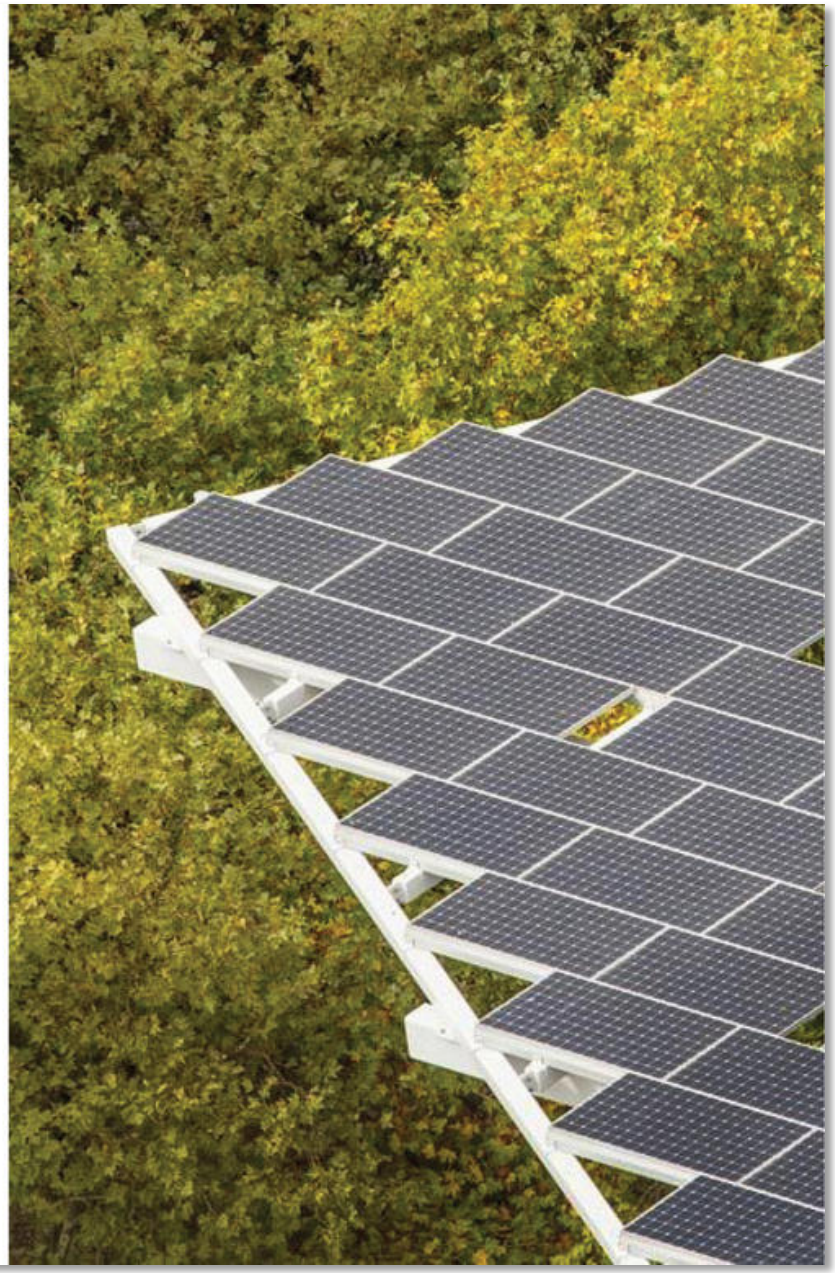
HEATING/COOLING/FRESH AIR

1. 26 (400-FOOT DEEP) CLOSED LOOP GEOTHERMAL WELLS
2. DEDICATED HEAT RECOVERY VENTILATION
3. CEILING FANS FOR THERMAL COMFORT
4. RADIANT IN-FLOOR HEATING & COOLING

