THE NEXT GENERATION OF ENERGY EFFICIENT BUILDING DESIGN: WHERE ARE WE AND WHERE SHOULD WE BE GOING?

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ABSTRACT

In the architecture, engineering and construction industry there are practical problems to defining environmental success with energy codes. It is assumed that energy conservation codes are designed to protect the environment and reduce energy consumption. By following energy codes, owners, designers and politicians believe they are reducing air pollution and energy demand. Yet, consumption continues to rise. It is clear that environmental performance benchmarks based energy codes and efficiency standards will not significantly alter the energy future of our industry. Designing the first buildings of the Next Generation will require revolutionary (as opposed to evolutionary) thinking about performance standards, technology, and consumption; and the development of an ethical relationship between architecture and the environment.

INTRODUCTION

As practitioners we are amazed - and often inspired - by the depth and breathe of investigation in the fields of building enclosures and building technology being conducted by researchers and scientists. The ideas presented here is an account of the struggles, observations, and revelations of a design team facing the challenges of the practical application of environmental and sustainable theory. We have attempted to provide a roadmap – or better yet, a travelogue – of our investigations and discoveries. It is our sincere hope that our explorations will present opportunities for further discussion and consideration – it is never the answer to a question that provides insight, but rather the path.

Architects and engineers have been engaged in a conversation since the mid-70s about ways of improving the performance of buildings, and yet consumption of energy and the production of greenhouse gas in the United States continue to rise at an alarming rate. In the past five years, design professionals and consumers alike have been bombarded with the statistics: US buildings are responsible for nearly 48% of our total energy consumption; 70% of the electricity produced in this country; and 33% of the carbon sent into our atmosphere every year.[1] The polar ice caps are melting, and without significant change, we face an ecological disaster of such magnitude we may not be able to fathom the consequences.[2] In the face of such facts, why are we unable to make the course correction[3] necessary to change the outcome?

As design professionals, we are on the front lines in the battle for climate change – and yet there have been few major changes in the way we design buildings over the last 20

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years. For the last decade been general uncertainty regarding the profession's capability to positively impact global climate change on a broad scale; and at the state level the design and construction industry continues to engage in a protracted debate with regulatory agencies on the rate of change that society will embrace in terms of energy-efficient design practices.

In 2006, however, the American Institute of Architects (AIA) working with the non-profit organization founded by Ed Mazria, AIA - *Architecture2030* - proposed a radical change in the discussion of building performance standards: *all* new buildings and major renovations shall reduce their fossil fuel emissions by 50% compared to the "average" building as defined by the EPA's Energy Finder standards. By 2010 the target will increase to 60%; 70% in 2015; 80% in 2020; 90% in 2025; and carbon neutral by 2030.[4] R.K. Stewart, FAIA, facilitator of the AIA Sustainability Summit Task Force, is quoted in a press release as saying, "The time has come to require specific goals for significant reductions in energy use, with enhanced performance assured through commissioning of building systems. And to truly make an impact, there needs to be far greater use of renewable energy sources and the use of innovative design principles that will dramatically improve environmental performance in the built environment. Because energy consumption reductions will be realized over the entire life of a building, we need to look beyond the first impacts associated with constructing a facility and really consider what happens over the many decades that the facility will be used."[5]

To be clear, it is our position that *the Next Generation of Energy Efficient Buildings must be low-energy carbon neutral buildings* in order to positively impact global climate change.

PRACTICAL PROBLEMS OF DEFINING SUCCESS WITH ENERGY CODES

The current state of energy efficiency

During the last thirty years building's energy performance is measured against a set of standards – the Energy Code. The intent of the energy code is to regulate the design of the building envelope to enable the effective use of energy by establishing minimum performance standards for the thermal properties of the building envelope and glazing, the mechanical systems, and the performance of lighting and power equipment. The International Energy Conservation Code (IECC) is one component of an integrated system of building code standards promulgated by the International Code Council (ICC). The first edition of the IECC was published in 1998 and was based upon the 1995 edition of the Council of American Building Officials (CABO) Model Energy Code.

The IECC provides *minimum requirements* for energy efficient buildings via prescriptive and performance design and construction requirements. The code covers both residential and commercial building construction. In the 1998, 2000, and 2003 editions of the IECC, commercial building requirements are accomplished by meeting the requirements of the ASHRAE/IESNA 90.1.

ASHRAE published the first national energy standard for buildings (Standard 90) in 1975, with subsequent revisions in 1980, 1989, 1993, 1999, 2001, and 2004. The 1999 edition of the standard was a substantial revision of the 1989 edition. Major changes included new equipment and building envelope efficiency levels based upon both economic and feasibility criteria, an expanded scope to cover existing buildings, a rewrite of the entire document into mandatory enforceable language suitable for code adoption, and significant reduction in the electric power allowances for interior lighting.

Standard 90.1-2001 is the current U.S. Energy Policy Act (EPAct) mandated commercial building energy standard based on Department of Energy's (DOE) formal determination of energy savings of that standard. The 2001 edition of Standard 90.1 clarified a number of ambiguities in the 1999 edition. In only a few instances were there changes to the stringency levels for specific building components. Standard 90.1-2001 is recognized as a compliance path for commercial buildings in both the IECC 2003 and IECC 2004S.

