HIGH OCTANE: ECO-ADAPTIVE ARCHITECTURE

ELIZABETH MARTIN-MALIKIAN
Southern Polytechnic State University

INTRODUCTION

The construction of an architectural enclosure system is bound, in no small part, to situating oneself in context of our contemporary social and 'cultural' conditions, as well as attendant aesthetic discourse. We cannot help but be 'here' and 'now', observing its intricacies from the midst of our subjectivity; but also reflect on our contemporary condition in the context of a number of pertinent events: changing weather patterns + technological advancements.

One of the central research themes in ecology is evaluating the extent to which biological richness is necessary to sustain the Earth's system and functioning of individual ecosystems. My aim is to illustrate an alternative perspective exploring how building enclosure elements can be combined to create cost-and-energy effective, yet adaptable homeostatic enclosures.

HIGH OCTANE

During WWI it was discovered that adding a chemical called tetraethyl lead (TEL) to gasoline significantly improved a car's octane rating. The octane rating of gasoline tells you how much the fuel can be compressed before it spontaneously ignites. When gas ignites by compression rather than because of the spark from the spark plug, it causes knocking in the engine. Knocking can damage an engine, so it is not something you want to have happening. Lower-octane gas (like "regular" 87-octane gasoline) can handle the least amount of compression before igniting.

Image 1. Octane Rating.

The compression ratio of a car engine determines the octane rating of the gas you must use in the car. One way to increase the horsepower of an engine of a given displacement is to increase its compression ratio; therefore, a "high-performance engine" has a higher compression ratio and requires higher-octane fuel. The advantage of a high compression ratio is that it gives the car's engine a higher horsepower rating for a given engine weight¾that is what makes the engine "high performance." The disadvantage is that the gasoline for your car's engine costs more. (Federal Trade Commission)

According to Tadeusz W. Patzek, an environmental-engineering professor at the University of California-Berkeley a significant environmental trade-off is not from the miles-per-gallon driving, but the emissions on the production end—a gas is usually made premium by the addition of oxygenates, or hydrocarbons that contain one or more oxygen atoms. Making a gallon of premium gas thus consumes more energy than making a gallon of regular. Theoretically, Patzek notes, "if all oil companies reduced the octane rating of their finest premiums one point, such as from 93 to 92, it would increase the nation's gasoline production efficiency by approximately 2%—or, in laymen's terms, it would enable us to make an additional 182,000 barrels of usable gasoline out of our crude oil supply each day. Over a full year, the reduction would save us about 143.1 million barrels of oil annually—enough to satisfy our national oil demand for about seven days." (Slate Magazine)

In the current context, in which we as consumers are choosing between functional performance and sustainability, the product with superior sustainability, such as gas in this case, is perceived to be the morally superior alternative because the preference for sustainability is motivated by altruistic goals; whereas, the preference for functional attributes is motivated more by self-interest goals. When looking at high-performance engine trade-offs between functional and sustainable performance both have hedonic and utilitarian attributes nor are either eco-efficient.

ECO-EFFICIENT VS. ECO-EFFECTIVE

While the normal strategies of eco-efficiency seek to reduce and minimize the unintended negative consequences of the processes of production and consumption, the concept of eco-effectiveness presents a positive agenda based on maximizing the ability of industry to truly support the natural and human world around it. The successful interdependent nature of biological systems suggest that achieving a sustainable system of consumption and production is not simply a matter of reducing the footprint of our activities on this planet, but transforming this footprint into a source of replenishment for those systems that depend on it. (Vision Statement½www.braungart.com)

In *Cradle-to-Cradl*e McDonough and Braungart argue that the conflict between industry and the environment is not an indictment of commerce, but an outgrowth of purely opportunistic design. The design of products and manufacturing systems growing out of the Industrial Revolution reflected the spirit of the day-and yielded a host of unintended yet tragic consequences. (*Cradle-to-Cradl*e, p. 16)

Today, with our growing knowledge of the living earth, technological advances and design can reflect a new spirit. As the cradle-to-cradle concept clearly identifies three key design principles:

- The distinction between the natural and man-made world is an artificial one,
- We are surrounded by reusable "technical nutrients," including metals, plastics and other compounds,
- The whole idea of "waste" should be eliminated.

