Re-Arch: The Initiative for Renewable Energy in Architecture

Workshop: Tuesday, April 24, 10:00 a.m. – 4:00 p.m.

Zero Energy Design for Commercial Buildings in Minnesota

Instructors:
Joel Loveland, Seattle Integrated Design Lab
David Eijadi and Tom McDougall, The Weidt Group
Jeff DeLaune, Wisconsin

Co-sponsored by:
College of Design, University of Minnesota
USGBC-Mississippi Headwaters Chapter
The Weidt Group
AIA Minnesota

This workshop is funded in part by the Minnesota Pollution Control Agency, Sustainable Development Unit
Building Value with Integrated Design

THE KEY CHARACTERISTICS OF AN idl PROJECT

TAKES ADVANTAGE OF DAYLIGHT
ENHANCES HUMAN PERFORMANCE
ENERGY EFFICIENCY

University of Washington
College of Architecture & Urban Planning
## Zero Energy Design for Commercial Buildings in Minnesota Workshop

1. Welcome  
   - Time: 10:00 AM

2. Introduction  
   - Time: 10:15 AM

3. Reducing Building Loads  
   - Time: 11:30 AM

**Lunch Break**  
- Time: 12:40 PM

4. Selecting efficient systems and controls  
   - Time: 1:00 PM

5. Renewable Energy Systems  
   - Time: 2:45 PM

6. Informed Building Operation  
   - Time: 3:30 PM

7. Wrap-up Discussion  
   - Time: 3:50 PM

**Adjourn**  
- Time: 4:00 PM
The Weidt Group

- A collaborative, analysis-based approach to finding cost effective solutions
- Energy Design Assistance
  - Consultation & analysis
- Daylighting Design Assistance
  - Consultation & analysis
- Sustainability Assistance
  - LEED consultation & coordination
The Weidt Group
29 7/8 Years of Innovation and Measurable Successes

- Founding Members Building Energy Performance Standards (B.E.P.S)
- Founding Members of ASHRAE 90.1 Committee
- Founding Members of the NFRC
- Participants in DOE’s Whole Building Design Round Table
- Pioneers in software for the A/E Industry
- Members International Program for Measurement and Verification Protocols (IPMVP) for New Construction
- Contributors to NCARB Sustainable Design monograph
- 9 LEED Accredited Professionals
- Contributors to the Minnesota Sustainable Design Guide B3
- Founders IESNA Daylighting Metrics Subcommittee
The Weidt Group
Energy and Software

- Focusing on
  - Decision support
  - Design Support
  - Operations Support
- Andersen Windows
- American Standard
- McQuay
- Electric Power Research Institute
- Herman Miller
- Rytec
The Weidt Group
Nationally and Internationally Recognized

- AIA Top 10 for Earth Day
  - Phillips Eco-Enterprise Center
    - With LHB Engineers and Architects
  - Northland College Environmental Living and Learning Center
    - With HGA Architects and Engineers and LHB Engineers and Architects
  - IAMU Office & Training Facility w/ RDG
  - Tofte Cabin w/ Sarah Nettleton Architects
  - The Program Most Likely to Meet the Intent of the Kyoto Protocols in the Shortest Time
    - Presented by European Council for an Energy Efficient Economy (ECEEE) Xcel Energy’s Energy Assets Program
Where We Work

- **Code**
  - Prescriptive w/ Performance Options

- **Guidelines**
  - Prescriptive w/ Performance Options

- **Practice**
  - Option Based w/ Prescriptive and Performance Variables

Significantly influenced by manufacturing industries

Significantly influenced by social politics

Significantly influenced by business economics

Design Assistance at the transformation sweet spot
The Energy Assets Program records an increasing trend in CO₂ reduction (with a program average of 31%) raising the Current Design practice levels beyond 25% by 2000.

Energy Design Assistance
In 1998 was Beyond Kyoto for 2001
LEED Certified

- Wisconsin DNR Northeast Regional Headquarters, Howard, WI (LEED-NC Gold)
- Quality Bicycle Products Headquarters Expansion, Bloomington, MN (LEED-NC Gold)
- St. Mary’s Duluth Clinic First Street Building, Duluth, MN (LEED-NC Gold)
- Speculative Office Building, McKinney, TX (LEED-CS Platinum)
- Pharmacia Laboratory Facility, Skokie, IL (LEED-NC Gold)
- Karges-Faulconbridge Offices, St. Paul, MN (LEED-EB Gold)
- U.S. DOT Office Building, Lakewood, CO (LEED-NC Silver)
- Van Allen Elementary School, North Liberty, IA (LEED-NC Silver)
- Telecom Building, Community College of Southern Nevada, Las Vegas (LEED-NC Certified)
- Westwood Elementary School, Zimmerman, MN (LEED-NC Certified)
LEED Registered

1.5%

- Labovitz School of Business, University of Minnesota, Duluth
- Science Building, St. Olaf College, Northfield, MN
- Fon du Lac Resource Center, Fon du Lac, MN
- Twin Lakes Elementary School, Elk River, MN
- Science Museum of MN Teacher Resource Center, St. Paul, MN
- Reflections at Bloomington Central Station, Bloomington, MN
- Polaris South Product Development Facility, Wyoming, MN
- EcoLab Building F, Eagan, MN
- United Health Group, Minnetonka, MN
- Wilder Center, St. Paul, MN
- Great River Energy Office Headquarters, Maple Grove, MN
- Burger Federal Courthouse, St. Paul, MN
- Boston Scientific Weaver Lake Campus, Maple Grove, MN
- Watertown/Mayer Elementary School, Watertown, MN
- Watertown/Mayer High School, Watertown, MN
- South Education, Richfield, MN
- Blue Earth Justice Center, Mankato, MN
- Myananda, Westminster, CO
- 1800 Larimar, Denver, CO
- Lincoln Station, Denver, CO
- Signature Center at Denver West, Golden, CO
- Wild Oats 29th Street Signature Store, Boulder, CO
- Oak Park Public Works, Oak Park, IL
- Vandalia Education Center, Kaskaskia College, Vandalia, IL
- Clear Creek Amana High School, Amana, IA
- Marshalltown Public Library, Marshalltown, IA
- Rockwell Collins Office Building 130, Cedar Rapids, IA
- Cedar Rapids Federal Courthouse, Cedar Rapids, IA
- State of Iowa Lab Building, Des Moines
- Davenport Police Station, Davenport, IA
- Public Health SD Services, University of Iowa, Iowa City
- Marion Arts & Environmental Center, Marion, IA
- Hygienics Lab, University of Iowa, Iowa City
- Rosemary Garfoot Public Library, Cross Plains, WI
- North Tract Athletic and Community Center, Arlington, VA
- Metropolitan Hospital, Grand Rapids, MI
- Centennial Hills Library, Las Vegas, NV
- Library/Classroom, Community College of Southern Nevada, Las Vegas
- Science Engineering & Technology Building, UNLV
- CCSD Miley Achievement Center, Las Vegas, NV
- CCSD Northwest Career & Technical School, Las Vegas, NV
- Wetlands Nature Center, Clark County, NV
- J.E. Manch Elementary School, Las Vegas, NV
- Desert Research Institute CRV Building, Reno, NV
- KLVX Studio and Virtual High School for CCSD, Las Vegas, NV
- CCSD-SSSC Service Center, Las Vegas, NV
- Greenbriar Elementary School, Wooster, AR
- Science/Math Complex, East Los Angeles Community College, CA
Daylighting and Sustainability

By Joel Lovelad

Why Use Daylight?
Lighting a space with daylight can make people happier, healthier, more productive, and if you turn the electric lights off, you can also save a great deal of energy. Recent studies, correlating lighting with productivity, show that integrating daylight with electric light in schools, offices and retail stores has a positive impact on a business' bottom line. As important as being better places to work is, these daylighted high-performance buildings offer an increased return on an owner's investment through the building's increased overall asset value at no additional total construction cost.

In the United States, access to daylight, views to corridors to the outside and the reduction of glare in the workplace are key components for compliance with the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED®) sustainable green building standards. Daylighting goals such as these are foreigners for architecture and hallmark a new era of high performance and highly productive building designs. They reveal the ecology of a building's landscape setting and attempt to reconcile its development through sustainable design.

In Europe, countries such as Denmark require employees to have access to daylight in their offices as a matter of health and safety. Most Danish schools have excellent daylight classrooms, less for the students but more from an awareness of how important it is to maintain the most productive and healthful workplace for its teachers.

Increased Productivity: Learning and Retail Sales
The overwhelming results from worker satisfaction, retail sales floor preference and student performance research indicates that people prefer to work, buy and go to school in spaces illuminated with glare-free daylight.

Because occupants feel better in their space, they can concentrate better and longer, which can lead to greater productivity. Many business-oriented professionals over the last few years have begun to underscore the role of daylighting in the results of recent workplace productivity research. Business Week and Fast Company have both highlighted the role of the built environment in attracting and retaining workers. The financial impact on the economy's bottom line is substantial considering the fact that when amortizing the 30-year cost of operating a business, where office work is the dominant activity, employee-related costs are generally 15
Daylight By Design

STUDIES FROM THE BETTWARENS DAYLIGHTING LAB IN SEATTLE ILLUSTRATE HOW DAYLIGHT CAN BE INTEGRATED INTO SITE AND BUILDING DESIGN

By Jeff Agnew

The simple act of sitting under a skylight and gazing at the sky on a sunny day can be profoundly restorative. The immediate benefits are well known: One feels refreshed and energized, both mentally and physically. Scientific research has also demonstrated the long-term benefits: Bright, natural light can improve mood, reduce stress, and boost productivity. The challenge for building designers is to translate these benefits into practical, sustainable design solutions.

Light is a key component of human well-being. It influences our mood, regulates our sleep cycle, and even affects our ability to learn. Yet in many buildings, artificial lighting often dominates the design, with little consideration given to the role of natural light. This can be especially problematic in buildings where people spend significant amounts of time, such as schools, hospitals, and offices.

A recent study conducted by the Betty Warren Daylighting Lab in Seattle examined the impact of daylight on student performance in a classroom setting. The study found that students in classrooms with abundant daylight showed significant improvements in focus, concentration, and overall academic performance. The benefits were most pronounced in subjects that require critical thinking and problem-solving, such as science and mathematics.

The design of the Betty Warren Lab was carefully planned to maximize daylight penetration. The building features large windows and a variety of skylights, allowing natural light to flood the interior spaces. The use of daylight also reduces the need for artificial lighting, which can be costly and energy-intensive. In fact, the building is designed to achieve net-zero energy, meaning that it generates as much energy as it consumes.

The success of the Betty Warren Lab has inspired other architects and designers to incorporate daylighting principles into their work. The challenge is to develop design strategies that are both innovative and sustainable, while also delivering measurable benefits to the occupants.

In conclusion, daylight is not just a luxury in the design of buildings; it is a necessity. By incorporating daylight into our designs, we can create healthier, more productive environments for all. The Betty Warren Lab is a testament to the power of daylight, and a model for how we can design buildings that truly support human well-being.
More Daylight Means Healthier Environments

In the last 50 years we have industrialized many landscapes to maximize production with the least investment of time, resources, and labor. The educational landscape is much the same. In many modern schools, we have turned classrooms into windowsless Lockboxes.

Joel Levinson

The fact that children have poor vision and a “short-sighted” curriculum, which we no longer value, has never been more apparent than in the new school buildings of the last 50 years. In most cases, we haven’t changed a single thing.

School Design History in Brief

In the late 19th century, we were public, on “common” schools with a mission to provide education to all children. The first modern school was built in the early 20th century, at the turn of the century, and in the late 1920s. These schools were windowless, with an emphasis on blackboards and no windows. Today, the focus is on natural light and views.

The Northwest Public Health Magazine

Spring/Summer 2005

Integrated Design Lab

Puget Sound

Northwest Public Health Magazine

Spring/Summer 2005

Integrated Design Lab

Puget Sound
Sky Lab

Simulations at Seattle’s Daylighting Lab teach designers how green their buildings can be.