The 2004 edition of the 90.1 Standard includes some major changes from the 1999 and 2001 editions. The climate zones were reduced from 26 to 8, and are now consistent with those in the IECC. The lighting power density requirements were reduced significantly and are generally comparable with those in the IECC 2003 and the IECC 2004S. The entire document was also reformatted to improve usability of the standard.[6]

It is clear that the evolution of the IECC and ASHRAE Standard 90.1 has had an overall positive impact on building energy efficiency. Recent studies indicate that an additional energy cost savings of 7% to 14% could be achieved through adoption of the most current version of the IECC, and thereby moving from ASHRAE Standard 90.1-2001 to ASHRAE Standard 90.1-2004. "The driving force behind these savings is lighting power allowance reduction. The newer standards call for the use of less lighting power and thus save energy because of lower lighting loads and reduced cooling loads."[7]

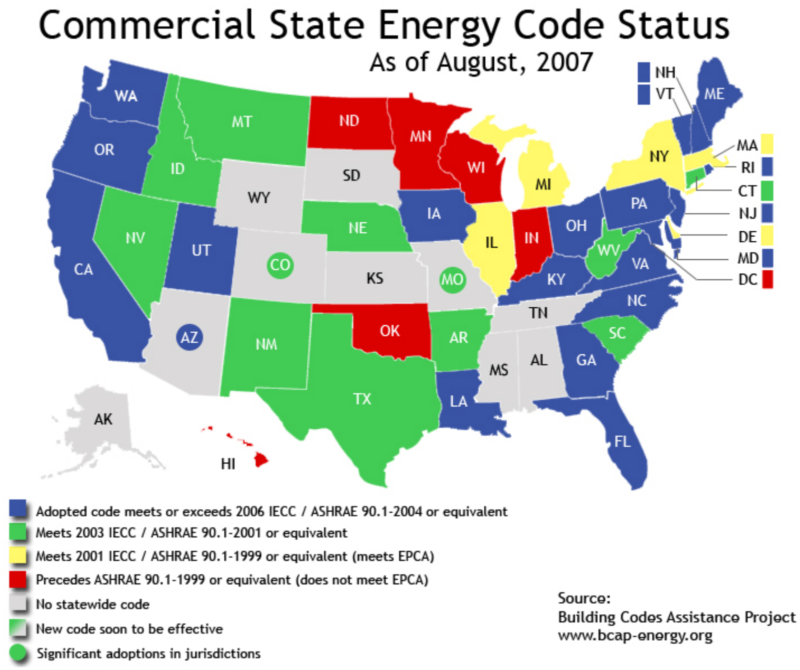
There is a strategic process in place, supported by both DOE and ASHRAE, to update and revise the Standard. As part of the DOE Energy Efficiency and Renewable Energy Program's "Building Technologies Multi-Year Plan 2007-2011" a process of updating both commercial and residential energy codes is outlined whereby the overall outcome is a 6 to 11 percent increase in the stringency in Codes by the year 2010, continuing to a 19 to 35 percent increase by the year 2025.[8] ASHRAE is in the process of receiving public input to ASHRAE 90.1-2007 with a strategic plan in place to significantly revamp the Standard in 2010.

Fundamental Problems with the Energy Code

As a national level the IECC and ASHRAE provide clear guidance for the performance of both residential and commercial building energy performance standards. However, for a vast majority of public and private building projects, codes are adopted and enforced not at the national level, but on a state-by-state basis. In other words, there is no consensus on the energy code. For example, as of August 7, 2007 (Figure 1):

- 19 states have statewide adopted codes that meet or exceed the 2006 International Energy Conservation Code (IECC) / ASHRAE 90.1-2004.
- 10 states have statewide adopted the 2003 IECC, which is equivalent to ASHRAE 90.1-2001.

- 5 states (includes District of Columbia) have adopted the 2001 IECC, which is based on ASHRAE 90.1-1999.
- 6 states have state codes that precede the ASHRAE 90.1-1999 standards; and
- 10 states have no statewide energy codes; local jurisdictions make their own rules - or not.[9]



It is interesting that the Energy Policy Act of 1992 amended the Energy Conservation and Production Act (ECPA) to establish the ASHRAE 90.1 Standard as the federally mandated minimum energy standard for commercial buildings throughout the United States. In 2002, the DOE made a positive determination for the 1999 Standard, triggering a *mandatory* two-year window that required all 50 states to certify by July 15, 2004 that they had commercial energy codes in place that are at least as stringent as 90.1-1999. Standard 90.1-1999 is also referenced in the 2001 version of the International Energy Conservation Code (IECC).[10]

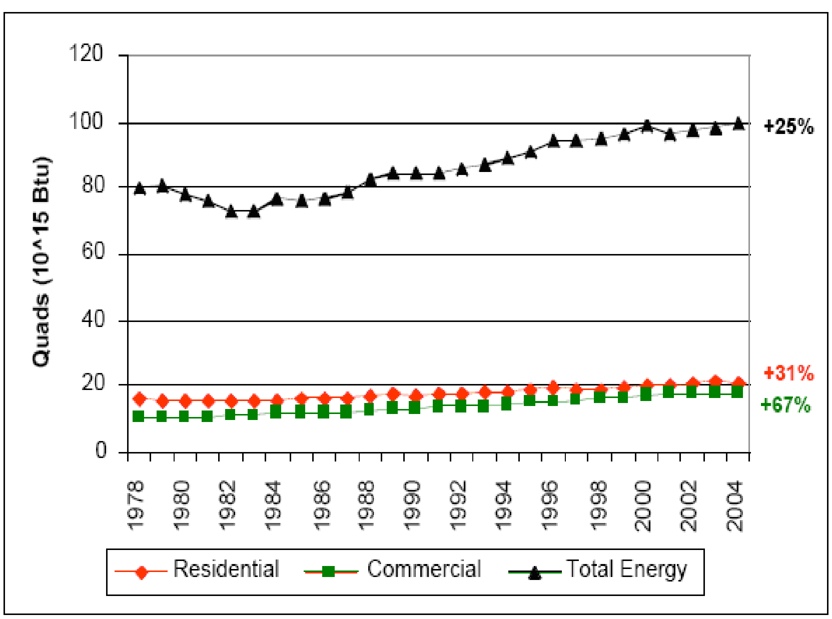
A practical problem with defining success based on the energy code is one of consistency. Without a consensus understanding of the code architects, engineers, and contractors are unable to develop a holistic design and construction approach focused on providing optimal efficiency. To further complicate the issue, design and construction teams are often challenged by local code officials to demonstrate compliance with older regressive energy codes even though they are exceeding the requirements of the most current standard, thus creating an additional level of bureaucracy to overcome. Finally, with a legacy of outmoded codes in more than sixty percent of the country, our national building stock has become a self-perpetuating example of inefficiency and “designed” obsolesce. By some estimates, in the 16 remaining states that have not upgraded their energy code to meet the requirements of ASHRAE Standard 90.1-1999, the nation is loosing in excess of $20 million per year in higher energy costs due to the continued non-compliance with the 2002 DOE directive.

