Technology Integration into Architecture Building Systems

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Abstract

Sustainable and green technologies in the building industry are in a state of explosive development. As these technologies move toward practical application and production, the need arises for critical examination of their infusion into the present system. As architects and engineers, we are in danger of creating a rash of future structures with "green warts" attached to them, all in the name of efficiency. How do we build a bridge of cooperation and collaboration between the various engineering fields to entrepreneur products that accomplish both engineering goals and aesthetic integration into building systems? As architects, the foundational strategy in building design is to first identify the vast array of requirements, then unite them to form multifunctional objects—namely buildings that heat, cool, protect, breathe, comfort, and satisfy within a capsule of safety for its human occupants. Ultimately, all new technology developments should exist to provide better living and working conditions for the people that use them. How do we humanize these building solutions so we do not feel like we are walking into a machine, but into a well-designed space appealing to all of our human senses? If the objective is to wear a wristwatch, the location, size, function, ease of operation, and aesthetics of that timepiece all can and should come into play. It follows that we should critically examine adding technology to our buildings in the same way. What may have been engineered initially as a single function element might now be combined with other aspects of the building to address multiple goals. One example of this might be a solar collector on a building, which would be engineered to serve multiple purposes such as a sunshade, light shelf, water collector, or wind diverter.

After reviewing historical precedent, this paper will first explore two energy saving green strategies of green roofs and solar collection as examples to reveal the importance of collaboration of architectural and engineering technologies. Secondly, we will explore how educators can instill a mindset of systems integration into the current generation of student and industry thinking. Sample student projects demonstrating these concepts will be presented.

Introduction: The Greening of America

Newsweek's 2006 cover story, "The Greening of America," highlighted the quiet revolution going on throughout the United States, as we struggle to move away from excessive dependence on imported energy and deal with the emerging and increasingly demonstrated issues of global warming [1]. *USA Today's* cover story on July 26, 2006 was about green

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buildings in Portland, Oregon. *Harvard Business Review* in June 2006 featured Charles Lockwood's new book, *Building the Green Way*. Prize winning *New York Times* columnist Thomas L. Friedman says, "Green technology is going to be the industry of the 21st century…green is the new red, white, and blue" (*Urban Land*, 2006). Other eco-friendly indicators are in the air. The public reception to Al Gore's *An Inconvenient Truth*, has been nearly all positive. The huge growth in hybrid vehicle sales, the continuing 15 to 20 percent annual growth in organic food sales, and many other indicators demonstrate a paradigm shift well underway [2].

With the stage set, the direction for the 21st century is clear for the architectural community. Historically, architecture has always sought to be an expression of the culture and beliefs of a society. What makes today's green movement so potent is the combination of public awareness of global environmental issues and energy issues coupled with the successful growth in the green economy. Green is also the color of money in America. Wall Street has seen a rise in investment offerings centered on energy savings and alternative energy production. In 2008, $21.2 billion of all new nonresidential construction will employ the use of green building principles [3]. Hundreds of new energy saving products are crowding the marketplace in an attempt to ride the green bandwagon, promising to save you money. As a result, most building industry products have merely remarketed themselves as "going green."

Architects and engineers are well positioned to have the strongest influence on the direction of energy conservation in the building industry but must never lose sight of the fact that buildings are designed for people and should be designed for their comfort, not just to meet energy requirements. Granted, it is difficult to deny the insulation value of the walls of a walk-in commercial freezer, but few people would want their office space located there. Architects know too well that people experience well-designed space not only physically but also emotionally and intellectually.

Analogous to our present culture where obesity is a burgeoning concern, we must recognize the fact that the majority of our buildings are obese from consuming massive amounts of energy (see Figure 1 and Figure 2).