It’s a typically overcast morning in Seattle, but an architectural model of Bobbi Gwinnicki Johnson’s new Ballard Branch Library is brimming with light. The model is being used at the Daylighting Lab, a facility sponsored by the local architecture firm. If architects study the use of natural illumination to reduce a building’s dependence on electric light, a group of architects planted studies that people are more productive in naturally lit spaces—more architects are turning to daylighting.

Josh Loveland, the Daylighting Lab’s director, has the library model inside a holodeck, a fixture that can be tilted in different directions to correspond with any time of day or year, allowing designers to study the effects of sun orientation, glare, and window placement on their building. Normally, a large electric spotlight is used to simulate the sun. Want to see the building in early January at noon? How about mid-August at 5:30 p.m.? It’s easy to forget all the different geometries of the sun,” Loveland says, adjusting the holodeck. Indeed, to witness its actual effect on a piece of architecture, you’d have to stand outside for 365 days straight.

Both labs also feature an “artificial sky,” a room lined with mirrors that simulate outdoor light but allow lift levels that are safe to be kept stable as that changes to the model (and therefore the design) can be reassessed accurately. Although the artificial sky and the holodeck have both been used for study at various institutions, the Seattle and Portland labs are the first to actively reach out to the commercial building market. With green building moving into public consciousness during the last five years, however, the Daylighting Lab has been busy, consulting on as many as 150 projects per year. Recent clients include Seattle’s city hall and justice center, as well as Arcinie Peck’s Tacoma Art Museum.

The Portland lab, which opened late last fall, hopes to offset some of the workload. Moreover, because it’s part of the University of Oregon’s downtown branch, it draws the interest of local designers as well as experienced green architects.

“A lot of architects are used to design ideas being proprietary, but we’re getting beyond that,” says Bob Carr of Yost Gambif Hall Architecture, who was instrumental in leasing the labs to Portland.

“The lab fosters a community where we can learn together,” – Bob Carr
Integrated Design Lab | Puget Sound

Miller Hull Partnership | Pierce County Environmental Services

Integrated Design Lab | Puget Sound

Mahlum Architects | Seminar Two, the Evergreen State College

AIA/COTE Top Ten Green Projects 2005

http://www.aiatopten.org/hpb/overview.cfm?ProjectID=656
Integrated Design Lab | Puget Sound

Mahlum Architects | Ben Franklin Elementary School

Integrated Design Lab | Puget Sound

Bohlin Cywinski Jackson Architects | Ballard Branch Library, Seattle

AIA/COTE Top Ten Green Projects 2006

http://www.aiatopten.org/hpb/overview.cfm?ProjectID=656
Primary Energy
Consumption per Capita

We are using 400 times the rate of annual renewal
Why We Care
Net Electrical Consumption
Zero-Energy and Carbon Neutral

The way these are defined affects the choices we make to meet the goal, and how we claim success.
Credible scientists give us 10 years to be well on our way toward global greenhouse gas (GHG) emissions reductions in order to avoid catastrophic climate change. Yet there are hundreds of coal-fired power plants currently on the drawing boards in the US. Seventy-six percent (76%) of the energy produced by these plants will go to operate buildings. As Architecture 2030 has shown, buildings are responsible for almost half (48%) of all energy consumption and GHG emissions annually; globally the percentage is even greater. Immediate action in the Building Sector, and a concerted global effort, are essential if we are to avoid hazardous climate change.

Stabilizing emissions in this Building Sector, and then reversing them to acceptable levels over the next ten years, is key to keeping global warming to approximately a degree centigrade (°C) above today’s level. To accomplish this Architecture 2030 has issued The 2030 °Challenge asking the global architecture and building community to adopt the following targets:

- That all new buildings, developments and major renovations be designed to meet a fossil fuel, greenhouse gas (GHG) emitting, energy consumption performance standard of 50% of the regional (or country) average for that building type.

- That at a minimum, an equal amount of existing building area be renovated annually to meet a fossil-fuel, greenhouse gas (GHG)-emitting, energy-consumption performance standard of 50% of the regional (or country) average for that building type (50% of the regional average through innovative design strategies, the application of renewable technologies and/or the purchase - 20% maximum - of renewable energy).

- That the fossil fuel reduction standard for all new buildings be increased to:
  - 60% in 2010
  - 70% in 2015
  - 80% in 2020
  - 90% in 2025

- Carbon-neutral by 2030 (using no fossil-fuel GHG-emitting energy to operate)
# The 2030 °Challenge

## 2030 CHALLENGE Targets

U.S. Average Site Energy Use and 2030 Challenge Energy Reduction Targets by Space/Building Type (CBECS 2003)\(^1\)

From the Environmental Protection Agency (EPA): Use this chart to find the site fossil-fuel energy targets.

<table>
<thead>
<tr>
<th>Primary Space/Building Type</th>
<th>Available in Target Finder</th>
<th>Average Source EUI (^4) (kBtu/Sq.Ft./Yr)</th>
<th>Average Percent Electric</th>
<th>Average Site EUI (^4) (kBtu/Sq.Ft./Yr)</th>
<th>50% Target</th>
<th>60% Target</th>
<th>70% Target</th>
<th>80% Target</th>
<th>90% Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative/Professional &amp; Government Office</td>
<td>✓</td>
<td>199.0</td>
<td>76%</td>
<td>84.2</td>
<td>42.1</td>
<td>33.7</td>
<td>25.3</td>
<td>16.8</td>
<td>8.4</td>
</tr>
<tr>
<td>Bank</td>
<td>✓</td>
<td>681.1</td>
<td>90%</td>
<td>241.4</td>
<td>120.7</td>
<td>96.5</td>
<td>72.4</td>
<td>49.3</td>
<td>24.1</td>
</tr>
<tr>
<td>Clinic/other outpatient health</td>
<td></td>
<td>82.9</td>
<td>61%</td>
<td>44.2</td>
<td>22.1</td>
<td>17.7</td>
<td>13.3</td>
<td>8.8</td>
<td>4.4</td>
</tr>
<tr>
<td>Convenience store (with or without gas station)</td>
<td></td>
<td>1196.0</td>
<td>64%</td>
<td>534.3</td>
<td>267.2</td>
<td>213.7</td>
<td>160.3</td>
<td>106.9</td>
<td>53.4</td>
</tr>
<tr>
<td>Distribution/shipping center</td>
<td></td>
<td>145.7</td>
<td>56%</td>
<td>77.9</td>
<td>39.0</td>
<td>31.2</td>
<td>23.4</td>
<td>15.6</td>
<td>7.8</td>
</tr>
<tr>
<td>Fast food</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Fire station/police station</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Hospital/inpatient health</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Hotel, Motel or Inn</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-12 School</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical Office</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-refrigerated warehouse</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nursing home/assisted living</td>
<td></td>
<td>234.8</td>
<td>54%</td>
<td>124.3</td>
<td>62.2</td>
<td>49.7</td>
<td>37.3</td>
<td>24.9</td>
<td>12.4</td>
</tr>
<tr>
<td>Post office/postal center</td>
<td></td>
<td>131.9</td>
<td>58%</td>
<td>63.5</td>
<td>31.8</td>
<td>25.4</td>
<td>19.1</td>
<td>12.7</td>
<td>6.4</td>
</tr>
</tbody>
</table>

\(^1\) U.S. Environmental Protection Agency (EPA).
Zero-Energy and Carbon Neutral

Zero-net-annual site energy
- Imported energy = exported energy generated on-site in a year

Zero-net-annual source energy
- Energy is generated offsite and transported to the building.
  - 3 units of fuel for a power plant to deliver each unit of electricity
  - 1.1 units of fuel to deliver unit of natural gas

Most zero-site-energy projects, import energy as electricity or natural gas, and produce energy as electricity from photovoltaics or wind turbines.

Buildings with adjacent sources of methane may also claim energy these sources as onsite production.

NREL researchers suggest limiting allowable onsite generation to energy produced within the building’s footprint.
Zero-Energy and Carbon Neutral

- **Zero-net-annual energy cost**
  - The money the utility pays the building owner = the amount it charges the owner for the energy the building imports.

- **Zero-net-annual emissions**
  - A building offsets emissions equivalent to the amount emitted through the source energy that powers the building.
    - Onsite electricity production, as a zero-source-energy building
    - Purchase renewable energy credits

Inefficient buildings can achieve climate neutrality through the purchase of enough RECs.

It makes sense to optimize a building’s efficiency first.
### Architectural Design Process

**Conservation and Efficiency Effectiveness**

<table>
<thead>
<tr>
<th>Conservation</th>
<th>Efficiency</th>
<th>Generation</th>
<th>Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building design fixes the load</td>
<td>Efficient systems meet the load</td>
<td>Energy sources supply energy to fuel systems</td>
<td>People run the systems</td>
</tr>
<tr>
<td>Building shape</td>
<td>Insulation</td>
<td>Sun-photovoltaics</td>
<td>Schedules</td>
</tr>
<tr>
<td>Glass location</td>
<td>Daylighting</td>
<td>Wind</td>
<td>Controls</td>
</tr>
<tr>
<td>Glass area &amp; type</td>
<td>Controls</td>
<td>Sun-active heat</td>
<td>Maintenance</td>
</tr>
<tr>
<td>Thermal mass</td>
<td>Lighting Design</td>
<td>Gas</td>
<td>Windows</td>
</tr>
<tr>
<td>Building volume</td>
<td>HVAC</td>
<td>Micro turbines</td>
<td>Equipment</td>
</tr>
<tr>
<td>Lighting concept</td>
<td>Load responsive controls</td>
<td>Fuel cells</td>
<td>Education</td>
</tr>
<tr>
<td>Mechanical concept</td>
<td>Lighting Controls</td>
<td>10% - 20%</td>
<td>Renewable</td>
</tr>
<tr>
<td>10% - 20%</td>
<td>HVAC</td>
<td>15% - 60%</td>
<td>Affordable</td>
</tr>
<tr>
<td>Minimize load as a first priority</td>
<td>Load responsive controls</td>
<td>1% - 5%</td>
<td>Non-polluting</td>
</tr>
<tr>
<td>10% - 20%</td>
<td></td>
<td>Use appropriate sources of energy</td>
<td>Local source</td>
</tr>
<tr>
<td>10% - 20%</td>
<td></td>
<td></td>
<td>Functionality</td>
</tr>
<tr>
<td>10% - 20%</td>
<td></td>
<td></td>
<td>Efficiency</td>
</tr>
<tr>
<td>10% - 20%</td>
<td></td>
<td></td>
<td>Comfort</td>
</tr>
</tbody>
</table>

Goals:
- Use simple, cost-effective systems
- Use appropriate sources of energy
- Operate the building well
Zero Energy Building Characteristics

1. Design that provides for low energy consumption - less than 30,000 Btus per square foot
   - Uses passive site energy to reduce loads, thru daylight, solar heat, and natural ventilation
   - Uses efficient systems and responsive controls to reduce energy consumption
   - Performance Measurement during design

2. Renewable energy generation
   - System on-site
   - What about purchasing green power?

3. Long term performance monitoring and feedback
   - Commissioning
   - Energy tracking
Zero Energy Economics

Example

- Typical 50,000 square foot office building
- $200 per SF to build
- *Current* Energy Costs $1.00 per SF to operate
- Generates 30 pounds of CO$_2$ per SF per year
Scenario 1
No building efficiency just add wind power

Building
Parking lot

300 KW
100'
Scenario 2
No building efficiency just add PV panels

Add 100,000 SF of PV panels to site
Scenario 3
30% building efficiency add PV and Wind

Reduce Building energy consumption by 30%

Add 40,000 SF of PV panels to site

Add 1 Wind Turbine

Building

Parking lot

300 KW
Scenario 4
70% building efficiency add PV only

Reduce building energy consumption by 70%
Add 40,000 SF of PV panels to site
### Economic First Cost Summary

<table>
<thead>
<tr>
<th>Scenario</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building efficiency improvement</td>
<td>0%</td>
<td>0%</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Energy consumption KBTU/SF</td>
<td>100</td>
<td>100</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>PV collector area SF</td>
<td>0</td>
<td>100,000</td>
<td>40,000</td>
<td>29,000</td>
</tr>
<tr>
<td>Wind turbine qty (300 KW)</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Cost of Building Efficiency $/SF</td>
<td>0</td>
<td>0</td>
<td>$1</td>
<td>$7</td>
</tr>
<tr>
<td>Cost of PV $/SF</td>
<td>$0</td>
<td>$120</td>
<td>$50</td>
<td>$35</td>
</tr>
<tr>
<td>Cost of Wind $/SF</td>
<td>$175</td>
<td>$0</td>
<td>$44</td>
<td>$0</td>
</tr>
<tr>
<td>Downsizing credit $/SF</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>($17)</td>
</tr>
<tr>
<td><strong>Total Cost $/SF</strong></td>
<td><strong>$175</strong></td>
<td><strong>$120</strong></td>
<td><strong>$95</strong></td>
<td><strong>$25</strong></td>
</tr>
</tbody>
</table>
Zero Energy Building
Implications

- Typical energy consumption: 100 kBtu/SF
- Design and Operation Challenge
- Energy consumption goal: 30 kBtu/SF or less
Building Value integrated design and Zero Energy (more for less!) inside-out...
What we know and how we know it, about buildings...
In new construction and renovation, the key practice to increase your building’s value is *integrated design* (idl).
In new construction and renovation, the key practice to increase your building’s value is integrated design (id).

id helps projects adopt key energy-related practices that...

