Webinar:
Fundamentals of Integrated Energy Design

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Architectural Energy Corporation
www.archenergy.com
Provides information and tools to architects, engineers, lighting designers, and building owners to create more energy efficient buildings in California. Administered by the following utility companies:
• The Big “Why?” Question
• What is an Energy-Efficient Building?
• Challenges and Opportunities
• The Integrated Energy Design Process
• Case Studies
• Tools and Resources
The Big “Why?” Question

- Why should a building owner or project architect and engineer be interested in incorporating energy-efficient and sustainable design features into their building?

- You may be surprised to learn that the primary reasons have little to do with energy savings!
The Big “Why?” Answer

- Improved occupant productivity
- Over a 30-year period, salaries account for 94% of a building’s total operating cost
- Energy and other operating costs account for only 4%
- Initial construction costs and design fees account for the remaining 2%

Information based on BOMA Data
Cost of Labor Eclipses Energy Cost

Information based on BOMA Data
The Big “Why?” Answer

• Improvement of 2 to 3% in annual occupant productivity combines with a 50% savings in annual energy costs to provide tremendous value to the building owner

• A $2 per square foot construction cost increment is equivalent to a productivity improvement of 90 second per worker per day in the first year

Information based on BOMA Data
Other Big “Why?” Answers

• Potential of improved educational performance
  – A study of 21,000 students in three school districts involving 2,000 classrooms
  – Daylighting through skylights and large windows indicated a beneficial effect on educational performance, with a 99% statistical certainty

Other Big “Why?” Answers

• Educational study indicated that students in the most daylit classrooms progressed:
  - 20% faster on math tests than those students with the least daylight
  - 26% faster on reading tests than those students with the least daylight
• Potential of Improved retail performance
  – A study of revenue from 108 stores of a chain retailer, where two-thirds had skylights and one-third did not
  – Skylights indicated a positive and significant correlation to higher sales, with a 99% statistical certainty

Skylights and Retail Store Sales (1999 and 2003) -- Heschong Mahone Group
Other Big “Why?” Answers

• Retail study indicated:
  – A skylit store had, on average, sales revenue 40% higher than a store without skylights
  – If a non-skylit store averaged $2/sf in revenue, a skylit store would average between $2.61 to $2.98/sf in revenue
Other Big “Why?” Answers

• Achieve greater occupant well-being, happiness, and satisfaction
• Improve employee retention and reduce employee “churn”
• Reduce absenteeism
• Reduce environmental impact of the building
Other Big “Why?” Answers

- Enhance architectural quality by creating a close link between the building and the site and microclimate
- Lower long-term energy operating costs
- Access energy saving performance contract financing, if appropriate
- Access financial incentives through utility sponsored energy efficiency programs like Savings By Design
“The AIA has adopted position statements to promote sustainable design and resource conservation to achieve a minimum reduction of fifty percent of the current consumption level of fossil fuels used to construct and operate buildings by the year 2010.”

December 2005 Press Release, American Institute of Architects
• The Big “Why?” Question
• **What is an Energy-Efficient Building?**
• Challenges and Opportunities
• The Integrated Energy Design Process
• Case Studies
• Tools and Resources
What is an Energy-efficient building?

- High performance building designed to efficiently use energy
- Building with efficient energy use results in lower annual operating costs
- Building that reduces environmental impact
What is an Energy-efficient building?

- Building with many non-energy attributes:
  - More comfortable
  - Improved air quality
  - Improved productivity
  - Better quality space

- And most importantly, a building that fully meets the functional needs of the occupants
• California Title 24 Energy Efficiency Standards represents “standard” practice, minimum design requirements

• Savings By Design Program requires:
  – at least 10% better than Title 24 for owner incentives
  – at least 15% better for design team incentives

• “Exemplary” buildings may be typically 25% to 40% more efficient than the Title 24 requirements
• Integrated Energy Design is both a process and an outcome

  – A design process that purposefully and systematically involves all the design disciplines to produce a high performance building
  – A building whose architectural, structural, mechanical, electrical, and interior systems are fully integrated to deliver high performance
• The Big “Why?” Question
• What is an Energy-Efficient Building?
• **Challenges and Opportunities**
• The Integrated Energy Design Process
• Case Studies
• Tools and Resources
Challenges and Opportunities