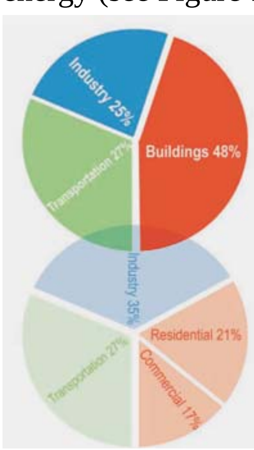

Figure 1: U.S. Energy Consumption by Sector [4]

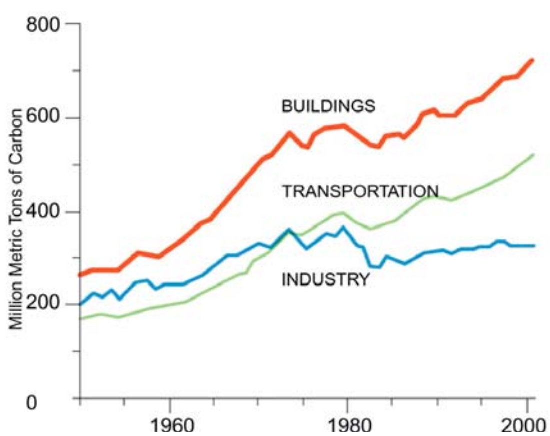

Figure 2: U.S. CO_2 Emissions by Sector Plant [4]

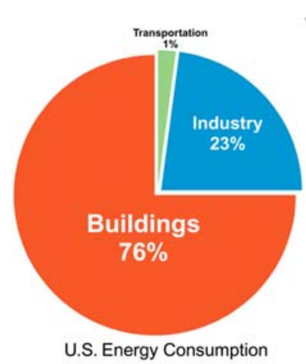

Figure 3: Power Generated Electricity [4]

Buildings account for half of all greenhouse gas emissions and are on a trajectory of continual increase. Seventy-six percent of all power plant generated electricity is used to operate buildings (see Figure 3). In the past, engineers would take pride in providing HVAC designs that could maintain human comfort within a building skin of glass on a west wall in Houston, Texas, at 3 p.m. in the summer. There is little intrinsic value in a high efficiency air handling system to a building only to mask its basic design flaw of excessive western façade glazing. We can no longer afford to operate with this mindset. Our buildings must do the equivalent of getting on the energy efficient treadmill. To use an automobile analogy, we must create Lexus style and performance buildings with Prius efficient engines. Architects know firsthand that most buildings can be designed to operate with far less energy consumption than the average U.S. building does, at little or no additional upfront cost. This is accomplished through proper site planning, building geometry, glazing properties and location, material selection, and by incorporating natural heating, cooling, ventilation, and daylighting strategies [4]. Many building performance improvements can occur with little, if any, visual impact; some examples include water saving fixtures, efficient air handling systems, high performance glazing, energy efficient lighting, and better overall insulation. Paul Hawken in his book, *The Ecology of Commerce*, states that double-glazing and ceiling insulation could be looked at as the most benign new energy sources. Effective installation of these materials in all our buildings would save more oil than what could be extracted from the Arctic National Wildlife Refuge at its most optimistic projections. Even more amazing is the fact this could be accomplished at approximately one-twentieth of the cost [5].

Buildings for the last 30 years have concentrated on the expression of form. Unnoticed by most of the public were many examples of structures driven by energy efficiency. If we go back 100 years, most architecture was climate sensitive and energy efficient by virtue of the fact that widespread inexpensive energy sources were limited. I think the world markets have clearly indicated that the days of $40 a barrel of oil are over, and now we must devise ways to deal with the reality of $140 (or higher) petroleum.

HOK, a leading architecture firm in sustainable design (www.HOK.com), has persuasively made the case that the old decision model and the balance between cost, time, and quality is no longer valid (see Figure 4). The new decision model is now five points, with the addition of Human Health and Earth Health (Ecology), as shown in Figure 5 [6].