ENERGY PRODUCTION

5. 244 KW PV ARRAY





MATERIALS & CONSTRUCTION

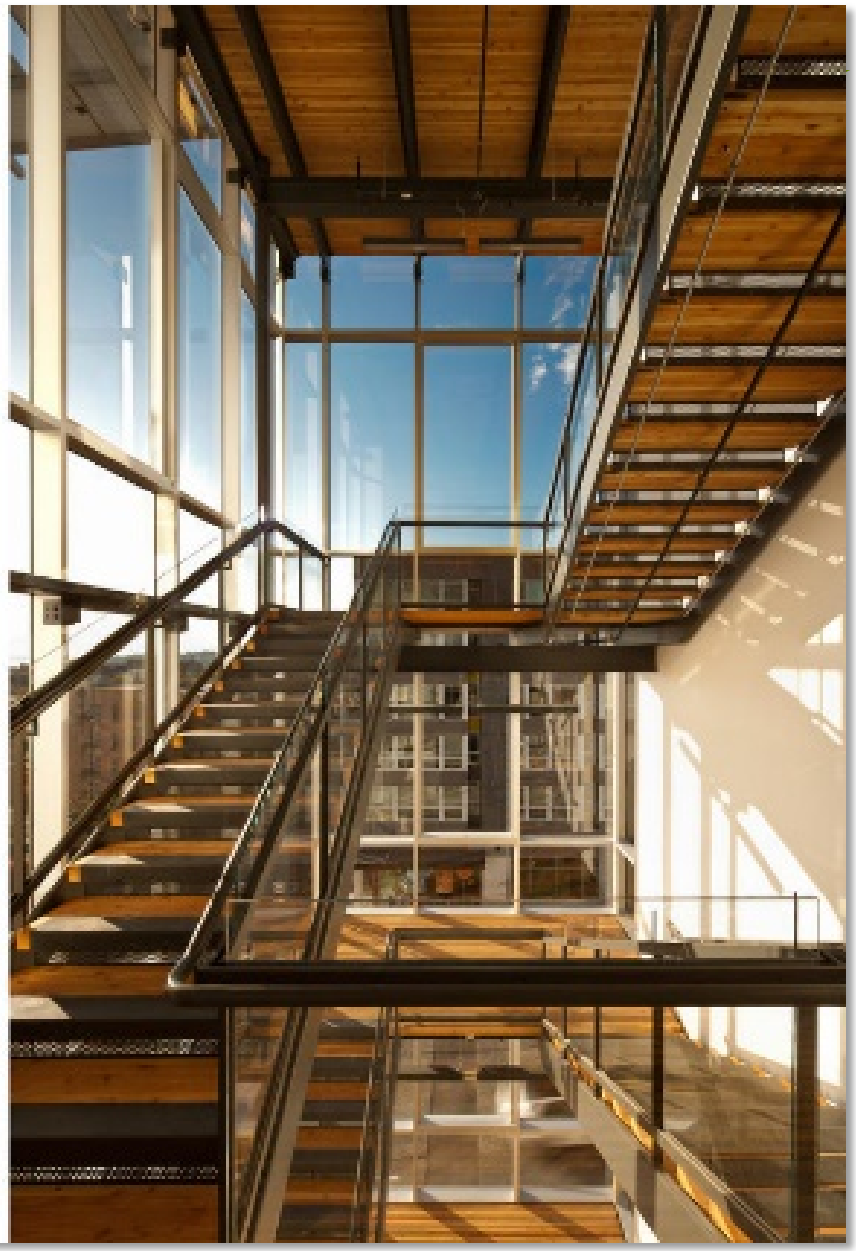
VOLUME OF WOOD USED:
24,526 CUBIC FEET

US & CANADIAN FORESTS GROW THIS MUCH WOOD IN:
2 MINUTES

CARBON STORED IN WOOD:
545 METRIC TONS OF CO_2

AVOIDED GREENHOUSE GAS EMISSIONS:
1,158 METRIC TONS OF CO_2

TOTAL POTENTIAL CARBON BENEFIT:
1,703 METRIC TONS OF CO_2




Bullitt Center

Bullitt Center

Plantings chosen should be:

- Natural to the area
- Perennial
- Able to survive with minimal watering
- Use NON potable (drinking) water

- *Readjust our thinking about what is beautiful?*

Bullitt Center

Bullitt Center


Bullitt Center

http://www.dialogdesign.ca/projects/york-region-forest-stewardship-education-centre/

Targeting
Living
Building
Challenge

Bill Fisch Forest Stewardship and Education Centre

2016
York Region, Ontario
DIALOG Design

Secure | https://living-future.org/lbc/case-studies/bill-fisch-forest-stewardship-education-centre/