CRITICAL THINKING ABOUT ARCHITECTURE AND THE ENVIRONMENT

Much of the popular discussion regarding energy efficient building design in recent years has centered on performance increases in comparison to a benchmark performance standard – often ASHRAE 90.1-2004. Observing a number of design teams (architects and engineers alike) navigate the design “optimization” process leaves an impression of half a dozen cooks all standing around the stove each adding a pick of this and that to “tweak” the design until the soup is just right. Each doing only enough so that they reach *the* magic number of 12, 15 or 20% “better than code.” Design teams have a tendency to view energy performance goals as a compliance issue that can be addressed in the tuning process. How often have we heard, or actually uttered, things like: ‘change the glazing or mechanical system performance’ or ‘add another inch of insulation and we’ll be good.’ Nothing has fundamentally changed in the process of design. No one is asking questions about the nature of finish line – is meeting the Code really all that great? Nor – once hitting the magic threshold – are they saying ‘why stop here.’ It is as if the performance threshold is a finish line, once crossed the no more effort needs to be expended.

In the United States, we have been tweaking the energy code for 30 years, and yet our consumption continues to rise. Nationwide, energy consumption and carbon emissions continue to grow, overall and per capita.[11] These national increases occurred despite large relative energy savings that have been attributed to energy efficiency. Between 1980 and 1999 (Figure 2), residential electricity consumption increased at a rate of 2.0% per year, while population increased at a rate of 1.8% per year (and the number of housing units increased at a rate of only 1.4% per year.[12] On a macro scale, energy efficiency has not led to a society that is environmentally less damaging than before. On a micro scale, energy-efficient things in general are not less environmentally damaging than their inefficient counterparts.[13]

Primary Energy Use in US Buildings, 1978-2004



Source: EIA 2004

As design professionals, this trend is confusing. How is it that we have made no headway in reversing the trend when we have made great improvements in the building performance? The observation was first made in 1865 by the economist Stanley Jevons, and is now referred to as the Jevons Paradox.[14] It finds that as technological improvements increase the efficiency with which a resource is used, total consumption of that resource – despite a short-term drop - may actually increase, rather than decrease, over the long-term. In other words, the effect of improving the efficiency of a resource is to lower its implicit price and hence make it more affordable, thus leading to greater use.[15]

Research by the National Renewable Energy Laboratory (NREL) arrived at the same conclusion, but for different causes: “Energy used by the building sector continues to increase, primarily because new buildings are added to the national building stock faster than old buildings are retired. Energy consumption by commercial buildings will continue to increase until buildings can be designed to produce more energy than they consume.”[16]

As a profession, we must come to terms with two truisms in order to begin a critical discussion about architecture and the environment: first, the energy code is a minimum performance standard – a barely passing grade; and second, insistence on efficiency as sufficiently “environmentally good” will divert attention away from recognition of the environmental burdens caused by consumption itself, “the elephant in the living room.”[17] Moezzi & Diamond (2004), Herring (2006), and others argue that the focus on energy efficiency since the late 1970s has essentially been a ‘red herring.’ Energy efficiency marketing campaigns in the United States began to distance themselves from “conservation,” identifying conservation with sacrifice, old-fashionedness, and unpleasant memories of the 1970s energy crisis.[18] This strategy provided a new look for efficiency, shaping it into a primarily purchase-oriented rational practice, as contrasted with conservation, which was taken to mean the curtailment of needed energy services. In contrasting energy efficiency with sacrifice, a strong message about consumption choices comes through: the consumer deserves to consume.

As Moezzi and Diamond (2004) observe “No doubt there will be substantial technological progress in various realms, but there is no reason to expect the emissions reductions, or other types of environmental benefits, to overcome the consumption increase. In the short run, it may be worse: for older end uses long governed by energy efficiency policy, it becomes harder to make marginal efficiency improvements. New end uses proliferate, but prove more difficult to address through traditional policy means.”