Figure 4: Old Decision Model

Figure 5: New Decision Model

Many green companies market directly to building owners and facility managers through organizations like the Building Owners and Managers Association (BOMA), so clients are already approaching architects and engineers with their own preconceived notion of green, which, in many ways, has been distorted or partially misunderstood. The rampant growth of the green building movement has brought with it the unsavory practice of "greenwashing." Greenwashing, according to Merriam-Webster, is "the expression of environmentalist concerns, especially as a cover for products, policies, or activities." In the building industry, greenwashing typically refers to the practice of making unsubstantiated or misleading claims about the environmental benefits of materials, finishes, or systems [7]. This has also resulted in the inaccurate perception that sustainability/green design can merely be an add-on to our buildings rather than an integrated add-in design approach. A rash of what I call "green warts" has made their way into existing and new building stock.

Measuring Results

In 2000, the new matrix set in North America that buildings are being measured against is the system developed by the U.S. Green Building Council called Leadership in Energy and Environmental Design (LEED). The rating system is a series of pre-requisites and credits associated with a point system that could yield a maximum of 69 points toward achievement levels of certified, silver, gold, and platinum. The rated categories are sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation and design process. LEED is predominately a quantitative analysis and framework for energy efficiency. Architects must not be satisfied with mere LEED compliance but strive, in collaboration with engineers, to design and build quality spaces for people.

Architecture 2030, a nonprofit, nonpartisan, and independent organization, was established in response to the global-warming crisis by architect Edward Mazria in 2002. Architecture 2030's mission is to transform rapidly the U.S. and global building sector from the major contributor of greenhouse gas emissions to a central part of the solution to the global-warming crisis [8]. Mazria is touring the country lecturing to architects, mayors, developers, legislators, and all of those who are influential in the building industry about his initiative, entitled the 2030 Challenge (www.2030challenge.org or www.architecture2030.org). This initiative calls for all buildings built by the year 2010 to use 50 percent less energy than currently used by the average regional building of that type; after 2010, the target percentage increases 10 percent each five-year period so that by 2030 all buildings built or remodeled will be carbon-neutral. Naturally, these buildings will still use energy, but that energy will not come from greenhouse gas-creating fossil fuels. Numerous influential groups have signed on and are now working to implement its targets, including the U.S. Conference of Mayors, American Institute of Architects (AIA), U.S. Green Building Council (USGBC), Leadership in Energy and Environmental Design (LEED), Environmental Protection Agency, the Royal Architecture Institute of Canada (RAIC), and many others [9]. One of the most influential groups is the U.S. Conference of Mayors, an official nonpartisan organization of cities with populations of 30,000 or more. There are 1,139 such cities currently in the country [8]. Each mayor has the power to legislate sustainable building policy for his or her region.

Multifunctional Technologies

Currently, the palette of energy saving options is burgeoning, and existing new technologies are rapidly changing, based on extensive research and development. Architects and engineers must be educated and prepared to make holistic comparisons between energy saving alternatives. As architects and engineers evaluate different sustainable strategies, a common goal should be to sensibly integrate and express these systems. Oftentimes, the nature of a specific system or application could lend itself to an intelligent solution that synergistically satisfies multipurpose functions. This can be achieved as we critically think of how energy-collecting devices lend themselves to serve other functions. A solar collector could be engineered to serve also as a sunshade, light shelf, a façade treatment, a water harvester, or a wind diverter. This approach would not necessarily result in the old Swiss army knife analogy of doing several things poorly at the expense of doing one thing well. In the quest for multifunctional solutions, we must not impair or compromise individual functions. The holistic solution should be better than the sum of the parts.

Let us explore two specific predominantly green approaches: green roofs and solar collection.

Green Roofs

To exploit an analogy, green roofs are popping up like weeds on the rooftops of buildings. Media awareness of them is so prevalent that oftentimes the first question in early building schematic discussions is whether to include a green roof in the project—a question rarely considered a few years ago. The installation of vegetated roofs in North America increased by 30 percent between 2006 and 2007, according to the third annual Green Roof Market Industry Survey. The Green Roofs for Healthy Cities nonprofit organization (www.greenroofs.org), which sponsors the annual survey, reported that slightly more than 2.4 million square feet of rooftop was planted during the past 12 months. This equals approximately 55 acres or 42 football fields [10].