INTERNATIONAL LIVING FUTURE INSTITUTE

LOGIN

PROGRAMS EDUCATION + EVENTS ABOUT US GET INVOLVED DONATE

BILL FISCH FOREST STEWARDSHIP AND EDUCATION CENTRE

Whitchurch-Stouffville, ON

OVERVIEW

- PLACE
- WATER

PETAL CERTIFIED

BILL FISCH FOREST STEWARDSHIP AND EDUCATION CENTRE

The Bill Fisch Forest Stewardship and Education Centre (BFFSEC) is designed to be an integral part of one of the most successful forest regeneration projects in the world with the purpose of helping residents of York-Region, and the extended community, learn about the importance of natural resources and forest ecosystems.

The DIALOG Project Team with the Regional Municipality of York, and corresponding Natural Heritage and Forestry team, worked

https://living-future.org/lbc/case-studies/bill-fisch-forest-stewardship-education-centre/

The first Living Building Challenge contender in Ontario, conservation strategies including:

- a high-performance envelope with R-40 walls and R-60 roof;
- a window-to-wall ratio of less than 30%;
- and triple-glazed windows oriented for optimal solar orientation
- 35kW photovoltaic array contributes to the net positive energy result. net zero water, with rain and well water meeting 100% of occupant needs.

http://www.sabmagazine.com/blog/2016/06/08/2016-ontario-regional-winner-and-technical-award-winner/

Bill Fisch Centre

Bill Fisch Centre

http://www.sabmagazine.com/blog/2016/06/08/2016-ontario-regional-winner-and-technical-award-winner/

Energy

Electrical System:

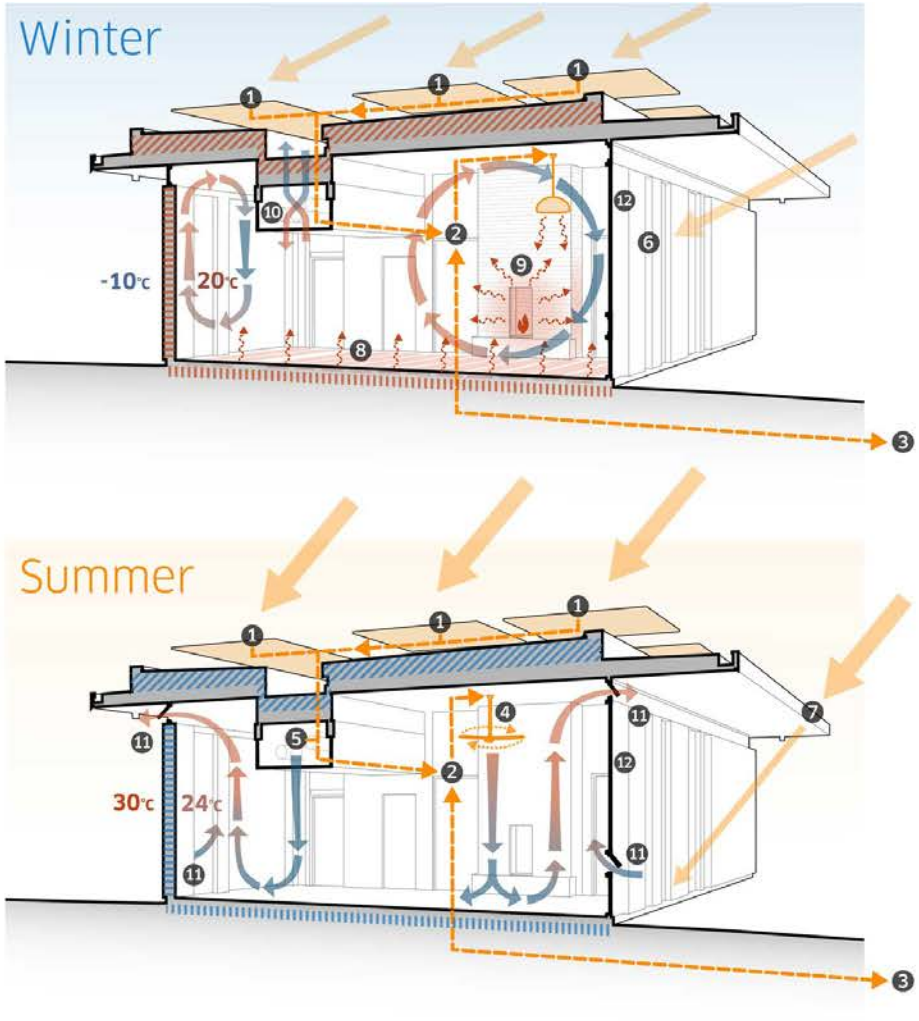
1. Photovoltaic solar panels w/ micro-inverters
2. Net meter
3. Grid connection
4. Displacement fan
5. Air conditioning