The above asserts that we live in a world of abundance and opportunity, not one of limits, pollution and waste. When we employ the intelligence of natural systems—the effective-ness of nutrient cycling, the abundance of the sun's energy—then we can create products, industrial systems, buildings, even regional plans that allow nature and commerce to fruitfully co-exist.

Eco-efficiency is generally understood as "creating more value with less environmental impact." Analysis the outcomes essentially relates two legs of the sustainability triangle: the economic and the environmental one. In other words, it specifies the relationship between economic value created and the environmental effects caused by doing so. (Huppes and Ishikawa 2005)

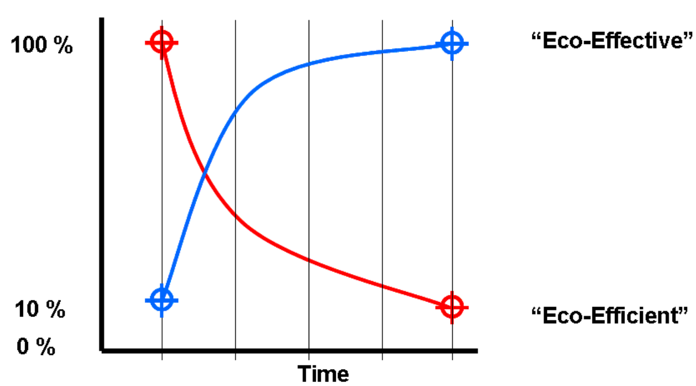

Image 2. Concept of eco-effectiveness.

While the normal strategies of eco-efficiency seek to reduce and minimize the unintended negative consequences of processes of production and consumption, the concept of eco-effectiveness presents a more positive agenda based on maximizing the ability of industry to truly support the natural and human world around it. The successful interdependent nature of biological systems suggests that achieving a sustainable system of consumption and production is not a matter of reducing the footprint of our activities on this planet, but transforming this footprint into a source of replenishment for those systems that depend on it. (www.braungart.com)

Products optimized for biological cycle are termed biological nutrients (e.g. plant-based and biodegradable materials) and are intended for safe return to the environment as nutrients for living things. Products optimized for the technical cycle are termed technical nutrients (e.g. metals and some polymers) and are intended to circulate in closed-loop industrial cycles.

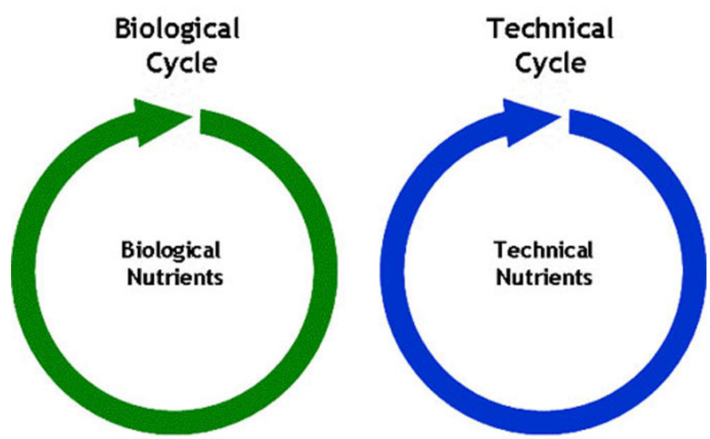

Image 3. Cradle-to-cradle design.

If we manage to make these kinds of cycles in the 'technosphere' standard like they are in the biosphere, we will have no waste (in the end, but maybe less for now) and we don't have to adjust our way and measure of consuming.

Approaching sustainability from a design perspective demonstrates the need for a fundamental conceptual shift away from current industrial system designs towards a more rigorous method of green engineering.

As you will see in the case-studies, when it comes to creating building enclosure systems that are not only eco-adaptive, but also work within the realm of both the biological and technical there is some success, but mostly at a "product" level; whereas solar responsive skins are have advanced within the technical cycle. Within this building enclosure system "material and emergy inputs (are) renewable rather than depleting.

PHOTOBIOREATORS

Photobioreactors contain colonies of algae that require CO2 and light at the front end, and generate hydrogen or biofuel at the other end. the electricity needed for the system to run is generated by thin-film solar transistors that are embedded in the transparent polycarbonate apertures.