Table 1: List of the Top Five Green Roof Cities [10]

City	Rooftop square footage planted in 2007
Chicago	517,633
Wilmington, DE	195,600
Baltimore	121,550
Brooklyn, NY	102,908
Virginia Beach, VA	100,500

Source: Green Roof Market Industry Survey

As shown in Table 1, Chicago has taken the lead in this area. Figure 6 shows the City of Chicago City Hall rooftop garden, which was designed to test its cooling effects and its ability to sustain a variety of plants in three different depths of growing media. Monitoring of the plants, birds, and insects is underway. Results from monitoring the cooling effects during the garden's first summer showed a roof surface temperature reduction of 70 degrees and an air temperature reduction of 15 degrees [11]. Mayor Richard Daley set the example by green roofing city hall, proclaiming that he wants to make Chicago the greenest city in the United States and offering economic incentives to builders to use green roofs. Green roofs can lower the heat island effect in urban centers, lower roof temperatures (therefore reducing cooling loads), provide storm water management, and absorb noise. Note that none of the major marketed assets includes any mention of human interaction. Incidentally, I found out why when I visited this roof in Chicago last month and was told that there was no public access.

Figure 6: City of Chicago City Hall Rooftop Garden
Landscape Architects: Conservation Design Forum, www.cdfinc.com

It is worth noting that the United States trails Europe and Asia in the use of green roofs. It is estimated that 10 percent of the roofs in Germany are green. In Tokyo, a 2001 law mandates that all new and remodeled buildings must have 20 percent of the roof area covered in vegetation. Going green means more than putting a green roof on your building, which can be effectively retro-engineered by some major providers. How do we make green roof technology a valuable urban green space and a catalyst for occupant interface? Green roofs can and should become a celebration of public green space. Numerous studies have shown that mere visual contact with green elements in nature improves the learning capacity of students and the satisfaction of employees, much the same as natural lighting. A green roof (if designed with the intent of bringing the human occupants of a building in contact with the various sensory elements of nature) will guide physical and spatial design composition, significantly amplifying the many benefits of a green roof and satisfying a multifunctional strategy.

Designs of this sort would not only allow easy access for occupants to the green space with landscape design elements but would also facilitate the necessary interplay between people and nature. Shaded seating areas promote extended stays and social interaction. Designing seating in closer contact with greened surfaces can be accomplished with a variety of green surface heights. Walking paths could be designed as a sequence of experiences, not just a path to see the green and leave. Such architectural forethought could also expose visitors to an educational opportunity to experience other energy saving devices on the roof for capturing solar energy, wind energy, or water harvesting.

Solar

"Solar architecture is not about fashion—it is about survival."
—Sir Norman Foster, Foster and Partners Architects (www.fosterandpartners.com)

Solar energy is the most promising area of development in terms of creating a sustainable, clean, non-polluting energy from an inexhaustible unlimited source. Major research and development is underway in all parts of the world, experimenting with different methods of solar collection. Flat plates, concentrating troughs, and tracking dishes are the predominant active solar collection systems, each with particular physical characteristics and different challenges to integrate into a building. A significant percentage of the cost of rooftop photovoltaic panel systems is the structural framework to support panels and the cost of multiple roof penetrations for the supports. Designs eliminating the support system or utilizing the support structure for secondary use should be considered. Examples might be an entire solar array functioning as a roof plane, a protective canopy for roof top seating, or as a plane to collect water. Solar panels could double as shading devices on vertical wall planes, mounted at angles to maximize solar collection in that particular geographic latitude and contributing to the overall facade treatment as shown in Figure 7. Translucent solar panels could be used as glazing units in skylights or curtain wall systems.