- Support highest quality and the most productive working, healing and learning environments.
In new construction and renovation, the key practice to increase your building’s value is *integrated design* (id).

*id* helps projects adopt key energy-related practices that...

- Support *highest quality and the most productive* working, healing and learning environments.
- Improve the building owner’s bottom line with *increased energy efficiency*. 
In new construction and renovation, the key practice to increase your building’s value is *integrated design (id)*.

*id* helps projects adopt key energy-related practices that…

- Support *highest quality and the most productive* working, healing and learning environments.
  - **Quality lighting**, *daylight* as the primary source of illumination
Utilize DIFFUSE daylight as your primary source of illumination.

**WHY**
In the United States - most school classrooms are either one-story or on the top floor under the roof.

**Daylight?**

**WHY Not?**
2/3’s of the remaining floor area is within 25 feet of a windowed wall

*A High-performance school is a THIN school!!*
Utilize DIFFUSE daylight as your primary source of illumination.

There is no reason that daylight shouldn’t be an integral element of every project TODAY!

Because...

WHAT WE KNOW, and HOW we know...

about DAYLIGHT.
Integrated Design Lab | Puget Sound

Laboratory Experimentation
Development and Use of a Quantitative Method for

Specification of Interior Illumination Levels

on the Basis of Performance Data

By H. RICHARD BLACKWELL

An eight-year program of research is reported here which has led to the development of a general method by which illumination levels may be determined for various practical tasks, based upon visual performance criteria. During those years, the author had the friendly guidance of the Technical Advisory Committee on Light and Vision of the Illuminating Engineering Research Institute, and he wishes to acknowledge his indebtedness to particular interest of Dr. G. A. Fry, Professor Everett M. Strong, Dr. Sydney K. Guth, and Mr. Willard Alpin of this committee for many helpful suggestions. In addition, Mr. A. S. Glancy, Secretary-Treasurer of the Illuminating Engineering Society, has been a strong motivating force in the conduct of this research, and has provided many extremely valuable ideas over the years. The lighting specifications report not only described the basic elements of the method but also recommended specific procedures to be followed in applying the method at the present time. The selection of procedures to be used currently was based upon all available relevant knowledge. The present report describes the method in its most general form, indicating the procedures recommended for current use. It goes beyond all other reports, however, by describing in addition what may well be the ultimate procedures for using the method, and by indicating the kinds of research needed to develop those procedures.

Laboratory Experimentation
Figure 1. Observers seated in the basic laboratory testing room. The observation screen may be varied in luminance. The standard disc target is produced by transillumination of the screen from behind.
<table>
<thead>
<tr>
<th>Task No.</th>
<th>Task Description</th>
<th>Method Involving Integer</th>
<th>Recommended Method:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reading while writing: sample of ink writing, one 6th grade student</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Reading while writing: samples of No. 2 pencil writing, twelve 6th grade students with poorest writing in class of 31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Reading: 2-point Redi-Point type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Reading: 8-point text type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Reading: 8-point text type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Reading: 10-point text type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Reading: 12-point text type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Reading while transcribing: sample of short-hand copy with No. 3 pencil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Reading: typed original, good ribbon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Reading: typed original, extremely poor ribbon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Reading: typed carbon, fifth copy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Reading: dark blue monograph mesh, with their plastic overlay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Reading: Tegmex copy, poor quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Reading: No. 2 pencil on tracing paper over water dry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Cutting: white chalk mark on blue paper cloth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Inspection: dot defects on dark blue cloth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Inspection: grey line defects on black cloth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Inspection: damaged finish on grey cloth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Inspection: brown stitching on brown silk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Vertical stitching</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Horizontal stitching</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Inspection: grey stitching on grey cloth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Cutting: orange chalk on light brown trowel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Cutting: orange chalk on light brown trowel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Cutting: orange chalk on light brown trowel</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Daytime manufacturing workers more satisfied than workers in the other two shifts.

Daytime workers almost as highly satisfied as office workers.

Highest satisfaction with daylight and windows.

_Herman Miller Headquarters: Case Study on Worker Satisfaction and Productivity_
Judith Heerwagen PH.D.

Case Study Analysis
Daylighting in Retail Sales and Schools
Heschong Mahone Group, 1999
PI EER Reanalysis, Daylighting in Schools
California Energy Commission, 2002
Utilize DIFFUSE daylight as your primary source of illumination.

**WHY** Daylight?
Light, Daylight and Healthfulness

Dilouie, 1996;

80% of perception is visual, with aspects of:

• View
• Environmental Information
• Spectral Quality
• Variability
• Photobiology

The Real (daylight)

The Consistent and Efficient -- the Commodified (electric light)
Dilouie, 1996;

80% of perception is visual, with aspects of:

- View
- Environmental Information
- Spectral Quality
- Variability
- Photobiology

Photobiology

*Non vision related effects:*

- Synthesis of Vitamin D
  - skin exposure to sunlight (UVb)
  - supports skeletal growth

University of Washington, College of Architecture & Urban Planning, Seattle
Zero Energy Design in Minnesota, Workshop
Dilouie, 1996;

80% of perception is visual, with aspects of:

• View
• Environmental Information
• Spectral Quality
• Variability
• Photobiology

Photobiology

Non vision related effects:

• Regulation of chronobiological system
  ▪ Minor Disruptions:
    Regulation of the sleep/wake cycle
    Jet lag – Daylight Savings Time lag
  ▪ Severe Disruptions:
    Seasonal Affective Disorder (SAD)
Dilouie, 1996;

80% of perception is visual, with aspects of:

- View
- Environmental Information
- Spectral Quality
- Variability
- Photobiology
Utilize DIFFUSE daylight as your primary source of illumination.

There is no reason that daylight shouldn’t be an integral element of every school project TODAY!

Because . . . .

WE KNOW - people feel healthier and are more . . . productive

with DAYLIGHT.
Common Worker Productivity Changes with Good or Bad Design

-20%  norm  +20%

-10%  +40%

-20%
Productivity and Daylight
Daylighting in Retail Sales
Heschong Mahone Group, 1999
Utilize DIFFUSE daylight as your primary source of illumination.

There is no reason that daylight shouldn’t be an integral element of every school project TODAY!

Because . . . .

WE KNOW - people feel Healthier, more productive AND Energy Efficient with DAYLIGHT.
In new construction and renovation, the key practice to increase your building’s value is *integrated design (idl).*

*idl* helps projects adopt key energy-related practices that…

- Support *highest quality and the most productive* learning environment.
- Improve the owner’s bottom line with *increased energy efficiency.*
Primary Energy
Consumption per Capita

Tonnes oil equivalent

We are using 400 times the rate of annual renewal.
Why We Care
Net Electrical Consumption

Net Electrical Consumption Chart:
- United States
- Japan
- Korea, South
- Taiwan
- Netherlands
- United Kingdom
- Ireland
- Hong Kong
- Italy
- Lebanon
- Brazil
- Mexico
- China
- Egypt
- India

Year: 1980 to 2002
Billion kWh per Million People

Why We Care:
- Net Electrical Consumption
Figure 8. U.S. carbon dioxide emissions by sector and fuel, 1990-2030 (million metric tons)
Figure 15. Additions to electricity generation capacity in the electric power sector, 1990-2030 (gigawatts, net summer capacity)
### Table 5. Miscellaneous electricity uses in the residential sector, 2005, 2015, and 2030 (billion kilowatthours)

<table>
<thead>
<tr>
<th>Electricity use</th>
<th>2005</th>
<th>2015</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee makers</td>
<td>4.0</td>
<td>4.7</td>
<td>5.5</td>
</tr>
<tr>
<td>Home audio</td>
<td>11.8</td>
<td>12.6</td>
<td>14.0</td>
</tr>
<tr>
<td>Ceiling fans</td>
<td>16.8</td>
<td>20.1</td>
<td>23.5</td>
</tr>
<tr>
<td>Microwave ovens</td>
<td>14.3</td>
<td>16.3</td>
<td>19.0</td>
</tr>
<tr>
<td>Security systems</td>
<td>1.9</td>
<td>1.8</td>
<td>2.4</td>
</tr>
<tr>
<td>Spas</td>
<td>8.3</td>
<td>9.6</td>
<td>12.7</td>
</tr>
<tr>
<td>Set-top boxes</td>
<td>17.1</td>
<td>30.0</td>
<td>32.7</td>
</tr>
<tr>
<td>Color TVs</td>
<td>52.1</td>
<td>72.9</td>
<td>92.5</td>
</tr>
<tr>
<td>Hand-held rechargeable devices</td>
<td>9.8</td>
<td>9.0</td>
<td>10.6</td>
</tr>
<tr>
<td>DVRs/VCRs</td>
<td>15.6</td>
<td>12.0</td>
<td>9.8</td>
</tr>
<tr>
<td><strong>Total, miscellaneous uses studied</strong></td>
<td>151.7</td>
<td>188.9</td>
<td>222.7</td>
</tr>
<tr>
<td>Other miscellaneous uses</td>
<td>232.5</td>
<td>325.2</td>
<td>432.7</td>
</tr>
<tr>
<td><strong>Total miscellaneous</strong></td>
<td>384.2</td>
<td>514.1</td>
<td>655.4</td>
</tr>
<tr>
<td>Total residential sector electricity use</td>
<td>1,364.8</td>
<td>1,591.2</td>
<td>1,896.5</td>
</tr>
</tbody>
</table>
Figure 24. Average annual growth rates of real GDP, labor force, and productivity, 2005-2030 (percent per year)
Zero-Energy and Carbon Neutral

The way these are defined affects the choices we make to meet the goal, and how we claim success.

Table 1. ZEB Renewable Energy Supply Option Hierarchy

<table>
<thead>
<tr>
<th>Option Number</th>
<th>ZEB Supply-Side Options</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Reduce site energy use through low-energy building technologies</td>
<td>Daylighting, high-efficiency HVAC equipment, natural ventilation, evaporative cooling, etc.</td>
</tr>
<tr>
<td>1</td>
<td>Use renewable energy sources available within the building’s footprint</td>
<td>PV, solar hot water, and wind located on the building.</td>
</tr>
<tr>
<td>2</td>
<td>Use renewable energy sources available at the site</td>
<td>PV, solar hot water, low-impact hydro, and wind located on-site, but not on the building.</td>
</tr>
<tr>
<td>3</td>
<td>Use renewable energy sources available off-site to generate energy on-site</td>
<td>Biomass, wood pellets, ethanol, or biodiesel that can be imported from off site, or waste streams from on-site processes that can be used on-site to generate electricity and heat.</td>
</tr>
<tr>
<td>4</td>
<td>Purchase off-site renewable energy sources</td>
<td>Utility-based wind, PV, emissions credits, or other &quot;green&quot; purchasing options. Hydroelectric is sometimes considered.</td>
</tr>
</tbody>
</table>
Owner’s Objectives
Four Elements of The Big Back Yard

- EarthScapes Mini-golf and Exhibits
- Prairie Maze
- Native American Heritage Gardens
- Science House
Owner’s Objectives

- The desire for outdoor space arose from two motivations - one idealistic and the other pragmatic.
- Idealistic – many scientific phenomena do not lend themselves to being demonstrated indoors.
- Pragmatic – dispel the notion of the Museum as being strictly an indoor experience.
Overall Project Goals
Science House and The Big Back Yard

Serve as

- A dynamic working model for energy efficiency and renewable energy
- A beacon for the Science Museum’s environmental initiatives
- An interpretive center for environmental programming
- Headquarters in a landscape that teaches Earth-systems science, while connecting people to their natural and built environments
Process
Design and Analysis
Process
Design and Analysis
Integration

The integration of architectural, lighting and HVAC components are important but …

- Integrating the owner and occupant in the design and operation of the building is even more important for a project’s long term success

- The missing Link in sound sustainable design performance today is our inability to measure and manage building performance

- This is a people thing; this is not a technology thing
Components are collaboratively resolved
Components are dependent and supportive
Components are tuned and attuned for optimal results
Components are not just cohabitant
Components are not just concurrent
Components are not just tandem
Components are not just parallel
Optimization Interdependence

Conceptual Design  Design Development  Contract Documents  Occupied Building

Broad Goal
Big Idea
Much Possibility

Optimized Solution
Experience informs us that we can at least reduce annual energy consumption requirements to 30 \( k\text{Btu/SF} \) or, roughly 10,000 kWh per year.