KNOW THE BOX, BE THE BOX, TRANSCEND THE BOX

In a recent issue of *Fast Company*, Dan and Chip Heath[19] wrote a short article describing how constraints can liberate thinking about a problem. “Developing great ideas when you are starting with a blank slate is tough. As jazz legend Charles Mingus said, ‘You can’t improvise on nothing, man.’ The best way to let your creativity flow is to place limits on it.”[20] Revolutionary thinking about building performance, energy consumption, and carbon emissions requires this industry to understand exactly how buildings consume energy. Architectural form, shading, daylighting, materials, orientation, and glazing all have significant impacts on building energy, comfort, and lighting performance. Mechanical system should be used to make up for what cannot be accomplished by architectural form and envelope alone - not to correct for a climatically ill-conceived architectural design.[21] Seeing buildings as complex dynamic systems engaged with, and responding to, the forces of nature requires a self-awareness of the implications of design decisions from the very beginning of the project. As a critical step in *Knowing the Box*, design professionals must educate themselves not just in the physics of architecture and engineering - as static rules of thumb, but rather understanding how architecture is comprised of a series of components of a dynamic cooperative system of conscious design decisions that relate to and impact the environment.

In an ongoing research project by the National Renewable Energy Laboratory (NREL) to assess a series of high-performance buildings - and the lessons learned from them - they have developed a set of best practices, design elements, technologies, and techniques that will enable design teams to: understand the goals of the project and the conditions of the site; effectively communicate individual and organizational needs and requirements; provide real-time feedback to team members on results to verify the validity of decisions; and encourage exploration of creative and natural design solutions.

The low-energy, or integrated, design process covers pre-design through post-occupancy phases of a project, and relies heavily on building energy simulation with real-time feedback to the members of the design team. The simulation process begins with pre-design, where the building size, type, location, and use are known. The process then continues through design, construction, and commissioning. The integrated design process requires the project team—the architect, engineers (lighting, electrical, and mechanical), energy consultants, and the building owner and occupants—to commit to work together to meet aggressive energy performance goals. Each member is encouraged to find solutions and offer suggestions that benefit other disciplines, the process, and ultimately the building design.[22] In other words: *Be the Box.*

The NREL Ten-Step Process for Low-Energy Buildings[23]

<u>Pre-Design Phase</u>

1. Set specific and measurable energy performance goals, which may include percent energy savings, percent energy cost savings, or emission reductions; and develop a thorough understanding of the building site, local weather patterns, and building functional requirements.
2. Create a base-case building simulation model to quantify base-case energy use and costs – this model should be based on the requirements of ASHRAE 90.1-2004/2007.
3. Complete a parametric analysis of the base-case model to determine sensitivities to specific load components. Sequentially eliminate loads from the base-case building, such as conductive losses, lighting loads, solar gains, and plug loads.
4. Develop preliminary design solutions that include strategies to reduce lighting and cooling loads by incorporating daylighting or to meet heating loads with passive solar heating.

Schematic Design Phase
5. Incorporate preliminary design solutions into a building simulation model of the proposed design. Energy impact and cost effectiveness of each variant are determined by comparing the calculated energy performance with the original base-case building and to the other variants. Variants with the most favorable results should be incorporated into the building design.
6. Prepare drawings based on the decisions made in Step 4. Architectural decisions made during the schematic design can have the greatest impact on the long-term building energy performance.

Design Development Phase
7. Identify the HVAC system that will meet the predicted loads. The HVAC system should complement the building architecture and exploit the specific climactic characteristics of the site for maximum efficiency. Verify that building simulations are updated with design changes.

Construction Document and Bidding Phases
8. Ensure that the building plans are properly detailed and that the specifications consistent with the design decisions developed in Step 7. The final building simulation should incorporate all cost-effective features.

Construction Phase
9. Rerun simulations before design changes are made during construction. Verify that changes will not adversely affect the building's energy performance.

Post-Occupancy Evaluation Phase
10. Commission all equipment and controls. Educate building operators. Only a properly operated building will meet the original energy efficiency design goals. Building operators must understand how to properly operate the building to maximize its performance. Measure and evaluate actual energy performance to verify design goals were met.

The Next Generation of energy efficient building designs will be informed by the work of the NREL and shaped by design professionals who are on the outer edge of today's state of design, systems, and building technology. At the heart of Next Generation thinking will be zero energy buildings (ZEB) - a concept that buildings can meet all their energy requirements from low-cost, locally available, nonpolluting, renewable sources. The path to achieve zero energy status is achieved by greatly reducing the energy needs of the building through efficiency gains and reduced consumption such that the balance of energy needs can be supplied with renewable technologies. At the strictest level, a ZEB generates enough renewable energy on site to equal or exceed its annual energy use.

According to a market assessment performed by the NREL in 2006,[24] Using today's technologies and practices, the technical potential is that 22% of the buildings could be ZEBs. With projected 2025 technologies, the technical potential is that 64% of the buildings could be ZEBs. If excess electricity production could be freely exported to the grid, then with the projected 2025 technology in every building, the commercial sector could generate as much as 37% more energy than it consumes.

- European building envelopes
- VIP and VIGs
- Passivhaus

While changes in technology over the next 22 years will have a major role to play in achieving carbon neutral and zero energy buildings, it will be important for designers not to loose sight of the role Occam's Razor[25] will play in the future of architecture. "All other things being equal, the simplest solution is the best." This is the model that nature has provided for us, and it is often the foundation of what is often referred to as Enduring Architecture. Fundamentally, however, the Next Generation of buildings must consider reducing consumption through adjustments in design, in building program, and in the way people use our buildings to be effective – the notion of *conservation* is at the heart of simplicity.