• Traditional design process does not always support efficient design strategies because of:
  – Sequential design process
  – Interaction among different disciplines may be minimal or not occur early enough
  – Concern that energy-efficient designs may raise cost and time requirements
Challenges and Opportunities

• Energy efficiency is often considered late in the design process, too late to have a significant impact
  – The longer you wait, the less impact you can have on the design
  – The longer you wait, the higher the cost to change the design
### Integrated Energy Design Paradox

- **Lost Opportunity Approach**
  - Building designed to just meet minimum standards for minimal performance

- **Upgrade Approach**
  - Standard design is upgraded with energy-efficient equipment for improved performance

- **Integrated Design Approach**
  - Energy issues are incorporated into overall design philosophy for optimal performance
• The Big “Why?” Question
• What is an Energy-Efficient Building?
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The goals are:
- Create functional and attractive architecture which costs less to operate
- Is easier to maintain and operate
- Is more comfortable and productive than a conventional building

Integration of architectural and energy design processes is essential to achieve energy efficiency goals
• Step 1: Make the commitment
• Step 2: Fully characterize the energy and sustainable design problem
• Step 3: Identify candidate energy and sustainable design solutions
• Step 4: Establish goals for energy-efficient, sustainable design
• Step 5: Integrate viable energy (sustainable) design alternatives into the architectural, structural, mechanical and electrical systems of the building
• Step 6: Use whole-building analysis methods to assess the energy and economic performance of the proposed design
• Step 7: Base decisions on life-cycle economics
• Step 8: Follow-through
Step 1: Make the Commitment

- Inform your staff and design consultants that integrated energy design is essential
- Make IED the standard practice for your projects -- the only way you do things!
- Incorporate energy efficiency and sustainable design goals into the Architectural Program
- Consider of energy efficiency issues early in design process
Step 2: Characterize the Problem

- Energy use/cost characterization of a reference building
- Baseline annual energy costs by end-use and by cause
- Identify sustainable design problems and opportunities
- Define realistic energy efficiency and sustainable goals
End-use Energy Cost Breakdown

Example: U.S. Federal Courthouse Expansion
Reference Building
DOE-2 Model

- Fans: 32%
- Heating: 14%
- Lighting: 17%
- Equipment: 20%
- Cooling: 10%
- Pumps: 3%
- Tower: 4%

End-use Energy Cost Breakdown
Elimination Parametrics

Denver U.S. Federal Courthouse Expansion
Reference Building DOE-2 Model

Annual Operating Costs

- Heating
- Fans
- Pumps
- Tower
- Cooling
- Equipment
- Lighting

Base  No Occupants gains  No Solar  No Cond  No OA  No Lighting  No Equip
Typical Office Building Impacts

Office equipment

Heating

Cooling

Lighting

Fans

Hot Water

Lighting Heat Gains

Office equip Heat Gains

Occupant Heat Gains

Shell Heat Gains

Solar Heat Gains

Outdoor Air Heat Gains
Winter Peak Load Shape

Source: EPRI Commend Database
**Summer Peak Load Shape**

Average of all U.S. commercial buildings

Source: EPRI Commend Database
LEED® Rating System

- Developed by U.S. Green Building Council
- LEED is a performance metric for what constitutes a sustainable building
- LEED rating criteria for various building types (NC, EB, CI, CS)
- Includes six categories and four levels of ratings (basic, silver, gold, platinum)
- Reinforces concept of Integrated Energy Design
Step 3: Identify Opportunities

- LEED rating system targets broad opportunities for reducing a building’s environmental impact
- Energy use/cost characterization targets end-uses and design elements having greatest opportunity for energy savings
IED Candidate Opportunities

• Daylighting
• High-performance glazing
• High-efficient electric lighting systems
• Properly sized cooling equipment
• Energy-efficient chillers and peripheral cooling equipment
• Alternative air distribution systems
• Efficient fan, pumps and duct design
• Thoughtfully designed control systems
• Renewable energy systems
**Step 4: Establish Energy Design Goal**

- Set overall goal to exceed Title 24 based on energy use/cost characterization
- Set aggressive but realistic design goals at the outset of schematic design
- Use LEED rating system to establish an overall sustainable design goal
- Integrate candidate energy design concepts into reference energy model and assess impact
- Establish whole-building and component level energy targets
### Reference Parametric Analysis