Conceived at the scale of a house and yet facilitate commercial activities:
- Office, classroom and display space

Original program called for a 1,500 square foot building with:
- Four-season greenhouse, outdoor and indoor classroom/laboratory and a project studio with full telecommunications and Internet capability.
To be a net energy producer, the fixed budget needed to include building a power supply as well as a building.

The cost of energy generation is not normally in the design and construction budget.

First assess the potential for energy conservation:
- Program area
- Interpretive Programming
- Interpretive Technologies
- Comfort and Control

The Defining Question:
“How much building can we build and generate power for with the given budget?”
Conceptual Design
Decision Support with Comparative Analysis

Four scenarios for building scale and cost were being considered. These figures show the smallest scenario under consideration.

The 1,500 square foot building becomes a 500 square foot building with a 500 square foot covered outdoor area.

The smallest scenario under consideration.
## Conceptual Design
### Decision Support with Comparative Analysis

<table>
<thead>
<tr>
<th>Program Area</th>
<th>Interpretive Programming</th>
<th>Interpretive Technologies</th>
<th>Comfort and Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base $/SF</td>
<td>Budget</td>
<td>PV Gen.</td>
<td>Base Cons.</td>
</tr>
<tr>
<td>$300</td>
<td>$450,000</td>
<td>10 kWh/sf</td>
<td>23.4 kWh/sf</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conditioned Area</th>
<th>1500</th>
<th>1000</th>
<th>1500</th>
<th>1304</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption Factor</td>
<td>1</td>
<td>1</td>
<td>0.7</td>
<td>0.4</td>
</tr>
<tr>
<td>Conservation Cost PSF</td>
<td>$ -</td>
<td>$ -</td>
<td>$2</td>
<td>$5</td>
</tr>
<tr>
<td>PV Cost PSF</td>
<td>$100</td>
<td>$100</td>
<td>$100</td>
<td>$100</td>
</tr>
<tr>
<td>Construction Cost PSF</td>
<td>$300</td>
<td>$300</td>
<td>$302</td>
<td>$305</td>
</tr>
<tr>
<td>PV Dollars</td>
<td>$150,000</td>
<td>$100,000</td>
<td>$105,000</td>
<td>$52,160</td>
</tr>
<tr>
<td>Construction Cost</td>
<td>$450,000</td>
<td>$300,000</td>
<td>$453,000</td>
<td>$397,720</td>
</tr>
<tr>
<td>Remainder</td>
<td>$150,000</td>
<td>$50,000</td>
<td>$108,000</td>
<td>$120</td>
</tr>
</tbody>
</table>

Consumption Factor is the inverse of Conservation Factor
Assumes a fixed schedule of use but flexibility with technology
Actual analysis used base load of 23.4 w/sf / generation capacity of 13 kWh/sf and $85 /sf as initial parameters
### Conceptual Design

**Decision Support with Comparative Analysis**

<table>
<thead>
<tr>
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<td>$(150,000)</td>
<td>$50,000</td>
<td>$(108,000)</td>
<td>$120</td>
</tr>
</tbody>
</table>

| kWh/ Consumption   | 35,100 | 23,400 | 24,570 | 12,205 |
| kWh/ Production    | 15,000 | 10,000 | 15,000 | 13,040 |
| % of Need          | 43%    | 43%    | 61%    | 107%   |
# 3. Reduce building loads

<table>
<thead>
<tr>
<th>Conservation</th>
<th>Efficiency</th>
<th>Generation</th>
<th>Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building design fixes the load</td>
<td>Efficient systems meet the load</td>
<td>Energy sources supply energy to fuel systems</td>
<td>People run the systems</td>
</tr>
<tr>
<td>Building shape</td>
<td>Insulation</td>
<td>Sun-photovoltaics</td>
<td>Schedules</td>
</tr>
<tr>
<td>Glass location</td>
<td>Daylighting Controls</td>
<td>Wind</td>
<td>Controls</td>
</tr>
<tr>
<td>Glass area &amp; type</td>
<td>Lighting Design</td>
<td>Sun-active heat</td>
<td>Maintenance</td>
</tr>
<tr>
<td>Thermal mass</td>
<td>HVAC</td>
<td>Gas</td>
<td>Windows</td>
</tr>
<tr>
<td>Building volume</td>
<td>Load responsive controls</td>
<td>Micro turbines</td>
<td>Equipment</td>
</tr>
<tr>
<td>Lighting concept</td>
<td>Lighting Design</td>
<td>Fuel cells</td>
<td>Education</td>
</tr>
<tr>
<td>Mechanical concept</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% - 20%</td>
<td>15% - 60%</td>
<td>1% - 5%</td>
<td>10% - 20%</td>
</tr>
<tr>
<td>Minimize load as a first priority</td>
<td>Use simple, cost-effective systems</td>
<td>Use appropriate sources of energy</td>
<td>Operate the building well</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Goals:
- Renewable
- Affordable
- Non-polluting
- Local source

Functionality
- Efficiency
- Comfort
Integrated Design Lab | Puget Sound

University of Washington, College of Architecture & Urban Planning, Seattle
Zero Energy Design in Minnesota, Workshop
Integrated Design Lab | Puget Sound

~ 7 watts/Sq. Ft.
(1 tower =~ 100,000 SF of PV)

660,000 watts/tower
Whoa... Trigger!

University of Washington, College of Architecture & Urban Planning, Seattle
Zero Energy Design in Minnesota, Workshop
Integrated Design Lab | Puget Sound

Whoa... Trigger!
Integrated Design: What is it?

A systems approach, that we call integrated design, has the potential to create buildings with lower first costs, better comfort conditions and large energy savings.
Integrated Design Lab | Puget Sound

Integrated Design: What is it?

Integrated design synthesizes climate, use, loads and systems resulting in a more comfortable and productive interior environment, and a building that is more energy-efficient than current best practices.
Integrated Design: What is it?

Considerations (traditionally)

- Patterns of Use
- Patterns of Climate
- Building Design
- Building “Systems”

Loads
Re-Actions (consume energy)
Integrated Design Lab I Puget Sound

Integrated Design: What is it?
Considerations (common today, code-compliant)

- Climate
- Building Use
- Site and Building Design

Loads

Systems

Energy Demands (100%)
Integrated Design: What is it? Considerations (common today, code-compliant)

Climate

Building Use

Site and Building Design

Loads

Systems

Double Efficiency (with better boilers, pumps, heat recovery, good glass etc.)

Energy Demands (75%)

25% System Efficiency reduction
Feature Story - July 2004

Designed Healing

Healthcare Architecture Changing with the Times

In the healthcare world, architectural innovation is at the vanguard. In the past, designers and builders are responding to increased stress levels, devastation and

Integrated Design Lab Puget Sound

Northwest Construction

PROVIDENCE NEWBERG GETS GREEN - AND GOLD!
NEW MEDICAL CENTER IS "GREENEST" HOSPITAL IN THE NATION

Aug 9, 2006

NEWBERG, Ore. - Oregon's newest hospital is also the nation's greenest. The U.S. Green Building Council has announced that Providence Newberg Medical Center (PNMC) received Gold LEED (Leadership in Energy and Environmental Design) certification, making it the "greenest" hospital in the United States. Providence Newberg is the first hospital in the nation to earn this designation.

"We've been working for this kind of recognition from the earliest stages of the project, and to see it come true is a tribute to everyone who has done so much to make it happen," said Larry Gowe, chief executive, Providence Newberg Medical Center. "This is a great honor and shows Providence's commitment to the health of our community."

This recognition makes Providence Newberg a national leader in creating a healthy hospital environment for patients, visitors and employees through design, construction and material selection.

"All the evidence shows that green hospitals help people heal faster," said Rick Podrazik, president, chief executive officer and founding chair, U.S. Green Building Council. "As the first LEED Gold hospital, Providence Newberg Medical Center is proving their commitment not only to the health of their patients, but also to the well-being of their staff, their community, and the environment. Providence's leadership is an inspiration to health care providers everywhere."

Providence Newberg is the first hospital to be built from the ground up in three decades by Providence Health System (PHS). Providence leaders decided early in the process that this $70.6 million facility would set the standard for good stewardship, a core value of PHS. It has.

The "built green" effort will pay off for Providence Newberg. In just 14 months, the facility will have repaid its initial investment - and in just over a year the new facility will save nearly 30 percent in annual energy costs.

"It's the smart way to build," explains Richard Baur, Providence Health System director of energy management services. "We use our natural resources responsibly, we reduce our energy costs, and as a result we put more money back into patient care and the community. Most importantly, we create a healthy building for patients and staff."

Highlights of this state-of-the-art green medical facility include:

- 100 percent of all electrical needs met by purchasing green power (30 percent wind, 25 percent geothermal, 25 percent fuel impact hydro), PNNL is the only hospital in the nation to purchase 100 percent green power.

University of Washington, College of Architecture & Urban Planning, Seattle
Zero Energy Design in Minnesota, Workshop
Executive buy in to high-performance.

The *id* process was supported by BetterBricks Integrated Design Lab Network.

High-efficiency HVAC; 100% outside air w/ 70% efficient exhaust heat recovery.

High-performance glazing.

Daylighting in public areas.

Efficient and well-controlled fluorescent light sources to minimize lighting load.

Increased insulation levels.

**Results:**
- LEED Gold!
- 26% less than Oregon energy code.
- $180,000/yr operating cost savings; over 50% IRR.
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Integrated Design: What is it?
Considerations (high-performance today)

Synergies >>

- Patterns of Climate
- Patterns of Use
- Design of Site and Building “Loads”
- Design of Building “Systems”

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Integrated Design: What is it?

Considerations (common today, code-compliant)

- Climate
- Building Use
- Site and Building Design

Loads
Cut by 30%

with better lighting & thermal comfort criteria, daylighting, natural ventilation, high thermal mass, & the elimination of whole systems, etc.

Energy Demands (70%)
Integrated Design: What is it?

Considerations (common today, code-compliant)

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Climate

Building Use

Site and Building Design

Systems

Loads Cut by 30%

Energy Demands (50%)

30% System Efficiency reduction
Lillis Business Complex

Overview

- Location: Eugene, OR.
- Building type(s): Higher education
- New construction
- 137,000 sq. ft (12,800 sq. meters)
- Project scope: 4-story building
- Urban setting
- Completed October 2003
- Rating: U.S. Green Building Council LEED-NC, v.2/v.2.1—Level Silver (33 points)

This state-of-the-art teaching facility replaced an outdated building and connected three existing buildings to form an integrated academic center. The site design redefined the open space network at the north end of the main campus quadrangle without compromising pedestrian circulation along its axis.