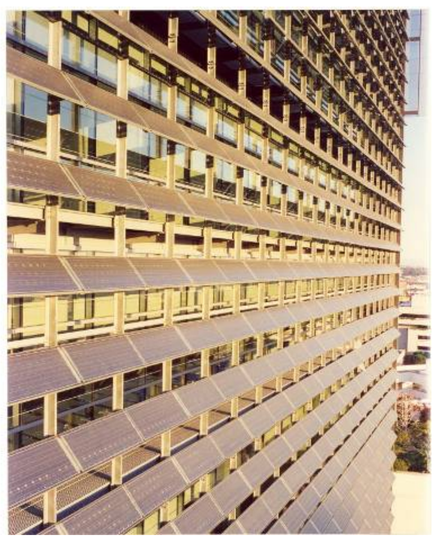

Figure 7: California Transportation Authority District 7 Headquarters,
Los Angeles, CA.
Solar panel/shading louvers with BIPV glass, angled to maximize efficiency while providing shade to the building.
Architect: Morphosis (http://www.morphosis.net) [12]

Recent advancements have been made in the area of building integrated photovoltaics (BIPV). BIPV are photovoltaic materials used to replace or combine with conventional building materials in parts of the building envelope such as the roof, skylights, or facades. Much of this has been possible through the advent and advancement of thin flexible energy producing solar films. These flexible films can adhere directly to a building material or integrate into a glazing unit. Our obligation as architects is to integrate BIPV with the building design by avoiding patchwork placement without sensitivity to the overall design. For example, consider the three applications below in Figure 8.

Figure 8: Patchwork Placement of Solar Collection Panels

This approach to intelligent design could be applied to both passive and active solar solutions. Passive solar refers to a system that collects, stores, and redistributes solar energy without the use of fans, pumps, or complex controllers versus active solar, which needs some sort of mechanical device to enable its operation [13]. Heat generated through glass windows exposed to the sun is the simplest form of passive solar energy. Passive and active systems can and do exist side-by-side, as shown in Figure 9, sharing the same sun and showing the same challenges and responsibilities for aesthetic integration.

Figure 9: Passive and Active Solar Collection

Anecdotally, the home where I grew up in South Florida had all the hot water it needed provided by a passive flat plate solar collector on the roof with thermo-siphon circulation. (If a pump were required for operation, this would technically be an active solar solution.) I can remember only a few times in the middle of winter when my shower time was shortened due to insufficient hot water. Most of the homes in the area eventually abandoned this energy efficient roof top system in favor of electric water heaters, succumbing to the mantra of the utility company, “Live better though Electricity.” This consumer preference met with little resistance at the time because of the low cost of energy. Passive and active solar collection is resurging again on single family and multi-family housing projects (see Figure 10).

Figure 10: Colorado Court, Santa Monica, California, 2002
One of the first housing projects in the United States achieving 100 percent energy independence. The solar electric panel system integrated into the façade and roof of the building supply most of the peak load electricity demand. Architect: Pugh + Scarpa www.pugh-scarpa.com [14].

Teaching the Next Generation of Architects

Students are typically overwhelmed by the number of terms and the broad range of topics clamoring to be associated with the green/sustainability movement. An initial comprehensive understanding of these terms is in order. As a professor of architecture, I have addressed this in either a comprehensive presentation in a class setting or by assigning teams with two to three members to prepare audio-visual presentations for the class. Interactive discussion during each presentation usually cements the concepts to the students. Naturally, comprehensive resource links are required with each presentation so that students may later explore each subject in greater depth outside of class. Furthermore, presentations are saved on the class web site. Some have heard the doomsday reports promoted by Al Gore and have viewed the movie *An Inconvenient Truth.* Personally, I tend to avoid the issues relating to human toxic annihilation and the death of the planet, focusing on an approach of doing what is sensible and right as an architect: designing buildings for humans without wasting resources. Edward Mazria's 2030 Challenge asserts that academic institutions should transform the design curriculum to be ecologically literate within the next three years. It further suggests that each design project carries the statement, "All projects must be designed to engage the environment in a way that dramatically reduces or eliminates the need for fossil fuels" [15]. I take Mazria's 2030 Challenge seriously with the realization that future significant change in our field to the approach of socially responsible design is greatly influenced by the ideologies of the incoming workforce of architects, who embrace the idea that architecture can be a catalyst for social change. Each project assignment begins with process demonstration and documentation as required foundational steps before any hint of a building form is allowed. I find Professor Tim White's book on site analysis to be an excellent reference source [16]. Careful study and diagramming of environmental conditions parlay focused group conversations on the viability of each of the major energy saving strategies applications to a building site in study.