Andrew Rudin argues that what is needed for sustainability is not more efficiency, which leads to greater consumption, but rather less consumption. What he argues for is limits to consumption through moral restraint and cultural change - “While efficiency tells us what to buy, conservation tells us how to behave.” Rudin argues:

...if we want to protect the environment, we have to emphasize conservation and restraint, not improved energy efficiency and consumption. This is a moral issue, not an economic one. Conservation is heroic because it implies discipline, sacrifice, caring for common interests. We should use less energy because it is the right action, not just because someone pays us to do so.[26]

ECOLOGICAL FOUNDATIONS OF NEXT-GENERATION DESIGN

The Architectural Land Ethic

Nearly a century ago, conservationist Aldo Leopold began his career by examining human impacts on the natural environment. His primary focus was the relationship, or lack thereof, between Man and Nature. He is most well known for the development of the *Land Ethic* which is his attempt to describe a responsible, meaningful relationship between individuals and the Land[27]. Leopold’s Land Ethic was developed from an earlier essay published in 1947, a year before his untimely death, entitled “The Ecological Conscience” in which he states “ecology is the science of communities, and the ecological conscience is therefore the ethics of community life.”[28]

While not the first conservationist to consider the ethical implications of the human/nature relationship, the importance of linking the pursuit of the understanding of the natural world with natural philosophy cannot be overstated. “First for Thoreau, and then for Leopold, wilderness was a state of mind rather than a description of a place. Both men championed a land *and* people ethic and not a land versus people ethic. Humans are a central environmental force shaping landscapes everywhere.”[29]

The underlying connection between Man and Nature was of influence and inter-relatedness – physically, morally, and emotionally. Leopold argued that humans are co-members of a community that includes soil, plants, and animals (the biotic community). Human actions must be understood, then, in terms of their impact on both the human community and the natural community. Therefore the ethical measure of human action must be understood in relation to the whole biotic community. For example, "It cannot be right, in the ecological sense, for a farmer to channelize his creek or pasture his steep slopes, because in doing so he passes flood trouble to his neighbor below, just as his neighbors above have passed on to him. In the cities we to not get rid of nuisances by throwing them across the fence onto the neighbor's lawn, but it water management we still do just that."[30]

The Ethic of Reciprocity...The Golden Rule: "Do unto others as you would have them do unto you" has it roots in many religions, but it has primarily been described as a human relationship. Leopold, however, believed that this ethical relationship extended into the whole biotic community. That is, *the human action on Nature has both consequences on the natural community as well as human.* It can not be considered merely as an obligation as the dominate species. To Leopold, being a *member of a community* implied the existence of an emotional connection that came through understand and compassion.

For us, considering the ethical implications of building design with understanding the conditions of the biotic "community" within the project context. That is to say, we consider what the basic conditions and needs of the human, soil, plant, and animal communities might be with a given project? What was the nature of the relationship between them? What opportunities existed on site and within our design to foster a deeper sense of understanding and compassion between the members of the biotic community?

In the most basic sense, Leopold argues for the reunification of natural philosophy and pure science. Leopold believed that a civilization functioning in concert with the land's conservation would be not only good for the land but also more productive of rich human lives, which were interwoven with it.[31]

Permaculture and the natural processes and energies

Permaculture is the art and science that applies patterns found in nature to the design and construction of human and natural environments. Founded in the mid-1970s by Australian ecologist Bill Mollison, Permaculture is seen as an environmentally benign system of land use – a "permanence" in culture modeled on natural patterns. Permaculture principles focus on thoughtful designs for small-scale intensive systems that are labor efficient, and which use biological resources instead of fossil fuels. Permaculture designs stress ecological connections and closed "energy" and "material" loops. At the core of Permaculture is the working relationship and connection between all things. Each component in a system performs multiple functions, and each function is supported by many elements. It is believed that the key to efficient design is observation and replication of natural ecosystems, where designers maximizes diversity with poly-cultures, utilizes efficient energy planning, and increases the highly productive "edge-zones" within the system.

Permaculture is both a design philosophy and a design system. As a philosophy it has a clear set of ethics that aim for, as Mollison (1988) puts it, the “harmonious integration of landscape and people, providing their food, energy, shelter, and other material and non-material needs in a sustainable way.”

As a design system, it is concerned with the process by which sustainable habitats can be created, based on working with, rather than against, nature. In Nature, total resource efficiency is accomplished by managing waste for productivity and balancing its consumption with contributions from each of the elements in the system. Human eco-systems, if would follow, are modeled after these natural patterns of multi-function and inter-connections.

Through reading patterns in natural the natural landscape, problems can be re-understood as resources and opportunities. Designers consider that every property has a unique pattern of natural characteristics. Proper alignment with these natural patterns is the basis of the Permaculture process. Instead of the "one size fits all" approach, Nature is allowed to direct the land use plan. By skillfully using Permaculture methods of site analysis and evaluation elements such as buildings and roads - and practices, such as farming and forestry - are established only in areas with optimum conditions. The result is an approach that works “with nature” in an efficient and economical way. Elements are placed not in isolation, but in relation to the dynamics of the total site. Proper placement is achieved when an element, or a practice, is designed to interact efficiently with all of the influencing elements.

The Permaculture approach treats the built environment and the natural environment as a whole. Buildings are designed not only for optimum solar advantage, but are carefully sited away from sensitive areas such as prime agricultural land and native habitat. Precautions are taken for the predictable threats of fire, flood, wind, and cold air drainage. One of the primary objectives in Permaculture is for designers to develop simple biological alternatives to reduce the need for the expensive and resource consuming demands of high technology.

Permaculture designs also consider and research naturally occurring plant and animal assemblies. Perennial fruit trees, shrubs, and vines are selected to mimic natural assemblies; each plant and animal benefits the other, providing a permanent and maintenance free resource system.