The facility declares the business school’s commitment to training future business leaders in the principles of sustainability. Its soaring atrium lobby is rimmed by a café, public meeting rooms, interview rooms, specialized learning centers, and administrative offices. The wings extending from this core house flexible tiered classrooms, case study rooms, faculty offices, a 283-seat auditorium, and a 238-seat lecture hall.
University of Oregon, executive buy in to high-performance.
The *id* process by ESBL of the BetterBricks Integrated Design Lab Network.
Daylighting in all classroom, office & public areas.
High-efficiency HVAC; 100% outside air w/ 70% efficient exhaust heat recovery.
Natural ventilation for average cooling.
High-mass with night ventilation for most peak cooling.
High-performance glazing.
Efficient and well-controlled florescent light sources to minimize electric lighting load.
Increased insulation levels.

**Results:**
- LEED Silver!
- 46% less energy use than Oregon energy code.
Integrated Approach for Lighting, Heating and Cooling with:
Early Energy Modeling in PRE-DESIGN!
Energy-Comfort Goals Programmed in PRE-DESIGN for:
Air Quality, Thermal Comfort, Electric Lighting & Daylight
Integrated Approach - Daylighting, SETTING CLEAR DESIGN GOALS ie.: REQUIRING a minimum level of daylight in critical task spaces.
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Integrated Approach: Daylighting, TESTING for Performance
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Daylight Factors

Early and persistent testing for daylighting and energy performance
Integrated Design Process

DESIGN PROCESS

- Master Planning & Programming
- Schematic Design
- Design Development
- Construction Documents
- Construction Administration
- Post-Occupancy

DESIGN STRATEGIES

1. Create Sm. Loads
2. Passive Systems
3. Efficient Systems
4. Controls

DESIGN TOOLS

- Other Tools
- Modeling

Adapted from "What is Integrated Design" by GZ Brown, University of Oregon, ESBL

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**Integrated Design Process**

**DESIGN STRATEGIES**

1. Create Sm. Loads
2. Passive Systems
3. Efficient Systems
4. Controls

**DESIGN TOOLS**

Other Tools
Modeling

**DESIGN TOOLS TOOLS**

Master Planning & Programming
Schematic Design
Design Development
Construction Documents
Construction Administration
Post-Occupancy

Adapted from “What is Integrated Design” by GZ Brown, University of Oregon, ESBL

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### Integrated Design Process

<table>
<thead>
<tr>
<th>DESIGN PROCESS</th>
<th>DESIGN STRATEGIES</th>
<th>DESIGN TOOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master Planning &amp; Programming</td>
<td>1 Create Sm. Loads</td>
<td>Other Tools</td>
</tr>
<tr>
<td>Schematic Design</td>
<td>2 Passive Systems</td>
<td>Modeling</td>
</tr>
<tr>
<td>Design Development</td>
<td>3 Efficient Systems</td>
<td></td>
</tr>
<tr>
<td>Construction Documents</td>
<td>4 Controls</td>
<td></td>
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<tr>
<td>Construction Administration</td>
<td></td>
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<tr>
<td>Post-Occupancy</td>
<td></td>
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</tr>
</tbody>
</table>

### Design Tools

- Adapted from “What is Integrated Design” by G.Z. Brown, University of Oregon, ESBL

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## Integrated Design Process

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<td></td>
</tr>
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### DESIGN TOOLS
- Other Tools
- Modeling

### DESIGN STRATEGIES
- 1 Create Sm. Loads
- 2 Passive Systems
- 3 Efficient Systems
- 4 Controls

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Adapted from “What is Integrated Design” by GZ Brown, University of Oregon, ESBL
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Providence Center for Orthopedic Recovery
Sacred Heart Medical Center
Spokane, WA

Integrated Design, Schematic Design Energy Analysis
Gary Signs and Chris Lamb Mahlum Architects
Bob Axley, Wood Harbinger Engineers

with
Mike Hatten, Solarc Engineers
Judy Theodorson, WSU BetterBricks Integrated Design Lab, Spokane
Joel Loveland, UW BetterBricks Integrated Design Lab, Puget Sound
A baseline “Energy Code” building, modeled in schematic design with Equest software – for comparison...
Annual Energy Use

Baseline “Energy Code” Building

- Hot Water @ 31%
- Lighting @ 14%
- Heating @ 41%

132,000 Btu/Sq. Ft.
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Peak Cooling - September 5th @ 4PM

- Lighting @ 21%
- Windows: Conduction @ 12%
- Windows: Solar @ 40%
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COMFORT PREDICTION?

I can't hear myself think.

It's really hard to type with your mittens on.

Another day at the sweat shop.

Another day working in the dark, literally.

I think I can see my breath.

Turn down the @#$!* heat.

It's too quiet in here.

Our new task force on cubicle comfort has been very effective. They've eliminated any trace of it.

You could fly a kite in this breeze.

I can still smell Wally's chili.

I don't think this air moved since 1957.

Turn up the @#$!* heat.
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Climate

Wind patterns and temperature profiles for the city can suggest design strategies for discussion:

Seattle

2006 weather

The National Weather Service provides information taken at Seattle-Tacoma International Airport.

<table>
<thead>
<tr>
<th>Month</th>
<th>Average High</th>
<th>Average Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>50.8°</td>
<td>36.0°</td>
</tr>
<tr>
<td>February</td>
<td>49.6°</td>
<td>36.1°</td>
</tr>
<tr>
<td>March</td>
<td>52.2°</td>
<td>38.3°</td>
</tr>
<tr>
<td>April</td>
<td>58.7°</td>
<td>41.9°</td>
</tr>
<tr>
<td>May</td>
<td>66.1°</td>
<td>54.0°</td>
</tr>
<tr>
<td>June</td>
<td>72.2°</td>
<td>54.7°</td>
</tr>
<tr>
<td>July</td>
<td>78.1°</td>
<td>56.9°</td>
</tr>
<tr>
<td>August</td>
<td>72.4°</td>
<td>52.2°</td>
</tr>
<tr>
<td>September</td>
<td>59.1°</td>
<td>45.5°</td>
</tr>
<tr>
<td>October</td>
<td>49.1°</td>
<td>35.4°</td>
</tr>
<tr>
<td>November</td>
<td>45.3°</td>
<td>39.2°</td>
</tr>
<tr>
<td>December</td>
<td>45.8°</td>
<td>36.4°</td>
</tr>
</tbody>
</table>

* Norms based on 30-year average.
** Figures through 12/30. This chart will be updated with year-end figures on seattletimes.com
Wind patterns and temperature profiles for the Spokane area suggest several points of discussion:

- Admit Solar Radiation
- Use Evaporative Cooling
- Use Ceiling Fans
Climate
Wind patterns and temperature profiles for the Spokane area suggest several points of discussion:
Climate

Wind patterns and temperature profiles for the Spokane area suggest several points of discussion:
**Climate**

Wind patterns and temperature profiles for the Spokane area suggest several points of discussion:

1. What opportunities, if any, exist for natural ventilation strategies? How do these factor into the knowledge of prevailing wind directions?

2. Given the average annual temperature profiles, what design considerations would increase the probability of achieving a consolidated “winter” economizer period where the chiller can be seasonally mothballed, and cooling loads met completely with outside air?
**Use**

An overview of the various uses (functional areas) currently slated to be included in to project suggests the following points of additional discussion, some related to previous climate issues:

1. Is there sufficient waste heat from any functions to recover for use in pre-tempering wintertime ventilation air or making potable hot water?

2. Can thermal zoning and systems assignment be designed in such a way as to separate areas that are anticipated to have discrete occupancy schedules from those that are anticipated to be occupied continuously?
A preliminary “shoebox” energy and loads model has been developed using Equest/DOE2. An evaluation of preliminary predictions for peak heating and cooling loads suggests the following points of discussion:

1. Can a set of design goals for ultra-efficient integrated lighting be developed that significantly reduce total connected load while overlaying controls that de-energize lights in response to daylight and occupancy? How can the amount of illuminated area that receives meaningful daylight be maximized?

2. What are the strategies for improving thermal performance of the windows while shading (or otherwise reducing) direct solar gain during the summertime cooling season?
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**Systems**

A preliminary “shoebox” energy and loads model has been developed using Equest/DOE2. An evaluation of preliminary predictions for peak heating and cooling loads suggests the following points of discussion:

1. What system **efficiency & supply options** / alternatives are possible to address energy use associated with space heating, plug loads and equipment, lighting, and potable water heating?

2. What **interior temperature design criteria** are to be used for system sizing?

3. How can **“extra” capacity** be designed into the air and water distribution systems (for future expansion) without compromising initial energy efficient system performance?
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Challenge:
Provide Diffuse Daylight with Adequate Solar/Glare Control

Second and Third Floors (North Facing Glass)
Data taken with all Clear Glass conditions and no sun-control devices

Second Floor Clear Glass in Skylight with Black Screen attached

Third Floor Translucent Glass in Skylight with Black screen attached

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Challenge:
Optimizing the Section for Light and Air

Well Aperture 1
Well Aperture 2
Well Aperture 3
Well Aperture 4

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Daily Conditions for May 27th

LEGEND
Comfort: Thermal Neutrality
Temperature | Direct Solar
Relative Humidity | Diffuse Solar
Wind Speed | Cloud Cover

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April

from the Southeast
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May

June

July

August

September

October

November

December
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2200 FC Summer
1500 FC Autumn/Spring
650 FC Winter - noon

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In new construction and renovation, the key practice to increase your building’s value is **integrated design (id)**.

**id** helps projects adopt key energy-related practices that…
- Support **highest quality and the most productive** learning environment.
- Improve the districts bottom line with **increased energy efficiency**.
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High Performance Classroom Prototype
Mt. Angel, Oregon

As sustainability and energy efficiency have come to occupy an ever-greater role in mainstream architecture and construction, no building type has embraced these principles more than schools. Maybe it’s because of the higher test scores that come when students learn in naturally lit classrooms. Or the reduced operating expenses that ease the burden of constrained school budgets. But the Northwest is now dotted with elementary, middle and high schools that offer better learning environments and significantly reduced operating expenses through sustainable high performance design.

Recently, a trio of the Northwest’s foremost experts on energy-efficient design resolved to build a full-scale mockup of a K-12 classroom: 102. “Charlie” Brown (professor of architecture at the University of Oregon and manager of the University’s Energy Study in Buildings Lab in Portland and Eugene supported by BetterBricks) and Mike Hatten, principal of SOWACO Architecture and Engineering, joined with Heinz Rudolf (principal with ROOKA Architects and designer of several nationally-renowned LEED-rated Northwest schools) to create a classroom that so adeptly utilized available light and outside air that no artificial lights, heating or air conditioning would ever be needed during the day. They also wanted to prove that such a prototype classroom could be built for less than a regular K-12 classroom.
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High Performance Classroom
Mt. Angel Abbey

- Fresh Air
- Fresh Light of Day
- Warm & Cool
- Energy Efficient!

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Puget Sound Building Value with Integrated Design

THE KEY CHARACTERISTICS OF AN idl PROJECT

TAKES ADVANTAGE OF DAYLIGHT

ENHANCES HUMAN PERFORMANCE

ENERGY EFFICIENT

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College of Architecture & Urban Planning
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Welcome</td>
<td>10:00 AM</td>
<td></td>
</tr>
<tr>
<td>2. Introduction</td>
<td>10:15 AM</td>
<td></td>
</tr>
<tr>
<td>3. Reducing Building Loads</td>
<td>11:30 AM</td>
<td></td>
</tr>
<tr>
<td>Lunch Break</td>
<td>12:40 PM</td>
<td></td>
</tr>
<tr>
<td>4. Selecting efficient systems and controls</td>
<td>1:00 PM</td>
<td></td>
</tr>
<tr>
<td>5. Renewable Energy Systems</td>
<td>2:45 PM</td>
<td></td>
</tr>
<tr>
<td>6. Informed Building Operation</td>
<td>3:30 PM</td>
<td></td>
</tr>
<tr>
<td>7. Wrap-up Discussion</td>
<td>3:50 PM</td>
<td></td>
</tr>
<tr>
<td>Adjourn</td>
<td>4:00 PM</td>
<td></td>
</tr>
</tbody>
</table>
Implement Efficient Systems

Building design fixes the load
Building shape
Glass location
Glass area & type
Insulation values
Thermal mass
Building volume
Lighting concept
Mechanical concept

Efficient systems meet the load
Envelope
Daylighting
Lighting
HVAC
Controls
District heating
Domestic hot water

Energy sources supply energy to fuel systems
Sun-passive heat
Sun-active heat
Sun-photovoltaics
Wind, Wood
Electricity
Gas
Micro turbines
Fuel cells

People run the systems
Schedules
Controls
Maintenance
Setpoints
Windows
Equipment
Education

Goals
10% - 20%
Minimize load as a first priority
15% - 60%
Use simple, cost-effective systems
1% - 5%
Use appropriate sources of energy

Renewable
Affordable
Non-polluting
Local source

Functionality
Efficiency
Comfort

Operate the building well
Evaluation Tools

- This phase of work is typically suited near the end of SD
- Evaluate energy performance using whole building energy simulations
- Evaluate interior environmental conditions using daylight and light design models
- Evaluate natural ventilation and air flow using CFD modeling
Strategies for Implementing Efficient Systems

- Envelope
- Glazing
- Daylighting control
- Lighting design
- HVAC efficiencies
- HVAC distribution
- Ventilation air
Ensemble Strategies

- Improving envelope performance beyond code requirements is necessary for Zero Energy building design
  - Increasing insulation levels
  - Reducing air flow inside walls

What are they?