Thermal System:

6. Solar heat gain
7. Deep overhang shading
8. Radiant floor
9. Wood burning hearth
10. Heat recovery ventilator
11. Natural ventilation
12. Triple-glazed window assembly

Insulation:

- R60 roof assembly
- R40 wall assembly
- R30 insulated slab



Electricity Generation/Use:

[Predicted]

[Annual]

+8Mwh/yr **Net Positive**

[October-May]

+12Mwh

-22Mwh

[April - September]

-10Mwh

+28Mwh

http://www.sabmagazine.com/blog/2016/06/08/2016-ontario-regional-winner-and-technical-award-winner/

Water

Rainwater Harvesting:

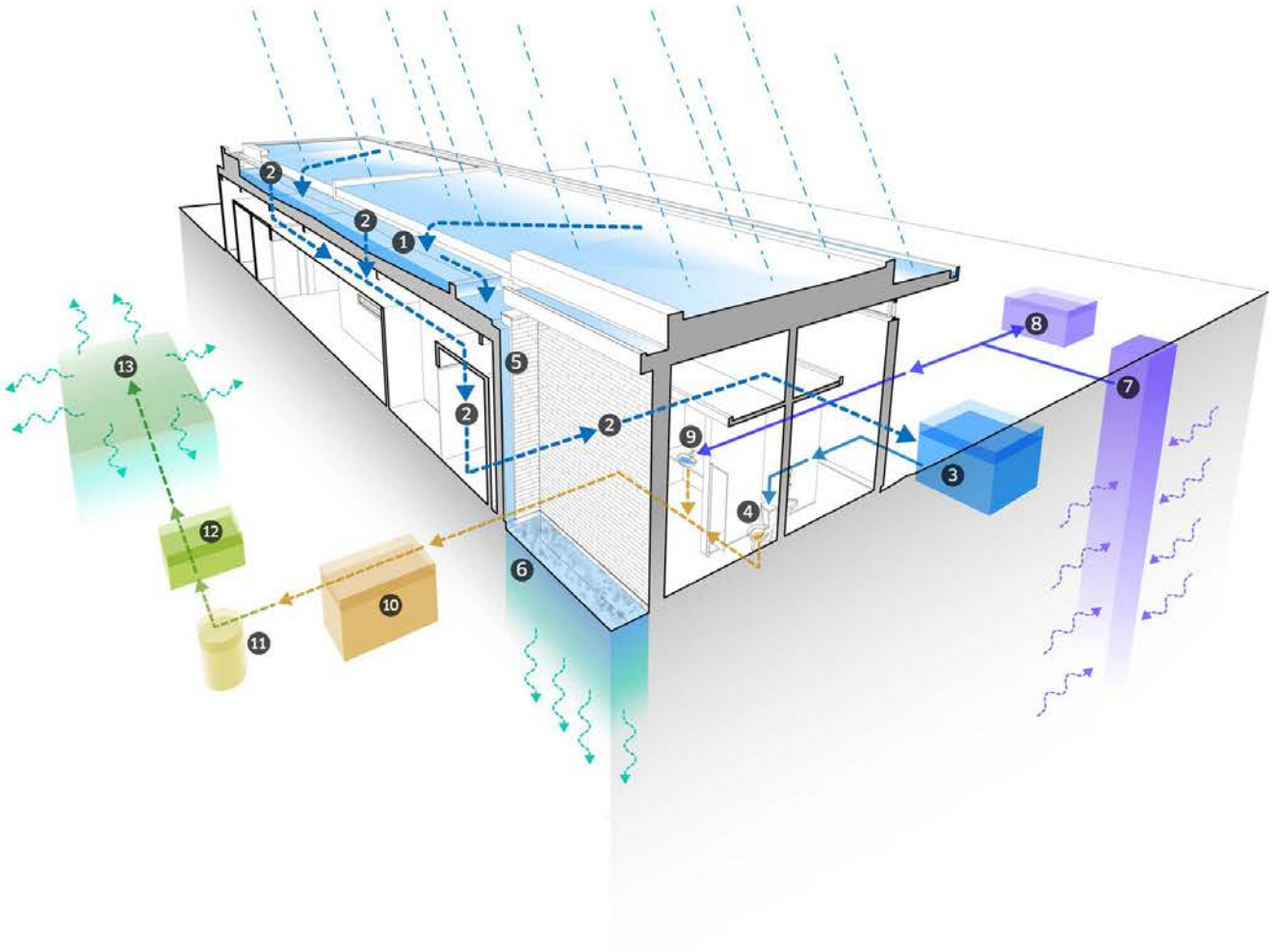
1. Central collection trough
2. Rainwater collection system
3. Rainwater cistern
4. Non-potable fixtures (toilets, urinals)
5. Vertical trough to ground
6. Ground infiltration