The paradigm that I strive to instill in the minds of my students is the approach that associates the development of building form as a byproduct of the environmental forces acting upon it. Some of these environmental forces will give credence to incorporation of systems that capture energy. The dynamics between these two forces (environmental and energy) have the power to transform, invent, and produce architecture.

Sample Student Project

In the spring semester 2008, the final undergraduate project assignment for my second year architecture studio was the design of a new architecture academic building. Our professional architectural program at Southern Polytechnic State University in Marietta, Georgia, has undergone explosive growth, which in turn, has necessitated a second new architecture building to be built on campus. All of this follows on the heels of the first architectural building, which opened in 2002. The new building is presently funded, and schematic design is under way. The studio assignment of a new architecture building had a similar program. One stated goal was to incorporate energy conserving systems within their design that became an expression of the building form, combining these systems as multi-functional elements. Green warts—systems tacked on to a building form as if one was decorating a wedding cake—were expressly forbidden. Each energy conservation system was expected to contribute aesthetically to the overall composition and form of the building. Emphasis was placed on green roofing, solar collection, daylighting, and water harvesting, with a challenge to make these technologies human interaction driven so they could be used as an easily accessible teaching tool. The following are four selected student projects.

<u>Kevin Kembel</u>
Immediately upon approaching the entry to this proposed design, one is greeted with a sloped solar collector array/window wall system arranged in a semi-circular pattern drawing attention to and emphasizing energy capture, while demarcating the main building entry (see Figure 11). The form expresses a multiplicity of functions. One must move through the subtractive exterior space via a footbridge, while being unconsciously engulfed in a myriad of collaborative solutions. The top of the semi-circular solar collector array acts as a handrail, providing security and protection to green roof dwellers. Additionally, they allow both inquisitive peering over the edge and deliberate direct tactile contact with the solar collection panels themselves (see Figure 12).

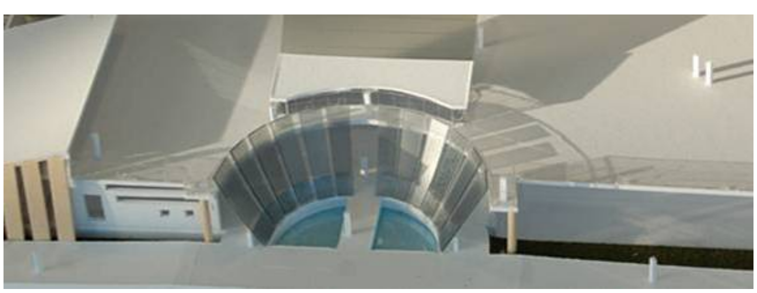

Figure 11

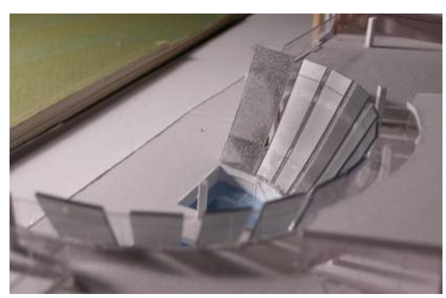

Figure 12

Translucency of the solar panels and minimal slivers of transparent glazing allow inhabitants (in this case, architecture students) to view pedestrian traffic, provide for natural daylighting, and appropriately restrict southern light exposure. Slope surfaces serve as rainwater diverters, leading water to a collection pool below that pedestrians transverse upon entry to the building.