- Code insulation levels are based on two building characteristics that are not characteristics of Zero Energy buildings
Why Improving Insulation Levels is a Good Idea

1. Code model based on a 1:1 aspect, while zero energy buildings will have elongated ratio. More surface area per building floor area with a zero energy design, improves cost-effectiveness of increased insulation levels.

2. Code base model is based on higher internal loads from lights and equipment than a zero energy design. Less internal loads (heat from lights and equipment) will require an increase in heating consumption to offset the reduction in internal loads in the winter.
## Insulation Effectiveness

Maintaining expected R-Values overtime is a function of:
- Installation effectiveness
- Material degradation
- Air diffusion

<table>
<thead>
<tr>
<th>Insulation Type</th>
<th>R – Value per inch</th>
<th>Installation Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foamed in place</td>
<td>3.6 to 5.9</td>
<td>Consistent installation process</td>
</tr>
<tr>
<td>Fiberglass Batts</td>
<td>3.6</td>
<td>Depends on installer</td>
</tr>
<tr>
<td>Extruded Polystyrene</td>
<td>5.0</td>
<td>Depends on installer</td>
</tr>
<tr>
<td>Polyiso-cyanurate</td>
<td>6.5</td>
<td>Depends on installer</td>
</tr>
<tr>
<td></td>
<td>U-Factor</td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>---------------</td>
<td>---------------------</td>
</tr>
<tr>
<td></td>
<td>1.10 Single pane</td>
<td>0.50 Double pane</td>
</tr>
<tr>
<td></td>
<td>0.30 Double pane LowE</td>
<td>0.15 Multi layer LowE</td>
</tr>
<tr>
<td>Heat transfer rate by conduction- Btu/Ft²/F°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar Heat Gain Coefficient</td>
<td>0.85 clear</td>
<td>0.50 light tinted</td>
</tr>
<tr>
<td></td>
<td>0.25 3rd generation LowE</td>
<td>0.15 Reflective</td>
</tr>
<tr>
<td>The fraction of total incident solar radiation that is transferred through the glazing system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visible Light Transmittance</td>
<td>0.90 clear</td>
<td>0.45 light tinted</td>
</tr>
<tr>
<td></td>
<td>0.65 to 0.40 LowE</td>
<td></td>
</tr>
<tr>
<td>Ratio of the amount of light radiation transmitted through the glass compared to the amount of light striking the exterior surface</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Upper right quadrant is known as spectrally selective glazing. They reflect infrared radiation wavelengths at a higher frequency than radiation in the visible light spectrum.

The upper left quadrant is applicable to windows on the south face with effective exterior summer sun control.
Why Use High Visible Light Transmittance Glazing?
Glass Types

18%
Glazing Type Visible Transmittance
Higher VT = More Daylight

Daylight Levels in ft candles
(1500 fc sky)

Distance from window

VT= 0.8
VT= 0.65
VT= 0.25
VT= 0.18
**Glazing Characteristics by Orientation for Zero Energy Buildings**

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Characteristics</th>
<th>Best use</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>Low U Factor below 0.30</td>
<td>Great daylight orientation. Use for deep spaces, open office, classrooms</td>
</tr>
<tr>
<td></td>
<td>High VT 0.50 to 0.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Avg SHGC 0.35 to 0.50</td>
<td></td>
</tr>
<tr>
<td>East and West</td>
<td>Low U Factor below 0.30</td>
<td>Worst daylight orientation. Use for shallow spaces, private offices, circulation. Minimize window area on these orientations.</td>
</tr>
<tr>
<td></td>
<td>Medium VT 0.40 to 0.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low SHGC 0.25 to 0.30</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>Low U Factor below 0.30</td>
<td>Good daylight orientation. Need to consider effective sun control. Use for deep spaces, open office, classrooms</td>
</tr>
<tr>
<td></td>
<td>Medium VT 0.45 to 0.55</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>SHGC w/ exterior shading 0.50 to 0.60</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SHGC no exterior shading 0.30 to 0.35</td>
<td></td>
</tr>
</tbody>
</table>
Daylighting Control Strategies

- Required for a zero energy building
- Identify some integration issues to be aware of
- Identify system features
- Identify system design method
Daylighting is Complex

- Successful daylighting is the product of many decisions
  - Windows
  - Shading
  - Interiors
  - Lights
  - Controls
  - Continued maintenance
Fundamentals of Integrated Daylighting

No **one** does Daylighting

It is a collaborative effort of the design team

Know what **others** must do so that your work comes out well

There are many key elements...

---

**Daylight Building Section Concept**

**Electric Lighting System**
- 8’ indirect industrial fixture mounted up
- T8 lamps w/ electronic dimming ballast
- Illumination level @ 30 to 35 fc - connected power density at 1.15 w/sf
- White painted metal deck ceiling 85% reflectance

**Window System**
- Low E wood frame operable windows
- Specifications vary by orientation
  - North/South: SC = 0.44, U-value = 0.35, VT = 0.67
  - East/West: SC = 0.25, U-value = 0.60

**North Daylight zone**
- One photosensor per three north facing offices
- No blinds on north windows
- Wall box occupancy sensor per each office
- Transom/vision glass to provide bi-directional source and transparency

**Center Daylight zone**
- One photosensor controlling all lights in center zone
- Seasonal banner to control low angle direct sun during winter months only
- Supply duct doubles as light shelf to control direct sun on south open office areas

**South Daylight zone**
- One photosensor controlling all lights in south zone
- Daylight transom window - 15’ head height w/ no blinds
- 5’ roof overhang and lower sunscreen effectively blocks direct sun during cooling season
- Horizontal blinds on south view window - light color - vertical blinds on east windows

---

**Private office 16 feet deep**

**Open office 32 feet deep**
### System Efficacy

Failure is not well understood...we fail by degrees

<table>
<thead>
<tr>
<th>Component</th>
<th>Perfection</th>
<th>Excellent</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window size</td>
<td>100%</td>
<td>98%</td>
<td>95%</td>
<td>100%</td>
<td>85%</td>
</tr>
<tr>
<td>Sun shading</td>
<td>100%</td>
<td>98%</td>
<td>95%</td>
<td>91%</td>
<td>85%</td>
</tr>
<tr>
<td>Lighting design</td>
<td>100%</td>
<td>99%</td>
<td>95%</td>
<td>85%</td>
<td>85%</td>
</tr>
<tr>
<td>Calibration</td>
<td>100%</td>
<td>95%</td>
<td>95%</td>
<td>90%</td>
<td>85%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>90%</strong></td>
<td><strong>81%</strong></td>
<td><strong>70%</strong></td>
<td><strong>52%</strong></td>
</tr>
</tbody>
</table>

- Source variables
- Building orientation & footprint
- Window size & location
- Sun shading
- Glass types
- Space programming
- Interior surfaces
- Lighting design & control
Elements of Integrated Daylighting

- Daylight source
- Building massing
- Building orientation
- Window size & location
- Sun shading
- Glass types
- Space programming
- Interior surfaces
- Lighting design & control
Daylight Control Systems

Implementing a lighting control strategy that controls the electric lights dynamically based on daylight to save energy without distracting occupants.

What do we want it to do?
- Stepped switching system
- Continuous dimming system
What Should a Daylight Switching System Do?
Daylight switching systems cannot start switching off lights until the interior illuminance in a space is 2.5 X to 3 X the design foot candle level.

Switching is appropriate for spaces with high levels of daylight for significant periods of the day.
What Should a Daylight “Dimming” System Do?
Dimming System
Conclusion

- Dimming systems provide a much smoother transition in illuminance levels.

- Dimming works in spaces were daylight levels are equal to or less than the electric design light levels, or where occupants would object to switching.
Daylighting Control System Components

Diagram courtesy of the Daylight Dividends program, Lighting Research Center
What Do the Components Look Like?

- Photocell
- Controller
- Relay
- Low voltage power supply
- Ballast

Images courtesy of the Daylight Dividends program, Lighting Research Center
Daylighting Control System

Move the slider to view daylight effects.

Diagram courtesy of the Daylight Dividends program, Lighting Research Center
Open Loop Daylighting Control System

Does not respond to or “see” the electric light that it controls

What conditions work best for this type of control?

Diagram courtesy of the Daylight Dividends program, Lighting Research Center
Open Loop Issues

- **Possible Advantages**
  - Lower cost because one photocell can control many light fixtures in multiple rooms within the building
  - Easier to commission because only one variable needs to be adjusted; no feedback is involved

- **Possible Disadvantages**
  - Does not sense changes within the building; for example, if someone closes the blinds
  - Is not sensitive to different daylighting conditions within individual rooms within a building; for example, some rooms may have furniture or outside elements such as trees obstructing the windows
Space Characteristics
Open Loop Systems

- Open loop systems are not sensitive to changing conditions within a space. They should be specified for spaces where:
  - Skylights without operable shades are the primary source of daylight for the space
  - Clerestory windows without operable blinds or shades are the primary source of daylight in the space
  - In atria or other public or common areas that are generally transitional spaces where there are not operable shades or blinds installed
Closed Loop Daylighting Control Systems

Closed loop senses and responds to the electric light that it controls.

What conditions work best for this type of control?

Diagram courtesy of the Daylight Dividends program, Lighting Research Center.
Closed loop systems are the most responsive to changing lighting conditions within the space. They should be specified for spaces where:

- There are operable shades or blinds
- There are obstructions within the room or outside the window which may change over time - large furniture or partitions that may be moved around, or deciduous trees outside the window
- The space is on the ground floor of the building in a climate where it snows - snow will reflect more light into the window than summer ground cover
Step-by-Step Process for Selecting Daylighting Control Products

1. Is there sufficient daylight?
2. Type of control – dimming or switching?
3. Type of system – open or closed loop?
4. Number of control zones?
5. Selection of equipment
Is There Sufficient Daylight?

- Window to floor area ratio → 25% goal
  - Don’t count window below task height
- Perform analysis to optimize windows
Electric Lighting
Design and Control

Sensor Location = 1/2 to 2/3 D

Dimming Ballast
Regular Ballast

To power supply & switch controlling all lights

Daylight Control Depth = D @ 2 to 2.5 Head Height

Photosensor

Window Head Height
Lighting Design Strategies

- Need to integrate with the daylight and daylight controls system
- Select lighting design criteria
- Compare lamp/ballast efficacy for a wide range of systems
- Compare fixture efficiencies for various fixture types
- Identify the impact of room surface reflectance on lighting design
So How Much Light Do We Need?

Graph showing the trend of light requirements over time from 1913 to 1990.