Finally, comprehensive water and soil conservation planning are integral to any sustainable design. For water conservation and flood controls, the Permaculture approach use roofs, parking lots, roadways and landscapes for harvesting run-off water. Basin, swale structures, and cisterns are constructed to collect run-off and convert flooding problems into helpful resources of low cost irrigation and gray water that can be used in the building.

CASE STUDY: THE GATHERING CENTER AT SCHAAR’S BLUFF

Touching the Land Lightly

The Gathering Center at Schaar's Bluff in Nininger Township, Minnesota is an ultra-efficient, near zero-energy building designed for the Dakota County Parks Commission. Impressive in both design and sustainability, Schaar's Bluff has been designed to give back to nature, healing the surrounding environment – both literally and figuratively. The project consists of a 3,500-SF nature center located on park land along the Mississippi River in the Spring Lake Park Reserve. The building sits on a dramatic 100-foot high bluff above the river – an area with an 8,000-year history of human habitation. Already a popular destination for hikers, Dakota County expects the nature center to draw even more visitors to the unique site.

The client provided the team with a challenge: design "Minnesota's first building for the next generation." The nature center's orientation and form is a reflection of the past, present and future. For thousands of years people have gathered on the bluff to look out over the river, often sitting around a campfire to stay warm or cook food. Consequently, the building hugs the edge of the bluff, its round shape mimicking the campfire ring. The simple forms of the structure allude to indigenous values, such as the importance of orientation s and the compass point, the sky above and the earth below our feet. At its core, the design is about gathering. Consequently, the design tries to resolve the conflicts between technology and nature. It really is one of the first buildings of the 21st Century, steeped in primitive history.

The site's wind turbine will balance annual electrical loads generated by the building. Wind studies of the area show more than sufficient winds to sustain the building. Excess power will be sent to the electrical grid and used by Dakota Electric, the local utility. Preliminary wind studies suggest that annually the turbine will produce 93% of the electricity needed to heat, cool and power the building.

The building itself is sited to take full advantage of natural patterns and energies of the site. The building's orientation was carefully studied to ensure sunlight, wind, rain, snow and all other elements benefit the closed-system. For instance, operable windows located on opposite sides of the building and linked to the building's HVAC systems allow breezes to cool or warm the building during the appropriate seasons. A beautiful trellis running alongside the building will sustain wildlife and provide shade on the building during the warm months once fruit-bearing vines are planted reach maturity.

The high performance building envelope is designed to seasonally adapt to and control heat gains and losses by using super insulation techniques, automated and fixed shading devices, and light/heat sensor-controlled window blinds. Sensors located throughout the interior interactively monitor everything including lights, HVAC, window shades and ventilation. The building is "alive", wired to responding to changing weather conditions to conserve energy. Interior temperature will be closely monitored to reflect weather conditions and building use. In-floor radiant heat keeps the building above 54-degress in winter, which is a reasonable temperature for short duration use as a trail head and. A high efficiency air-to-air heat exchanger provides supplemental heat or cooling only when needed for longer term occupation of the portion of the building available for rent for private and public events. Finally, rainwater captured on the roof is used in Minnesota's first commercial gray water recovery system to flush toilets, and then treated in an on-site septic system before recharging the aquifer.

CONCLUSIONS

Move beyond an evolutionary mode of energy efficient buildings and benchmarks toward revolutionary thinking.

Identify and address barriers to “Next Generation” building design.

Making smart and truly sustainable choices requires thinking in broad, conceptual terms coupled with exploration and research that relies on deep technical and practical knowledge.

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REFERENCES

[1] These figures have been widely circulated in the past few years including a recent presentation by ASHRAE President Kent Peterson entitled “Achieving Energy Efficiency in the Built Environment Through Standards.”
[2] Gore, A., 2006. An Inconvenient Truth: The Planetary Emergency of Global Warming and What We Can Do About It. Rodale Books / Viking Press, New York.
[3] See Anderson, R.C., 1999. Mid-Course Correction: Toward a Sustainable Enterprise: The Interface Model. Peregrinzilla Press, Atlanta.
[4] See http://www.aia.org/SiteObjects/files/HPB_position_statements.pdf.
[5] See http://www.aia.org/release_121905_fossilfuel.
[6] See Richmann, E., et. al. 2005.
[7] See Halverson, M., et. al. 2006.
[8] The EERE Building Technologies program Multi-Year Plan (MYP) was completed in August 2005 and updated in January 2007. It describes the planned research, development and demonstration activities for building technologies through 2012 for the Office of Energy Efficiency and Renewable Energy for the US Department of Energy. The MYP is a significant step forward to reaching the Department’s Zero Energy Buildings (ZEB) goal. The path to ZEB focuses on incremental steps and a series of technical targets. http://www.eere.energy.gov/buildings/about/mypp.html
[9] See also http://www.bcap-energy.org/home.php.
[10] See DiLouie, C., 2004.
[11] EIA 2003, 2004.
[12] Brown and Koomey 2003.
[13] Moezzi, M. and Diamond, R., 2004.
[14] See Polimeni, J.M., et.al., 2008 and Herring, H. 2006.
[15] Herring, 2006.
[16] See Torcellini, P., S. Pless, M. Deru, B. Griffith, N. Long, and R. Judkoff. Lessons Learned from Case Studies of Six High-Performance Buildings. NREL Report No. TP-550-37542. June 2006.
[17] Moezzi, M. and Diamond, R., 2004.
[18] See Moezzi 1998
[19] Dan and Chip Heath are the best-selling authors of Made to Stick: Why Some Ideas Survive and Others Die, 2007, Random House, New York.
[20] Heath, D. and Heath, C., 2007. “Get Back in the Box.” Fast Company, Issue 121, December ‘07/ January ’08. pp 74-76.
[21] Long, N., et.al. 2006.
[22] Long, N., et.al. 2006
[23] Long, N., et.al. 2006.
[24] Griffith, B., et.al., 2006.
[25] This is often paraphrased as "All other things being equal, the simplest solution is the best." In other words, when multiple competing theories are equal in other respects, the principle recommends selecting the theory that introduces the fewest assumptions and postulates the fewest entities.
[26] Rudin A. How improved efficiency harms the environment; 1999. http://home.earthlink.net/wandrewrudin .
[27] Callicott and Freyfogle, 1999.
[28] Leopold, 1947.
[29] Seidensticker, 2002.
[30] Leopold, 1947.
[31] Newton, JL, 2006.