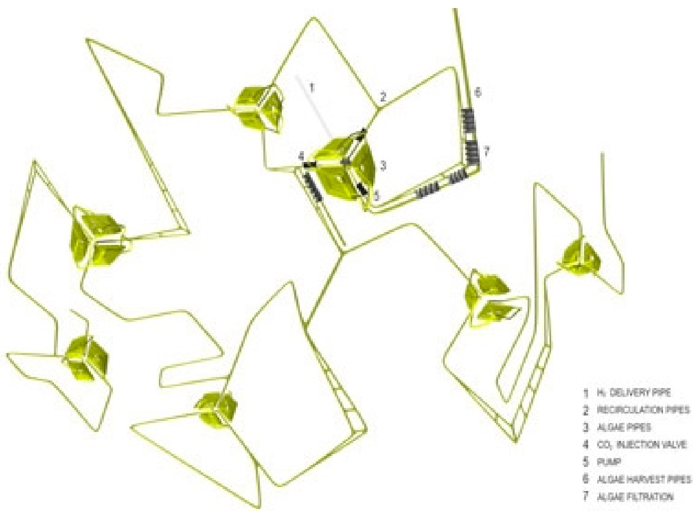

Image 4. Photobioractor.

Generally speaking, a photobioreactor is a bioreactor, which incorporates some type of the light source. Virtually any translucent container could be called a photobioreactor, however the term is more commonly used to define a closed system, as opposed to an open tank or pond. Because these systems are closed, all essential nutrients must be introduced into the system to allow algae to grow and be cultivated. A photobioreactor can be operated in "batch mode," but it is also possible to introduce a continuous stream of sterilized water containing nutrients, air, and carbon dioxide. Algae can also be grown in a photobioreactor. As the algae grows, excess culture overflows and is harvested.

A pivitol project conceived in 1981 by Mike Davies¾while working for Richard Rogers ¾formulated the idea of a polyvalent wall. It was the first example of a façade made up of one layer that was able to cater to different functional attributes within a glass element. The polyvalent wall provided sun and heat protection, and regulated the functions automatically according to current conditions. The wall itself (image 5) was to generate the necessary energy. As a matter of fact, the label *'Intelligent wall'* derives from Davies' concept of the polyvalent wall. His idea, not yet realized, still acts as a driving force for new facade technologies, and many researchers have been engaged in this topic over the last two decades. "What is needed is an environmental diode, a progressive thermal and spectral switching device, a dynamic interactive multi-capability processor acting as a building skin. The diode is logically based on the remarkable physical properties of glass, but will have to incorporate a greater range of thermal and visual adaptive performance capabilities in one polyvalent product. This environmental diode, a polyvalent wall as the envelope of a building, will remove the distinction between solid and transparent". Davies (1981)

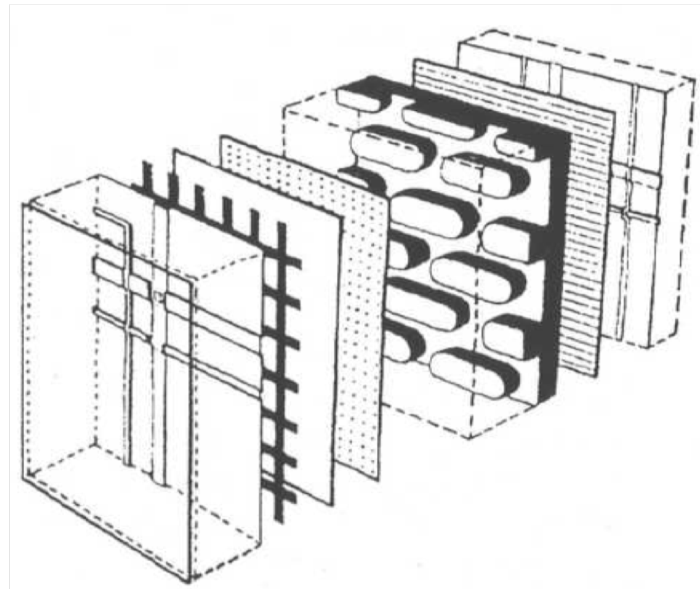

Image 5. Polyvalent wall by Mike Davis. The layers between the two glass panes are a thickness of a few microns.

Since 1981, modern glazing technology has come a long way. The complex multi-layered build-up of state of the art glazing products allow the integration of most requirements of modern building envelopes: thermal insulation, adjustable shading by means of electrochromic coatings and even energy generation through integrated photovoltaics. However, because most of the material resources would be lost at the end of its life, the multi-layered composite glazing build-ups contradict the principles of cradle-to-cradle. Is there a smarter solution for adaptive shading devices based on fewer components and material combinations?