- **Watts psf**
- **IES Rec Foot-candles**

Graph axes:
- Y-axis: Foot-candles (FC) and Watts per square foot (W/sf)
## Integrate Electric Lighting

### Design and Control Fixture System/Daylight Control Compatibility

<table>
<thead>
<tr>
<th>Fixture Type</th>
<th>Stepped Control</th>
<th>Dimming Control</th>
</tr>
</thead>
</table>
| **Indirect** | Ideal fixture for stepped control  
Compatible w/ 2 or 3 lamp fixtures | Very Compatible |
| **Direct/Indirect** | Compatible w/ 3 lamps for symmetrical  
“inboard/outboard” switching  
Compatible w/2 lamps if direct component shields lamps | Very Compatible |
| **Task/Ambient** | Compatible based on fixture types above  
Task lamp provides user more control of their desired lighting requirements | Very Compatible |
| **Direct** | Compatible w/ prismatic lense or new perforated “indirect” fixture  
Parabolic fixtures not advised | Compatible |
## Integrate Electric Lighting

### Design and Control Lamp Type/Daylight Control Compatibility

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Stepped Control</th>
<th>Dimming Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Size Fluorescent</td>
<td>Very Compatible</td>
<td>Very Compatible</td>
</tr>
<tr>
<td></td>
<td>Instant start</td>
<td>Electronic dimming ballasts for both T8 and T5 lamps</td>
</tr>
<tr>
<td>Compact Fluorescent</td>
<td>Compatible with multi-lamp fixtures</td>
<td>Very Compatible</td>
</tr>
<tr>
<td></td>
<td>Instant start</td>
<td>Electronic dimming ballasts for both T8 and T5 lamps</td>
</tr>
<tr>
<td>Metal Halide</td>
<td>Not Recommended</td>
<td>Not Recommended</td>
</tr>
<tr>
<td></td>
<td>Long lamp warm up</td>
<td>Available but not mature technology</td>
</tr>
</tbody>
</table>
Lamp Color Temperature

- New studies showing improved visual acuity at higher lamp temperatures. Meaning you can use lower illuminance levels – much debate on this.

- Daylight has a high color temperature, at over 7,000 K, and superior color rendering qualities.

- Old cool white lamps in the 1970s had high color temperatures at 4100 K, however very poor color rendering qualities.

- Most fluorescent lamp installed over the last 5 to 10 years are at 3500 K.

Light color temperature is expressed in degrees Kelvin.

Incandescent lamps have low color temperatures at 2500 to 3000K and are called warm light.

Warm light is comfortable at night. Daylight color temperatures are nice during the day.
What’s New for Lamps and Ballasts

Lamp efficacy is the ratio of light output in lumens divided by power input in watts.

It is best to compare the lumen output at the mean life of the lamp system, not at its initial life.

- **Super T8 systems – 15% increase in lamp efficacy**
- **New energy-efficient electronic ballasts can increase lamp efficacy by an additional 5 to 8%**
- **25 W T8 systems – same efficacy as standard T8 systems, proportionately less light and less power and can’t be dimmed**

Lamp efficacy is the ratio of light output in lumens divided by power input in watts.
Super T8
Fluorescent Lighting

- Savings using low ballast factor ballasts, OR
- Savings from using fewer fixtures
- Cost is about $5 - $15 additional per fixture
- Additional life, 20% - 40%
  Huge savings
**Lamp/Ballast Efficacy**

<table>
<thead>
<tr>
<th>LAMP TYPE</th>
<th>MEAN LUMENS per WATT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent</td>
<td>12</td>
</tr>
<tr>
<td>T12 Fluorescent</td>
<td>67</td>
</tr>
<tr>
<td>Standard Metal Halide 400W</td>
<td>58</td>
</tr>
<tr>
<td>Pulse Start Metal Halide 320W</td>
<td>66</td>
</tr>
<tr>
<td>Standard T8 Fluorescent</td>
<td>83</td>
</tr>
<tr>
<td>High Output T5 Fluorescent</td>
<td>88</td>
</tr>
<tr>
<td>Standard T5 Fluorescent</td>
<td>89</td>
</tr>
<tr>
<td>HP T8 Fluorescent</td>
<td>94</td>
</tr>
</tbody>
</table>

Where would production grade White LEDs fall on this chart?
Fixture Efficiency

- Select fixture types with efficiencies at 85% or higher
- Which fixture to the left has a higher fixture efficiency?
Surface Reflectance
HVAC Systems

- Cooling systems
- Heating systems
- New system trends
  - Displacement ventilation
  - Radiant cooling and heating systems
  - Dedicated outside air systems
  - Energy recovery
  - Hybrid natural ventilation systems
### Cooling System Type Efficiency

<table>
<thead>
<tr>
<th>System Type</th>
<th>Efficiency Ranges kW/ ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Expansion Rooftops</td>
<td>1.40 to 0.90</td>
</tr>
<tr>
<td>Air Cooled Chillers</td>
<td>1.40 to 1.00</td>
</tr>
<tr>
<td>Water Cooled Chillers</td>
<td>0.70 to * 0.45</td>
</tr>
</tbody>
</table>
## Cooling System Type Efficiency

<table>
<thead>
<tr>
<th>Cooling System Type</th>
<th>Architectural Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Expansion Rooftops</td>
<td>Installed on Roof, does not take up floor space inside building</td>
</tr>
<tr>
<td></td>
<td>Smaller project</td>
</tr>
<tr>
<td></td>
<td>1 and 2 story buildings</td>
</tr>
<tr>
<td>Air Cooled Chillers</td>
<td>Installed on Roof, does not take up floor space inside building</td>
</tr>
<tr>
<td>Water Cooled Chillers</td>
<td>Installed in Mechanical room or enclosed penthouse</td>
</tr>
<tr>
<td></td>
<td>Requires a cooling tower</td>
</tr>
</tbody>
</table>
### Heating System Type Efficiency

<table>
<thead>
<tr>
<th></th>
<th>Efficiency Ranges kW/ ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof Top Gas Furnace</td>
<td>80% rated conditions</td>
</tr>
<tr>
<td>Conventional Boilers</td>
<td>80 to 85%</td>
</tr>
<tr>
<td>Condensing Boilers</td>
<td>88 to 93%</td>
</tr>
</tbody>
</table>
HVAC Distribution Strategies

- **Variable air volume systems**
  - Reduces supply air volume based on space thermal load requirements
  - Saves energy by using VFD on fan motors to reduce motor power based on reduce air volume

- **Displacement Ventilation systems**
  - Uses warmer supply air temperature 65 vs. 55 F
  - Air supplied low and returned high at low velocities to achieve laminar flow
  - Saves energy by increasing hours of economizer cycle, improved ventilation effectiveness, and lower fan static pressure
HVAC Distribution Strategies

- Radiant Cooling Systems
  - Uses chilled water in radiant panels or beams
  - Energy used to distribution chilled water can be less than energy used to distribute cool air
  - Reduce reheat energy

- Radiant Heating Systems
  - Uses hot water to raise surface temperature of floor
  - Saves energy by lowering heating temperature set point to maintain similar comfort condition, reducing conduction and infiltration loads in the winter time
Ventilation Air Strategies

- **Dedicated Outside Air Systems**
  - Usually used in conjunction with radiant systems
  - Can accurately deliver the correct volume of fresh to a space based on demand control ventilation sensing
  - Save energy by reducing ventilation loads based on actual building occupancy

- **Energy Recovery Systems**
  - Transfers sensible and or latent energy from building exhaust air to incoming fresh air stream
  - Saves heating and cooling energy by reducing the load to condition ventilation air
Group Exercise
Strategy Selection to Reduce Loads

- Classroom building
- 20,000 SF floor area
- Schematic floor plan and fenestration design developed to daylight 95% of the floor area
- Dedicated outside air system with 100% exhaust
Group Exercise
Strategy Selection to Reduce Loads

- 100 feet square
- 2-story building
- Center atrium with clerestory
- 15’ floor to floor height
## 5. Renewable Energy System

<table>
<thead>
<tr>
<th>Conservation</th>
<th>Efficiency</th>
<th>Generation</th>
<th>Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building design&lt;br&gt;Fixes the load</td>
<td>Efficient systems&lt;br&gt;Meet the load</td>
<td>Energy sources&lt;br&gt;Supply energy to fuel systems</td>
<td>People run the systems</td>
</tr>
<tr>
<td>Building shape&lt;br&gt;Glass location&lt;br&gt;Glass area &amp; type</td>
<td>Insulation&lt;br&gt;Daylighting Controls&lt;br&gt;Lighting Design</td>
<td>Sun-photovoltaics&lt;br&gt;Wind&lt;br&gt;Sun-active heat&lt;br&gt;Electricity</td>
<td>Schedules&lt;br&gt;Controls&lt;br&gt;Maintenance</td>
</tr>
<tr>
<td>Thermal mass&lt;br&gt;Building volume&lt;br&gt;Lighting concept&lt;br&gt;Mechanical concept</td>
<td>HVAC&lt;br&gt;Load responsive controls</td>
<td>Gas&lt;br&gt;Micro turbines&lt;br&gt;Fuel cells</td>
<td>Windows&lt;br&gt;Equipment&lt;br&gt;Education</td>
</tr>
<tr>
<td>10% - 20%</td>
<td>15% - 60%</td>
<td>1% - 5%</td>
<td>10% - 20%</td>
</tr>
<tr>
<td>Minimize load as a first priority</td>
<td>Use simple, cost-effective systems</td>
<td>Use appropriate sources of energy</td>
<td>Operate the building well</td>
</tr>
</tbody>
</table>

Goals:
- 10% - 20%
- 15% - 60%
- 1% - 5%
- 10% - 20%

Conservation + Efficiency = Generation - Optimization

- **Functionality**
  - Renewable
  - Affordable
  - Non-polluting
  - Local source

- **Efficiency**
  - Use appropriate sources of energy

- **Comfort**
  - Operate the building well
On-site Renewable Energy Options

- Thermal Energy
- Electricity
Thermal Energy

Active Solar Water Heating

![Diagram of Active, Closed Loop Solar Water Heater]

- Flat plate collector
- Antifreeze fluid in collector loop only
- Pump
- Solar storage/backup water heater
- Double-wall heat exchanger
- Hot water to house
- Cold water supply
Thermal Energy

Active Solar Water Heating
Thermal Energy

Active Solar Water Heating
Thermal Energy

Active Solar Water Heating
Thermal Energy

- Active Solar Space Heating
Thermal Energy

- Active Solar Space Heating
Thermal Energy

- Active Solar Space Heating
Electricity

- Rooftop Wind Energy
- Biomass fueled generator
- Photovoltaics
Electricity

- Rooftop Wind
Electricity

- Biomass fueled generator
  - Biodiesel or bio-methane
Electricity

- Photovoltaics – standard
- Photovoltaics – Building integrated
Electricity

- Photovoltaics - Standard
Electricity

- Photovoltaics - Standard
Electricity

- Photovoltaics - Standard
Electricity

- Photovoltaics - Standard
Electricity

- Photovoltaics – Building Integrated
Electricity

- Photovoltaics – Building Integrated
Electricity

- Photovoltaics – Building Integrated
Electricity

- Photovoltaics – Building Integrated
Electricity

- Photovoltaics – Building Integrated
Electricity

- Photovoltaics – Building Integrated
Electricity

- Photovoltaics – Building Integrated
Electricity

- Photovoltaics – Building Integrated
Electricity

- Photovoltaics – Building Integrated
Electricity

- Photovoltaics – Building Integrated
Electricity

- Photovoltaics – Building Integrated
Electricity

- Photovoltaics – Building Integrated
Electricity

- Photovoltaics – Building Integrated
Renewable Energy Exercise

- Develop a renewable energy generation plan to meet the building load you selected in the last session.
- Use the following energy generation slides to locate and size the system.
## Annual Estimated Renewable Energy Production Metrics - Minneapolis

<table>
<thead>
<tr>
<th>PV System</th>
<th>South</th>
<th>Southwest</th>
<th>West</th>
<th>North</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh/SF/YR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>12.6</td>
<td>12.6</td>
<td>12.6</td>
<td>12.6</td>
</tr>
<tr>
<td>15° Tilt</td>
<td>14.4</td>
<td>13.8</td>
<td>12.4</td>
<td>No data</td>
</tr>
<tr>
<td>45° Tilt</td>
<td><strong>15.5</strong></td>
<td>14.2</td>
<td>11.1</td>
<td>5.8</td>
</tr>
<tr>
<td>Vertical</td>
<td>11.1</td>
<td>10.4</td>
<td>7.9</td>
<td>No Data</td>
</tr>
<tr>
<td>PV Cost $/SF</td>
<td>$60</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Wind Turbine       | 500,000 | 100’ hub height | 100’ rotor diameter | 300 KW |
| kWh/YR             |         |                 |                   |       |
| Cost / kW          | $1,300  |                 |                   |       |

**3.413 KWh = 1 KwH**
6. Informed Building Operation

- Conservation + Efficiency = Generation – Optimization

Conservation:
- Thermal mass
- Building volume
- Mechanical concept
- Minimize load as a first priority

Efficiency:
- HVAC
- Load responsive controls
- 15% - 60%

Goals:
- Use appropriate sources of energy
- 1% - 5%

Generation:
- Gas
- Micro turbines
- Fuel cells
- 10% - 20%

Optimization:
- Windows
- Equipment
- Education
- Functionality
- Efficiency
- Comfort

Generation + Conservation + Efficiency – Optimization = Operate the building well

Goals:
- Renewable
- Affordable
- Non-polluting
- Local source
- 10% - 20%

Conservation:
- 10% - 20%

Efficiency:
- 15% - 60%

Goals:
- 1% - 5%

Operation:
- People run the systems
- Schedules
- Controls
- Maintenance
- 30%
The missing link in high performance buildings is the feedback loop of actual building performance to the buildings occupants and managers.