BIBLIOGRAPHY

ACEEE Emerging Technologies Report: Integrated Daylighting Controls. The American Council for an Energy-Efficient Economy, September 2006

Antipolis, S. "The User's Perspective: Living and working in low-energy buildings - A View From Northern Climes." Proceedings of the Cooling Buildings in a Warmer Climate, A Future Buildings Forum Event. 2004

Arasteh, D., C. Curcija, J. Huang, C. Huizenga, and C. Kohler. Evaluating Fenestration Products for Zero-Energy Buildings: Issues for Discussion. Lawrence Berkeley National Laboratory Report No. 61249. 2006

Arasteh, D., H. Goudey, J. Huang, C. Kohler, and R. Mitchell. Performance Criteria for Residential Zero Energy Windows. Lawrence Berkley National Laboratory Report No. 59190

ASHRAE 1989. ANSI/ASHRAE/IES Standard 90.1-1989. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

ASHRAE 2004. ANSI/ASHRAE/IES Standard 90.1-2004. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Brown, Richard, and J. Koomey. 2003. "Electricity Use in California: Past Trends and Present Usage." Energy Policy, vol. 31: pp. 849–864.

Building Envelope Technology Roadmap. Office of Building Technology, State and Community Programs Energy Efficiency and Renewable Energy, U.S. Department Of Energy.

Callicott, JB and Freyfogle, ET, eds., 1999, *Aldo Leopold. For the health of the land: Previously unpublished essays and other writings, University of Wisconsin Press, Madison.*

Diamond, R., Opitz M., Hicks T., Vonneida B., and Herrera S. 2006. "Evaluating the site energy performance of the first generation of LEED-certified commercial buildings," published in the Proceedings of the 2006 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Washington DC, August, 2006. LBNL-59853.

Craig DiLouie, C., 2004. Energy Code Control Update. White paper. Lighting Controls Association. December.

Emmerich, S., A. Persily, and T. McDowell. Impact of Infiltration on Heating and Cooling Loads in U.S. Office Buildings. National Institute of Standards and Technology.

Emmerich, S., T. McDowell and W. Anis. Investigation of the Impact of Commercial Building Envelope Airtightness on HVAC Energy Use. National Institute of Standards and Technology Reoprt No. NISTIR 7238. June 2005

Energy Information Administration (EIA). 1998. "A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption and Expenditures." DOE/EIA-0625(95). Washington, D.C.: Energy Information Administration.

Energy Information Administration (EIA). 2000. Annual Energy Review. DOE/EIA-384(00). Washington, D.C.: Energy Information Administration. http://www.eia.doe.gov/emeu/aer/contents.html.. Last accessed November 5, 2007.

Energy Information Administration (EIA). 2004. *Annual Energy Outlook 2004 with Projections to 2025*. U.S. Department of Energy. DOE/EIA-0383(2004). www.eia.doe.gov/emeu/aer.

Griffith, B., P. Torcellini, N. Long, D. Crawley, and J. Ryan. Assessment of the Technical Potential for Achieving Zero-Energy Commercial Buildings. National Renewable Energy Laboratory Report No. TP-550-39830. June 2006

Halverson, M., K. Gowri and E. Richman. Analysis of Energy Saving Impacts of New Commercial Energy Codes for the Gulf Coast. Pacific Northwest National Laboratory Report No. 16282. December 2006.

Harris JP, Diamond, R., Iyer M., Payne C.T., and Blumstein C., 2006. "Don’t supersize me! Toward a policy of consumption-sensitive energy efficiency." published in the Proceedings of the 2006 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Washington DC, August, 2006.

Harris, C. Passive and Low-Energy Building – The Future. Proceedings of the INFORSE-Europe Seminar. Wales, UK. September 2003

Hawken, P., 1993. The Ecology of Commerce, Harper Collins, New York.

Herring, H., 2006. Energy efficiency—a critical view. Energy. Vol. 31, No. 1, pp. 10-20.

Holmes, M., and J. Hacker. 2006. Low-energy Design techniques for a Sustainable Future. Arup. London.

Holmgren, D. 2007. The Essence of Permaculture. Holmgren Design Services, Hepburn, Victoria, Australia.

Holmgren, D. 2002. Permaculture: Principles & Pathways Beyond Sustainability. Holmgren Design Services, Hepburn, Victoria, Australia.

Leopold, A, 1947, ‘The ecological conscience’, The Bulletin of the Garden Club of America, September, pp 45-53, Reprinted in Flader, SL and Callicott, JB, eds., *The River of the Mother of God: and other essays by Aldo Leopold,* University of Wisconsin Press, Madison, pp 338-346.