Wellwater:

7. Existing well
8. Fire orotection reservoir
9. Potable fixtures (sink, shower)

Wastewater Treatment:

10. Sewage collection tank
11. Septic pump chamber
12. Biofilter processing unit
13. Tertiary water infiltration bed



Non-potable water
Potable water

Rainwater
Well Water
Ground Infiltration
Blackwater
Secondary Treated
Tertiary Treated

http://www.sabmagazine.com/blog/2016/06/08/2016-ontario-regional-winner-and-technical-award-winner/

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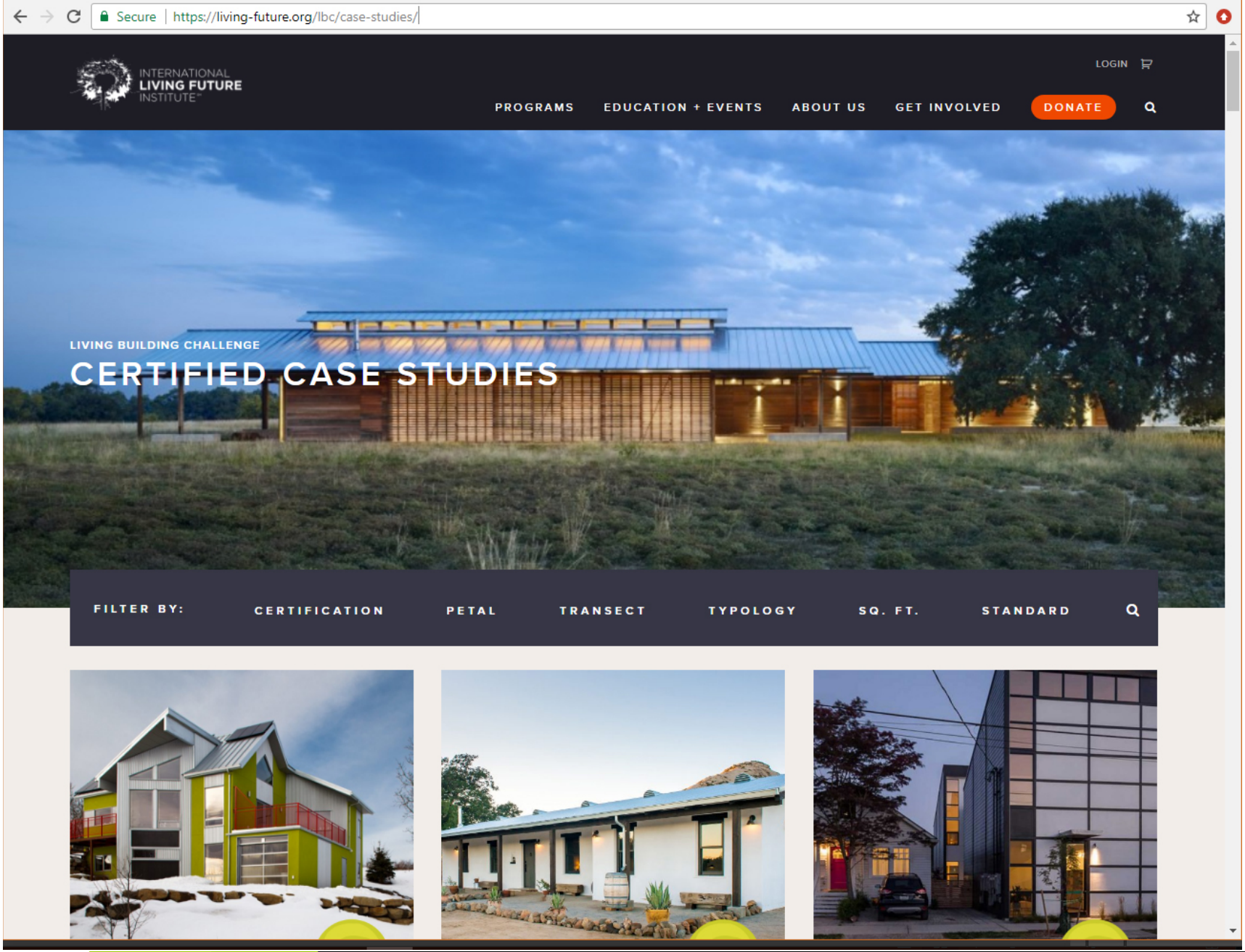
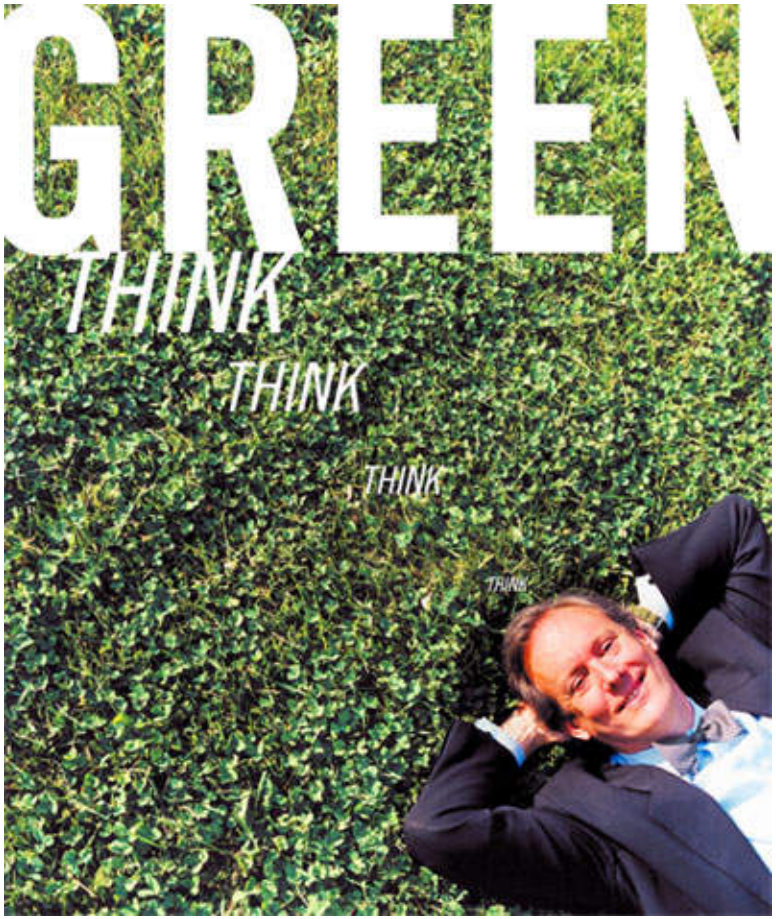


https://living-future.org/lbc/case-studies/

so …the new design assignment

- Build buildings, that like trees, produce more energy than they consume and purify their own waste water
- Factories that produce effluents that are drinking water
- Products that when their useful life is over do not become waste but can be tossed onto the ground to decompose and become food for plants and animals and nutrients for the soil; or that can return to industrial cycles to provide high quality raw materials for new products
- Billions of dollars of worth of materials that can be accrued for use each year
- Transportation that improves the quality of life while providing service
- A world of abundance, not one of limits, pollution and waste.

- William McDonough


GREEN
THINK
THINK
THINK
THINK