Yuliya Nikolayevskaya

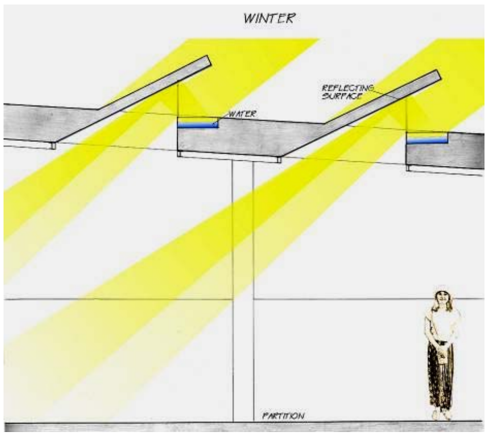

Figure 13: Winter Sun

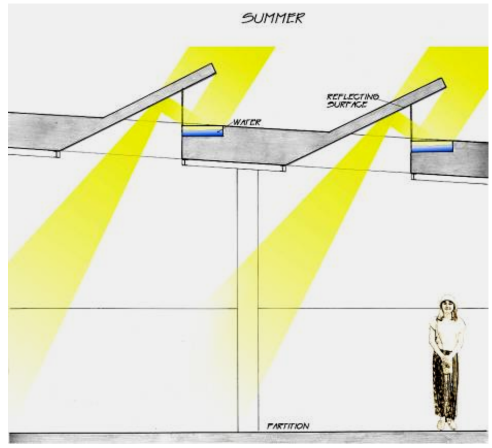

Figure 14: Summer Sun

One of the features of this building is the light shelves placed below southern glazed daylighting openings (see Figure 13 and Figure 14). Bounced light enters into the building indirectly during summer months, restricted by shielding overhangs. Direct lighting, with solar heat gain through the same glazing, occurs in the winter months when the sun's lower angle is not blocked by the overhangs. The light shelf was designed as a shallow water harvesting collection pool, directing excessive runoff to a storage tank but allowing a thin layer of water to remain. This thin layer of water has a slight cooling effect in the summer months but was mainly designed to create a moving dynamic reflective surface. Light reflecting off this surface of water into the spaces below changes as the wind crafts the plane of water.

Figure 15

Sloped planes of photovoltaic panels frame the light shelves on both sides and are angled to maximize solar collection (see Figure 15). The vertical wall intersecting the high side of these roof planes is fitted with clear glazing to allow rooftop pedestrians to interact visually with students in the studio space below. A smaller, controlled area of rooftop access to the east is ringed with planters that double as seating height surfaces and allow a deeper depth of soil for more substantial plantings to shade the roof and roof visitors. This eastern roof area placement is highly reactive to intense existing pedestrian activity generated by adjacent academic buildings.

Kevin Chong

Since photovoltaic (PV) films can now be integrated within glazing units, Kevin's design combined translucent PV glazing units to form a glass arch roof that delineates and covers the jury pit—the main focal space of the building (see Figure 16 and Figure 17.). The spring point of the arch creates an expressive building entry. As the photovoltaic glazing units progress upward from south to north, past 90 degrees vertical on the arch, they gradually change to full transparent units to allow the maximum amount of north daylighting to enter the space.

Figure 16

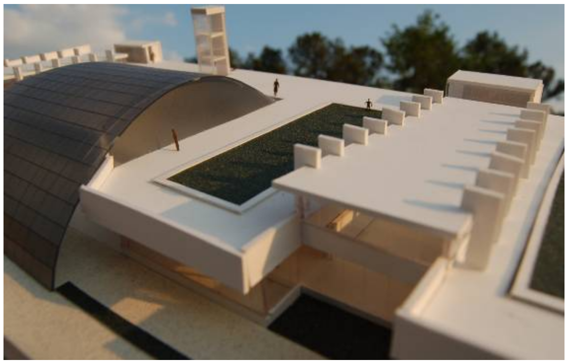

Figure 17

Raised sections of flat insulated roof express the studio pinup areas and result in clerestory glazing for natural daylighting (see Figure 18). Clerestory glazing is appropriately protected from east and west direct solar gain by vertical shading devices that double as structural supports for the roof. South glazing is appropriately protected by extended overhangs.