#### High Rise Office Building

<table>
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<tr>
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<th>Annual Energy Cost, $</th>
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<tr>
<td><strong>Baseline</strong></td>
<td><strong>Envelope</strong></td>
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<tr>
<td>Gas DHW</td>
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<td>Plug Loads</td>
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<tr>
<td>Ext. Lighting</td>
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<tr>
<td>Area Lighting</td>
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Component Level Design Goals

- **Lighting Power Density**
  - 10% to 30% less than Title 24

- **High Efficiency Lighting System**
  - Ambient / task lighting design
  - Efficient light sources - T-5, T-8, CF, Metal Halide
  - Luminaires with improved optics
  - Effective, simple lighting controls
Component Level Design Goals

- **Daylighting Performance**
  - Glare free
  - Uniformly distributed daylight
  - Promotes ambient illumination

- **Glazing Properties**
  - Shading coefficient of 0.35 or less
  - U-value of 0.33 or less
  - Tune by function and orientation
Component Level Design Goals

- Fan Power
  - W/cfm 10% to 30% less than Title 24

- HVAC Efficiency
  - Equipment efficiency 10% to 30% better than Title 24
A Word about Plug Loads

- Plug loads are a big energy issue for most building types and occupants (especially high-tech companies)
- Plug load allowances of 5 W/sf or more common
- Operating load is about 30% of connected load
- Diversity reduces peak loads even further
- Be diligent in accurately assessing plug load impacts!
Step 5: Design Integration

- Design team interaction is essential for successfully integrating selected energy strategies
- Interactions include owner; architect; structural, mechanical and electrical engineers; lighting designer; interior designer; and other specialty consultants
- Use design charrettes and workshops to facilitate brainstorming, development of integrated solutions, and coordination
Professionals among various disciplines, working independently, will make conservative assumptions when information is not available from other team members.

Conservative assumptions influence schematic design decisions and cost estimates.

Integration during schematic design is crucial.
Step 6: Use Whole-building Analysis

- Consider building systems interactions from an energy perspective
- Avoid rules-of-thumb for sizing anything
- Start with conditioned space
- Work upstream through distribution system to energy supply systems
- Compounding effect reduces size and capital costs
Cumulative Impact of Design

Denver U.S. Federal Courthouse Expansion
Final Design - DOE-2 Model

Annual Energy Cost

- Base
- Lighting and daylight
- Add HP glass
- Add displ. vert
- Add evap
- Add VSD
- Add fan and duct eff
- Add chiller and tower

Costs:
- Heating
- Fans
- Pumps
- Tower
- Cooling
- Equipment
- Lighting
Step 7: Calculate Life-cycle Costs

- Facilitates evaluation of alternative building systems (glazings, HVAC, etc.)
- Incremental costs yield impressive returns on life-cycle basis
- Simple payback analysis undervalues life-cycle benefits
ROI vs. Simple Payback

Return on Investment (ROI) = Investment Benefit – Investment Cost
(for a given period of time)

Adjusted Internal Rate of Return

Simple Payback (years)
Step 8: Follow-through

- Integrated energy design process starts during pre-design
- Continues through schematic design, design development (DD), construction and commissioning
Step 8: Follow-through

• Design intent at risk throughout process:
  – Lack of quantified energy efficiency goals
  – Design changes during DD and CD phases due to value engineering
  – Substitutions and change orders during construction
  – No commissioning
  – No consideration of O&M issues
Integrated Energy Design

- The Big “Why?” Question
- What is an Energy-Efficient Building?
- Challenges and Opportunities
- The Integrated Energy Design Process
- Case Studies
- Tools and Resources
San Mateo Public Library

- 90,000 ft² three-story building
- Opened in August 2006
- Energy use 26% below Title 24 standards