Another design research project is being done at ARUP building on Mike Davis's work using bio-chemical processes. Photosynthesis generates biomass by absorbing day-light and CO2. Because cell division rates respond directly to the external conditions, trees and plants have long been used in landscaping as Smart Shading Devices. Higher plants go through a relatively slow yearly cycle, but micro-organisms such as algae respond to changing conditions within hours. But the question ARUP is exploring is: can micro-organisms be utilized to shade buildings?

Early in 2012, ARUP's research consortium installed their first operational prototypes of external louvers with integrated photo-bioreactors (PBR). The prototypes were about 2.60m high and 60cm wide and consist of four panes of monolithic glass. The panes form a central cavity of 18mm for the circulation of the medium and 16mm insulating cavities on either side. An entire façade with integrated PBR will be fitted in 2013 on the Smart Material House in Hamburg, designed by Splitterwerk Architects for the International Building Exhibition in Hamburg. This project will be the first to utilize bio-chemical processes in building components, generating biomass and heat, absorbing CO2 and providing adaptive shading.

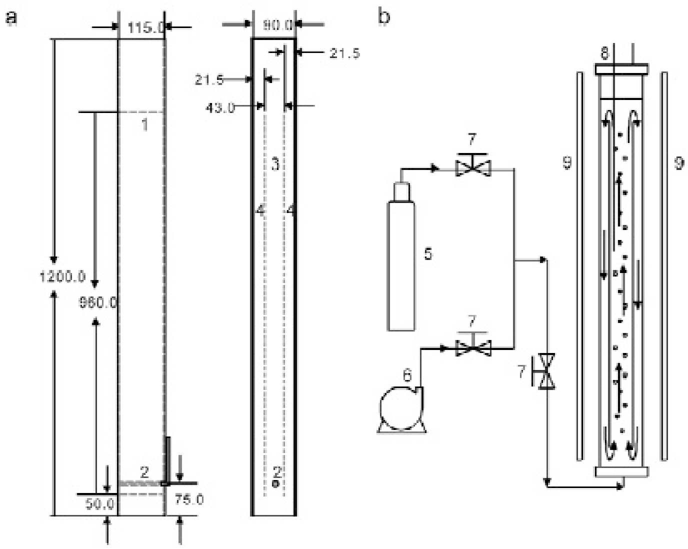

Image 6. Photobioractor façade (ARUP).

In a more whimsical solution, Los Angeles-based Tim Wiscomb of Emergent Architecture, designed a public space in Perth made up of photobioreators. There are seven elements, tied together by a pleated, color-variegated groundscape which tracks a network of biofuel lines leading across the street to the Perth train station. (image 4)

Wiscomb's innovative structures support large transparent polycarbonate apertures to allow sunlight, while also protecting internal moving parts. Inside are coils of transparent acrylic, which contain green or red algae colonies. The photosynthetic process of the algae requires carbon dioxide on the front end, and produces bio-diesel or hydrogen at the back-end.

As a result, these devices simultaneously remediate the environment by removing carbon dioxide from the local atmosphere and generate fuel in a closed-loop, off-the-grid system. One of the implications here is that energy production may, in the future, be micro-localized and embedded in daily behaviors, rather than available from distant sources.

HIGH-COMFORT½LOW-IMPACT

The fast-paced evolution of the fabrication and construction methods of eco-adaptive building enclosure systems are quickly becoming a major issue in today's architectural practices. In the past, many of the buildings that were considered to be energy efficient, use the building itself, not the façade, as part of their energy strategy.

In 1987, the innovative use of photosensitive mechanical devices put Jean Nouvel's Arab World Institute on the map. He created a dynamic façade with thousands of diaphragms which operated on the principle of a camera lens, changing the natural light coming into the building. It was one of the first high-designed building façades that incorporated active or smart technologies to aid the building installations in creating a comfortable indoor climate, apart from shading technologies through blinds or louvers and operable windows for ventilation.

Building on Nouvel's Arab World Institute, newer eco-adaptive skins differ radically from 'conventional' façades in a way that they are able to adjust their characteristics to and mediate between the changing environments. By doing so they are able to provide a comfortable indoor temperature, lighting level and air quality (parameters influencing energy consumption) without excess use of energy.