You can’t manage what you can’t measure.

We don’t need LEED.

We need LEEP.
Informed Building Operation

- Have kiosks in common spaces that illustrates how the building is designed to operate at its 50,000 KBTU/SF goal. Provide historic and current performance results.
- Have a permanent environmental and energy monitoring system separate from the BAS to produce energy tracking reports and to compare with expected results.
Kiosk Information System
Examples of Informed Operation

- Wisconsin DNR NE Regional HQ
- IAMU Office & Training Facility
- Science House
DNR Northeast Regional Headquarters
Howard, WI

- LEED Gold certified building in Wisconsin
- Building orientated with the long axis running east – west, enabling maximum southern and northern exposure to natural daylight
- East and west elevations are essentially solid – light from these directions is difficult to control with the sun angles being so low
- Natural light from the south is easier to control with overhangs and light shelves because of high sun angles
- Sun control on the north facade is not an issue and provides the best natural light. It also has the added advantage of not allowing solar heat gain because the sun never directly reaches that facade during business hours
Daylighting Zones

Open Office: 0.70 w/sf
Private Office: 0.44
Optimized energy design model showed 50% energy savings compared to the energy code.

The lighting and mechanical system were tuned for a number of months.

The metered data of the building shows a 57% energy savings compared to the code.
Longer daylight hours in July, thus no peaking at the beginning and end of each day

- Overcast conditions
- Significant reduction in lighting power compared to connected lighting power full load (36 kW)

Shorter daylight hours cause peaking at the beginning and end of each day
- Significant reduction in lighting power compared to connected lighting power full load (36 kW)
The Iowa Association of Municipal Utilities

Office and Training Facility
Ankeny, Iowa
“Wendell Berry once said that as we came across the continent, cutting the forests and plowing the prairies that ‘we never knew what we were undoing because we never knew what we were doing’.”
Establish Whole Building Energy Consumption Goals and Method to Evaluate

- Establish energy goals and evaluate throughout design
- DOE-2.1E - Hour by hour building thermal and daylighting simulation model
- Visualization model for sun path studies
- Physical daylight models

**Annual Operating Energy Consumption Goals**

![Graph showing annual operating energy consumption goals with categories for lighting, cooling, fans/pumps, heating, miscellaneous equipment, and domestic hot water.]
Introduction
The Iowa Association of Municipal Utilities

Building Design - 1997

Building Program:
Office and training facility
12,500 square feet
Located in central Iowa
Operated all year

Building Cost:
$116 / square foot

Annual Metered Energy Consumption:
28,000 Btu / ft² - yr
Energy Design Strategies

- Build DOE-2.1e model of schematic design to evaluate over 70 alternatives within the following categories:
  - Glazing types and window designs
  - Wall and roof insulation levels
  - Lighting design and controls
  - HVAC system types and modifications

- This evaluation included both energy costs and construction costs
Building Section Concept

Transom/vision glass to provide bi-directional source and transparency

8’ indirect fixtures w/ T8 lamps w/ electronic dimming ballast

1 photo-sensor per three north facing offices

No blinds on north windows

Heat Pump

Private Office: 16’ deep

Occupancy sensor in each office

200’ deep ground wells connected to heat-pump provide cooling source during summer season

Summer mode

Open Office: 32’ deep

Illumination level @ 30 to 35 fc connected power density: 1.15 w/sf

Operable lower windows - Low-E, wood-frame, aid cross-ventilation

Insulation levels - isocyanurate

White painted metal deck ceiling - 85% reflectance

5’ roof overhang blocks direct sun during cooling season

Daylight transom window - 15’ head ht. w/ no blinds

1 photo-sensor in each center & south zone

lower sunscreen blocks direct sun during cooling season
Building Section Concept

Seasonal banner to control low-angle direct sun during winter months only

Heat Pump

Private Office: 16' deep

Open Office: 32' deep

Winter mode

200' deep ground wells connected to heat-pump provide heating source during winter season

Horizontal blinds on south view window-light color

Supply duct doubles as light shelf to control direct sun in south open office
Energy simulations utilizing DOE-2.1E were performed to investigate various strategies and estimate the final performance.

Long-term building environmental and energy monitoring is being performed to further evaluate and improve the building’s operation.
Actual Building Energy Performance Results

**Annual Site Energy KBtu/sf**

<table>
<thead>
<tr>
<th>Code Compliant Building</th>
<th>Final Design Estimate</th>
<th>Actual Metered Energy Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>50% Reduction in Energy Consumption</strong></td>
<td><strong>28 KBtu/Sq. Ft</strong></td>
<td></td>
</tr>
</tbody>
</table>

- **Equip:** 10.9
- **Lights:** 17.6
- **Fan/Pump:** 7.6
- **Cool:** 9.9
- **Heat:** 6.7

- **Equip:** 9.5
- **Lights:** 4.0
- **Fan/Pump:** 3.5
- **Cool:** 3.2
- **Heat:** 4.5

**28 KBtu / Sq. Ft**
## 2004 Monthly Sub-metered Data

<table>
<thead>
<tr>
<th>MONTH YR</th>
<th>HEAT</th>
<th>COOL</th>
<th>ELECTRICITY BILLED (1)</th>
<th>ELECTRICITY SUB-METERED (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Degree</td>
<td>Degree</td>
<td>Energy</td>
<td>Demand</td>
</tr>
<tr>
<td>04 Days</td>
<td>Days</td>
<td>Days</td>
<td>KWH</td>
<td>KW</td>
</tr>
<tr>
<td>January</td>
<td>1,438</td>
<td>-</td>
<td>14,460</td>
<td>50</td>
</tr>
<tr>
<td>February</td>
<td>1,207</td>
<td>-</td>
<td>11,220</td>
<td>47</td>
</tr>
<tr>
<td>March</td>
<td>728</td>
<td>1</td>
<td>8,820</td>
<td>39</td>
</tr>
<tr>
<td>April</td>
<td>417</td>
<td>13</td>
<td>7,740</td>
<td>35</td>
</tr>
<tr>
<td>May</td>
<td>178</td>
<td>80</td>
<td>6,840</td>
<td>31</td>
</tr>
<tr>
<td>June</td>
<td>34</td>
<td>135</td>
<td>6,180</td>
<td>27</td>
</tr>
<tr>
<td>July</td>
<td>3</td>
<td>219</td>
<td>7,200</td>
<td>34</td>
</tr>
<tr>
<td>August</td>
<td>45</td>
<td>141</td>
<td>6,900</td>
<td>35</td>
</tr>
<tr>
<td>September</td>
<td>41</td>
<td>114</td>
<td>7,020</td>
<td>32</td>
</tr>
<tr>
<td>October</td>
<td>371</td>
<td>-</td>
<td>6,720</td>
<td>34</td>
</tr>
<tr>
<td>November</td>
<td>716</td>
<td>-</td>
<td>9,480</td>
<td>33</td>
</tr>
<tr>
<td>December</td>
<td>1154</td>
<td>-</td>
<td>12,420</td>
<td>38</td>
</tr>
<tr>
<td>Average</td>
<td>8,750</td>
<td>36</td>
<td>553.88</td>
<td>6.33</td>
</tr>
<tr>
<td>Annual Total</td>
<td>6,332</td>
<td>703</td>
<td>105,000</td>
<td>6,646.56</td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td>1.42% Variance to Sub-Metered</td>
<td>23.3%</td>
<td>30.5%</td>
</tr>
</tbody>
</table>
Building energy consumption has been very consistent over the last 3 years.
HVAC Results

- Constant speed geothermal loop circulating pump operates 24/7
- Loop circulating pump consumes 36% of the total HVAC energy
- Use of a variable pumping system could reduce building energy consumption further – maybe an additional 15%
Lighting Control Results

Lighting demand - March 18 to March 24

Connected Lighting Power Load 11.8 KW

Parking and Driveway Lighting
Photos: Assassi Productions - 2001
Net Zero Energy Building
Case Study: Science House
Key Project Metrics

- Building floor area is 1,000 square feet
- The building consumes 23,000 Btu/square foot for heating, cooling, lighting, plug loads, and DWH
- The improvement of buildings systems beyond the minimum requirement of the energy code cost $10,000 or about $10/square foot of building floor area
- The integrated PV roof system generates 30,000 Btu/square feet
- The cost to install the PV system was $80,000 or $80/square foot of building floor area
- The building generates 36% more energy than it currently consumes
Design Development Process

Energy performance in annual KWh for the three bundles are shown below as compared to the Code Base Model energy consumption and the photovoltaic electric generation capacity.

The energy efficiency savings potential for the three bundles ranges from 50% and 60% of the Code Base Model, and annual energy performance for Bundle 3 is very close to the estimated annual electric generation provided by the photovoltaic system.

### Annual Energy Consumption for Bundles by End Use kWh/year

<table>
<thead>
<tr>
<th>Bundle</th>
<th>Annual kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code Base Model</td>
<td>25,795</td>
</tr>
<tr>
<td>Bundle 1</td>
<td>13,648</td>
</tr>
<tr>
<td>Bundle 2</td>
<td>11,173</td>
</tr>
<tr>
<td>Bundle 3</td>
<td>10,988</td>
</tr>
<tr>
<td>PV Electric Generation Capacity</td>
<td>10,000</td>
</tr>
</tbody>
</table>

Close Enough
Verified Results

Actual performance has been monitored with the assistance of the National Renewable Energy Laboratory in Golden, Colorado. There are many variables at play. Design and construction variables have been managed as closely as possible. The weather and actual operating activities play a big role in this being a Zero Energy Building.
Single Line Electrical Plan
and Monitoring System Meter Location

Monitoring

27 Points

- Total Energy
- PV Generation
- Lighting
- Plug Loads
- HVAC
- DHW
- Indoor Temp /RH
- Outdoor Temp/RH
- Solar Radiation

PV

WM3

Main Electrical Panel

WM7

HVAC

WM9
CT3
CT1
CM
Blower
Pump
Elec Heat
Heat/Cool

WM1

Science Museum (Grid)

WM2

WM1 = 1

WM8

HVAC

WM10

DHW

WM11

ERV

CM

CM

WM6

Plugs

Total Lights

WM4

Daylight Lights

WM5

Other lights

CT2

Mez. Lights
Passive Solar Heating

Cold Minnesota day, heat pumps not operating.

MN climate has 7876 HDD (base 65)
Initially heat pump system was not operating.

Back-up electric resistance heater was heating the building.
The first year of PV system operation there were some problems.

Monitoring system showed a drop off in PV output.

Ground fault problem caused by PV panels sliding on the roof.
2004 produced 7900 kWh
2005 produced about 9000 kWh
Solar radiation was similar for both 2004 and 2005
Produced more than consumed

More usage in 2005 = more energy consumed
Lessons Learned

- Keep technologies visible for use as education tools

- Monitoring system
  - Needs to be a standard component for any zero energy building
  - Cost justified due to the large expense of the renewable energy system
  - Able to pay for itself by solving problems with factual information versus guessing