Courtesy of City of San Mateo
• Use of overhangs, fins, and vegetation reduce solar gains on the west exposure
• Light-colored ENERGY STAR® roof reduces thermal gain
• High-performance windows, clerestories, and roof monitors maximize access to daylight while reducing glare and solar gain
• Daylight is integrated with electric lighting, daylight controls, and motion sensors reduces lighting energy
• Energy-efficient electric lighting and layout reduces lighting energy and enhances illumination in the stack areas
• Under-floor air distribution system reduces HVAC energy consumption, increases thermal comfort, and improves air quality
• Other measures that were analyzed but not implemented because of long payback or reduced energy savings included:
  – Optimizing chilled water delta T/pumping requirement
  – Adding indirect coil to pre-cool supply air prior to cooling coil in AHU
  – Replacing the central plant with Indirect Direct Evaporative Cooled Air Handling Units (IDEC)
San Mateo Public Library

Courtesy of City of San Mateo

© Architectural Energy Corporation
Xilinx Office Building

- 127,000 ft² R&D Center
- Completed in 2001
- $202/ ft² Construction Costs

Courtesy of Downing Thorpe James Architects
Sustainable Design-- Inside and Out

• Corporate Goals
  – Employee Satisfaction and Retention (high productivity) -- the highest priority.
  – Reduce Energy and Environmental Impact

• Sustainable Site Design and Aggressive Daylighting

• Low Environmental Impact Building Materials

• Energy-efficient Mechanical and Lighting Systems
Sustainable Site Design

• Retain large open space on site
• Low water use landscaping
• Relocate Prairie Dogs within planned open space
• Preserve Wetlands, use as site feature
Environment Friendly Materials

- Use
  - Sustainable Materials and Products
  - Local Materials
• High Efficiency HVAC equipment
• Underfloor air distribution
• Daylight Harvesting
• High Efficiency Lighting and Controls
**Total Annual Energy Cost Comparison by End-Use**

**XILINX Schematic Design**

- **Total Cost:** $139,893/ yr
- **Normalized Cost:** $1.128/ sf/ yr

**ASHRAE 90.1-1999 Minimally Compliant Building**

- **Total Cost:** $89,704/ yr
- **Normalized Cost:** $0.723/ sf/ yr

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**ASCEHC 90.1-1999 Minimally Compliant Building**

- **Total Cost:** $139,893/ yr
- **Normalized Cost:** $1.128/ sf/ yr

**Schematic Design As-Designed**

- **Total Cost:** $89,704/ yr
- **Normalized Cost:** $0.723/ sf/ yr
Daylighting

- Building Orientation
- Solar Shading
- LightLouver™ Optical Daylighting System
- Photosensors / Dimming Ballasts
- Occupancy Sensors
• The Big “Why?” Question
• What is an Energy-Efficient Building?
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Tools and Resources

- www.pge.com/biz
- New construction design assistance
- Cash incentives
- Customized energy efficiency/demand response incentives
- Energy efficiency equipment rebates
- Self generation incentives and rates
- Education and training
EDR Web Site and Tools

- www.energydesignresources.com
- Design Briefs and Guidelines
- Case Studies
- Software tools (Skycalc, SPOT, eQuest)
- Building commissioning resources
- eNewsletter
- Training Seminars (webinars, on-site, on-line)
Savings By Design Program

- www.savingsbydesign.com
- Set guidelines for exceeding T-24 standards
- Design assistance
- Incentives for owner ($150k max)
- Incentives for design team ($50k max)
- Two approaches:
  - system or component
  - whole building
Other Relevant Resources

- LEED Green Building Rating System®
  - www.usgbc.org
- Whole Building Design Guide
  - www.wbdg.org
- Smart Communities Network
- Collaborative for High Performance Schools
  - www.chps.net
Other Relevant Resources

• Building Green
  – www.buildinggreen.com

• Great Energy Efficient Buildings

• National Renewable Defense Council
  – www.nrdc.org/buildinggreen/

• State of California
  – www.green.ca.gov/default.htm
Lighting and Daylighting Analysis Tools

- Skycalc - Skylighting spreadsheet from Energy Design Resources
- Radiance - Lighting and daylighting rendering and analysis
- SPOT™ - Sensor Placement Optimization Tool, analysis of daylighting/electric lighting
Energy Analysis Tools
- DOE-2 and Visual DOE - Hourly simulations
- eQUEST - Simplified DOE-2 inputs
- Energy-10 - Simplified tool
- Trace and HAP – HVAC-focused simulations

Economic Analysis Tools
- energy eVALUator
Thank you for participating in this Webinar

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