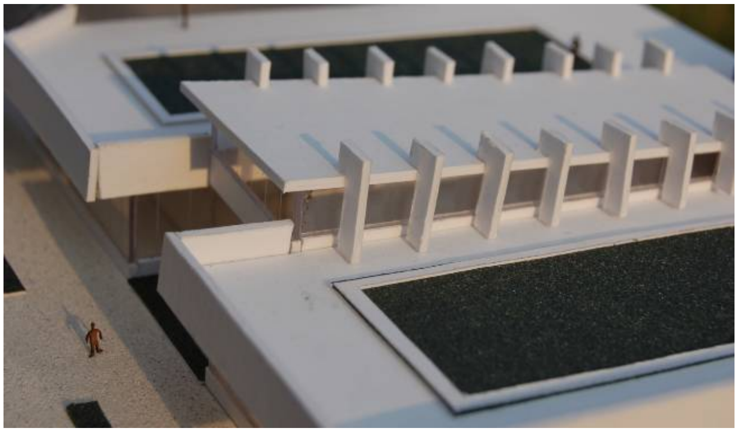

Figure 18

Kyri Prowett

Here, we see a strong expression of south oriented solar collection panels appropriately angled for maximum efficiency. The high side of the panels terminated a vertical glass plane to receive natural daylighting from the north into the jury space below. The overall composition reflects the profile and importance of the jury pit area below. Water runoff from solar panels is collected at the low side of the panels in a gutter that is open at both ends; then, it is combined with others to cascade as a water wall feature from the roof to a ground floor pool and underground storage tank. The glass water wall forms the separation between the semi-circular gallery and the main building. Continuous horizontal louvers shade the southern facing clear glazing (see Figure 20), and translucent glazing protects the gallery. Figure 19 and Figure 20 show the twisting elevator and stair towers, portraying a combination of rotation and motion. Housed in the upper section of the towers are vertical wind turbines for generating electricity.

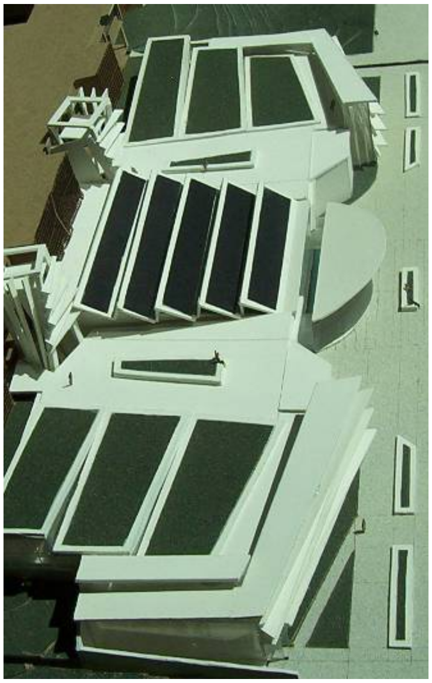

Figure 19

Figure 20

Conclusion

We must never lose sight of the fact that all sustainable projects within the fundamental aspects of architecture design grant us not only the ability to intelligently conserve energy but also enhance the human spatial experience. Integrating technology in architecture to reduce energy consumption is not a new idea, but one that has been at the root of socially conscience design for centuries. I know firsthand that in 1970, when I was an architecture student, “low energy” design was the primary focus in design studio. In 1974, a prominent architectural firm, CRS, with a strong energy conscientious design philosophy wrote a design primer on how to conserve energy through responsible architecture even before the term “sustainable” was embraced [17]. That design philosophy is still valid today.

The primary approach for energy conservation begins with responsible architectural design. The proper order to accomplish energy reduction should be first to incorporate classic design strategies such as site orientation, building geometry, and daylighting, respective of its geographical location and climate. Only after these variables are maximized to full advantage should we begin to add transparent and expressive multifunctional technologies, without ever compromising or subordinating the human experience to function.

Dr. Harold Gores states in the foreword to the book *A Bucket of Oil*, “Our buildings should grace the land, praise our culture, and by their nature be not only good neighbors to the earth, but sensible consumers of it bounty” [17].

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Biography

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