The recently completed Q1 headquarter building (2011) in Essen Germany is shaded by 3,150 kinetic "feathers" that open and close based on user input and sensor data. The system of folding shades produced by Kiefer technic, a manufacturer of stainless steel medical equipment for their showroom in Bad Gleichenberg, Austria was design was conceived by Giselbrecht + Partners in 2008. (http://www.wallpaper.com/architecture/video-kiefer-technic-office-graz/2329)

SUMMARY

Researchers and the construction industry are now providing material assemblies that are making enclosures of just 20-years ago obsolete. In the next decade if not before, wholesale building skin replacement systems will be adaptable to seasonal or daily climatic changes.

As pointed out by William McDonough in the Journal of Environmental Science & Tech-nology, a C2C point-of-view sets a course for "***What do I do*?**" whereas, the principles of green engineering answer, "***How do I do it?***" (p. 436). The projects cited above excelled in the technical cycle as defined by the cradle-to-cradle definition, but are not so successful in the biological cycle and clearly identifies with one of the three C2C tenets: usage of solar income.

By beginning to combine ideas of green engineering and C2C by creating an ecologically intelligent building enclosure system that interfaces directly with and controls heat gain within buildings, is a big step forward to achieving the long-term goal of controlled solar and minimal energy usage. I cannot help but think the technical advances in eco-adaptive skins has far outweighed the total C2C package and ecological goal of providing no waste; but creating buildings that are commercially productive, socially beneficial and create an ecologically intelligent industrial system.

ILLUSTRATION CREDITS

Image 1: Low Down of High Octane Rating http://www.ftc.gov/bcp/edu/pubs/consumer/autos/aut12.shtm
Image 2: concept of eco-effectiveness http://www.braungart.com/ecoeffect%
Image 3: cradle-to-cradle design http://www.braungart.com/c2c
Image 4: photobioractor, emergent architecture (www.solaripedia.com)
Image 5: Polyvalent wall by Mike Davis, Adaptive Facades. http://www.springerlink.com/content/u07067k584158557/
Image 6: Photobioractor Façade (Arup)

REFERENCES

Davies, Mike, *A Wall for all seasons + Uses for glass in building*, *Riba Journal-Royal Institute of British Architects,* 88 pp. 55-57, 1981.

El-Khoury, Rodolphe, and Payne, Andrew. *States of Architecture in the 21st Century*. Buenos Aires: Oscar Riera Ojeda Publishers, 2011.

Huppes, Gjalt, and Ishikawa, Masanobou. *"Why Eco-efficieny?" Journal of Industrial Ecology, volume 9, Issue 4, October 2005, pp. 2-5.*

Koerner, Brendan. *The Premium Premium: Is high-octane bad for the environment*? Slate Magazine, January, 2008.

Kolareviv, Branko, and Klinger, Kevin. *Manufacturing Material Effects: Rethinking Design and Making in Architecture*. New York: Routlege, 2008.

Leatherbarrow, David, and Mostafavi, Mohsen. *Surface Architecture.* Cambridge: The MIT Press, 2005.

McDonough, William and, Braungart, Michael. *Cradle-to-Cradle: Remaking the Way We Make Things*. New York: North Point Press, 2002.

McDonough, William, Braungart, Michael, Anastas, Paul and Zimmerman, Julie. *Cradle-toCradle Design and the Principles of Green Design: Towards a New Perspective and Practices for Engineering*. Journal of Environ-mental Science Technolgy. 2003, pp. 434-441.

Mostafavi, Mohsen, and Leatherbarrow, David. *On Weathering: The Life of Buildings in Time.* Cambridge: The MIT Press, 1993.

Moloney, Jules. *Designing Kinetics for Architectural Facades: State Change*. London: Routledge, 2011.

Murray, Scott. *Contemporary Curtain Wall Architecture.* New York: Princeton Architectural Press, 2009.

Rickey, G.W. *The Morphology of Movement: A Study of Kinetic Art.* Arts Journal, vol. 22, pp. 220-231, 1963.

Tschumi, Bernard. *The Manhattan Transcripts: Theoretical Projects*. London: St. Martin's Press / Academy Editions, 1995.

Wigginton, Michael, and Harris, Jude. *Intelligent Skins.* Burlington, MA: Architectural Press, 20007.