Levine, M., D. Ürge-Vorsatz, K. Blok, L. Geng, D. Harvey, S. Lang, G. Levermore, A. Mongameli Mehlwana, S. Mirasgedis, A. Novikova, J. Rilling, H. Yoshino, 2007: “Residential and commercial buildings.” In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Long, N., P. Torcellini, S. Pless, and R. Judkoff. Evaluation of the Low-Energy Design Process and Energy Performance of the Zion Park Visitors Center. National Renewable Energy Laboratory Report No. CP-550-39013. October 2005

Madsen, J. Zero-Energy Buildings Defined. Buildings.com. August 2007.

Malin, N., and J. Boehland. Getting to Zero; The Frontier of Low-Energy Buildings. Environmental Building News. Volume 14, Number 10, pp.1,12.

Moezzi, M. and Diamond, R. 2004."Is Efficiency Enough? Towards a New Framework for Carbon Savings in the California Residential Sector." California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2005-162.

Moezzi, Mithra. 1998. "The Predicament of Efficiency." In *Proceedings of the 1998 ACEEE Summer Study on Energy Efficiency in Buildings*. Pacific Grove, California. Washington D.C.: American Council for an Energy Efficient Economy.

Muller, H., *et al*. European High Quality Low Energy Buildings. Intelligent Energy Europe Report No. EIE-2003-172 EULEB. February 2007

Newton, JL, 2006, *Aldo Leopold's Odyssey: Rediscovering the author of a sand county almanac*, Island Press, Washington, DC, pp 177-216.

Norgard, Jorgen S., 2000. "Models of Energy Savings: The Battlefield of Environmental Planning." International Journal of Global Energy Issues. Vol. 13, Nos. 1–3, pp. 102–122.

Norgard, Jorgen S., 2006. "Consumer efficiency in conflict with GDP growth," Ecological Economics, vol. 57, no.1, pages 15-29.

Pless, S., and P. Torcellini. Energy Performance Evaluation of a Low-Energy Academic Building. National Renewable Energy Laboratory Report No. CP-550-38962. October 2005

Polimeni, J.M., Mayumi, K., Giampietro, M., Alcott, B., eds., 2008. Jevons' Paradox and the Myth of Resource Efficiency Improvements, Earthscan Publications Ltd., London.

Pratsch, L. Zero Energy Buildings. Proceedings of the 2003 RESNET Conference. San Diego. February 2003

Richmann, E., M. Halverson, D. Belzer, and D. Winiarski. "Comparison of Commercial Building Energy Design Requirements for Envelope and Lighting in Recent Versions of ASHRAE/IESNA Standard 90.1 and the International Energy Conservation Code, with Application to the State of Arizona." Pacific Northwest National Laboratory Report No. 15357, August 2005

Romm, J.J. and Browning, W.D. (1995). Greening the Building and the Bottom Line: Increasing Productivity through Energy-Efficient Design. Rocky Mountain Institute, Snowmass, CO.

Scofield, J.H. 2002. "Early Performance of a Green Academic Building." ASHRAE Transactions, Vol. 108, Part 2, pp. 1214−1230. Atlanta, GA: American Society for Heating, Refrigerating and Air-Conditioning Engineers.

Seidensticker, J, 2002, 'Aldo Leopold's wilderness, Sand County, and my garden', in Knight, RL and Riedel, S, eds, *Aldo Leopold and the Ecological Conscience*, Oxford University Press, New York, pp47-59.

Simmler, H., and S. Brunner. Vacuum insulation panels for building application Basic Properties, aging mechanisms, and service life. Energy and Buildings Report No. 37 (2005) 1122-1131

Tenpierik, M., and H. Cauberg. Vacuum Insulation Panel: friend or Foe?. Proceedings of the 23rd Conference on Passive and Low Energy Architecture, Geneva. September 2006

Torcellini, P., S. Pless, M. Deru, and D. Crawley. Zero Energy Buildings: A Critical Look at the Definition. National Renewable Energy Laboratory Report No. TP-550-39833. June 2006.

Torcellini, P., S. Pless, M. Deru, B. Griffith, N. Long, and R. Judkoff. Lessons Learned from Case Studies of Six High-Performance Buildings. National Renewable Energy Laboratory Report No. TP-550-37542. June 2006.

Torcellini, P., S. Pless, R. Judkoff, and D. Crawley. Solar Technologies & The Building Envelope. ASHRAE Journal April 2007, pp.14-22

Torcellini, P.; Hayter, S.; Judkoff, R. 1999. "Low-Energy Building Design—The Process and a Case Study." ASHRAE Transactions, Vol. 105, Part 2. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.; pp. 802−810.

Torcellini, P.; Long, N.; Pless, S.; Judkoff, R. 2005. "Evaluation of the Low-Energy Design and Energy Performance of the Zion National Park Visitor Center." NREL Report No. TP-550-34607. Golden, CO: National Renewable Energy Laboratory.

Twinn, C. BedZED. The Arup Journal. January 2003

U.S. Department of Energy Office of Energy Efficiency and Renewable Energy (EERE) Program, 2007. "Building Technologies Multi-Year Plan 2007-2011." Chapter 4: Technology Validation and Market Introduction. http://www.eere.energy.gov/buildings/about/mypp.html. Site last accessed on December 5, 2007.

United Nations Environment Program. Buildings Can Play A Key Role In Combating Climate Change. Science Daily. April 2007.

Weidt Group, The. High Performance Building Design in Minnesota. Minnesota Office of Environmental Assistance. June 2005.

Yeang, K., 1995, *Designing with nature: The ecological basis for architectural design,* MacGraw-Hill, New York, pp 65-106.