HIGH PERFORMANCE DESIGN STRATEGIES

Jean Ascoli | Program Director for New Construction | SEDAC
Rockford IL | November 20, 2014
ComEd
Ameren Illinois

Electric Efficiency
(75% of $)

DCEO

Electric Efficiency
Gas Efficiency
(25% of $)

Nicor Gas
Peoples/North Shore
Ameren Illinois

Gas Efficiency
(75% of $)

Private Sector
Businesses
Residential
Non-profits

Public Sector
Governments
K-12 Schools
Community
Colleges
Public Universities

Low-Income
Residential
Affordable Housing
PHAs
Implementation
Agencies

Private Sector
Businesses
Residential
Non-profits

SEDAC
What will it take to achieve high performance?

A. **Goal Setting**: design & performance energy goals

B. **Pick the right team**: identify an energy champion

C. **Focus on energy**: in design & construction

D. **Verify energy goals**: model & measure

E. **Plan to maintain**: training & ongoing verification
Minimum Compliance in Illinois
As of January 1, 2013

Illinois Energy Conservation Code (IL ECC)

To comply…You must follow either

- *International Energy Conservation Code 2012 (IECC-2012)* using one of these paths:
  - ‘Prescriptive’ method
  - ‘Total Building Performance’ method

OR

  - ‘Prescriptive’
  - ‘Energy Cost Budget’ method

*You must follow either IECC-2012 or ASHRAE 90.1-2010 in its entirety.*
A. GOAL SETTING

Minimum Compliance in Illinois
As of January 1, 2013

The bar was raised!

ASHRAE 90.1-2010 estimated to result in **19% savings** compared with ASHRAE 90.1-2007

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1 Pacific Northwest National Lab
New Commercial Construction Code Stringency
A. GOAL SETTING

Audience Poll:
Q: Is the bar too high for energy efficiency in Illinois?

Another Perspective?:
Q: Is the bar too low for energy efficiency in Illinois?

“Average” = new & existing (yes!)

2-Year-old State office building in Des Moines, Iowa – Actual Usage! (more on this later…)

<table>
<thead>
<tr>
<th>KBTU/SF/YEAR</th>
<th>AVERAGE</th>
<th>POSSIBLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDUCATION</td>
<td>83</td>
<td>42</td>
</tr>
<tr>
<td>RETAIL</td>
<td>74</td>
<td>37</td>
</tr>
<tr>
<td>OFFICE</td>
<td>93</td>
<td>46</td>
</tr>
<tr>
<td>PUBLIC ASSEMBLY</td>
<td>94</td>
<td>47</td>
</tr>
<tr>
<td>RELIGIOUS WORSHIP</td>
<td>44</td>
<td>22</td>
</tr>
</tbody>
</table>
A. GOAL SETTING

SEDAC Schools Energy Use Intensity (EUI)

“Average” = new & existing (yes!)
A. GOAL SETTING

The vision for today’s workshop is better-than-code energy efficient buildings.

Teams will need two goals to get there:

Design energy goal

and

Performance energy goal
A. GOAL SETTING

Design Energy Goals:


ASHRAE Standard 90.1 - 2013

LEED® v.4 – EA Credit 1 Optimize Energy Points

Designed to Earn The ENERGY STAR ®

2030 Challenge
Confused yet?

Goals target a percent (%) beyond or below a moving baseline can be very confusing! For Example:

i. LEED gives point for % better than code but uses different versions of ASHRAE 90.1 for baseline.

ii. ASHRAE Advanced Energy Design Guides:

* The 50 Percent AEDG series offer recommendations for achieving a “50% energy savings” compared to buildings that meet the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004.

* Whereas…The 30 Percent AEDG series offered recommendations for achieving a “30% energy savings” compared to … ANSI/ASHRAE/IESNA Standard 90.1-1999.
A simpler alternative:

Goals that target operational energy use and energy cost.

i. Energy Use Intensity (EUI) – expressed as kBtu/sf/year [site]

ii. Energy Cost Intensity (ECI) – expressed as $$/sf/year [billed]

iii. Other metrics to consider:
  - Electric Use Intensity – kWh/sf/year
  - Natural Gas Use Intensity – Therms/sf/year
  - Carbon Emissions – CO2e/year [site or source]
Performance Energy Goals:

Performance energy goals are typically based on actual performance—such as goals for a maximum annual energy usage and cost:

- Energy Use Intensity – in kBtu/sf/year
- Energy Cost Intensity – in $/sf/year

May seem scary now…but should not really be that much more challenging than required construction cost estimating:

Both types of ‘estimating’ are a combination of “science and art.”

Must include owner’s commitment to controlling operational impacts.
Performance Energy Goals:

Case Study:
Iowa Utilities Board and Office of Consumer Advocate, Des Moines, IA

Design Goal EUI: 28 kBtu/sf/year
Actual EUI: 21.2 kBtu/sf/year
Actual EUI with renewables (small PV array): 16.7 kBtu/sf/year

http://www.state.ia.us/iub/about_iub/IUBOCA_building.html
http://www.kjww.com/project?id=07.0375.01
A. GOAL SETTING

Performance Energy Goals:

Case Study:
What does this mean in terms of $$?

Iowa Utilities Board and Office of Consumer Advocate, Des Moines, IA
Project Cost:<$225/sf (44,460 gsf | $9,870,000)

<table>
<thead>
<tr>
<th>Goal</th>
<th>EUI</th>
<th>ECI</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average New Office Building</td>
<td>~90 kBtu/sf/year *</td>
<td>~$1.00/sf/year</td>
<td>$44,460/year</td>
</tr>
<tr>
<td>Design Goal</td>
<td>28.0 kBtu/sf/year**</td>
<td>~$0.66/sf/year</td>
<td>$29,188/year</td>
</tr>
<tr>
<td>Actual EUI</td>
<td>21.2 kBtu/sf/year **</td>
<td>~$0.50/sf/year</td>
<td>$22,100/year</td>
</tr>
<tr>
<td>Actual EUI with renewables</td>
<td>16.7 kBtu/sf/year**</td>
<td>~$0.39/sf/year</td>
<td>$17,409/year</td>
</tr>
</tbody>
</table>
Performance Energy Goals:

Case Study:

Coming to Illinois…

University of Chicago
Campus North Residence Hall
800-bed Residence Hall and Dining Commons
Budget: $150 Million

Client Goal: Maximum Site EUI of 55 kBtu/sf/year

Design/Build Team Lead: Mortenson Construction | Architect: Studio Gang | Engineer: dbHMS |
https://ww2.aievolution.com/gth1401/files/content/events/1826/0830_Morton_0210_1006_133859.pdf
http://facilities.uchicago.edu/construction/current/campus_north_residence_hall_and_dining_commons/
Experience matters - but so does commitment!

Look for these qualities in your team members:

1. Experience working within a fully integrative design process
2. Prior success in high performance design projects
3. Experience with whole building energy modeling
4. Enthusiasm for energy efficiency and sustainability
5. Clear buy-in on the team’s / owner’s energy goals

**DOES YOUR TEAM HAVE AN ENERGY CHAMPION?**
Commitment and focus on energy efficiency goals are needed from the earliest possible point in the design process:

And maintain that commitment and focus throughout design, construction, and building operation.
C. FOCUS ON ENERGY

Pre-Design/ Programming: Benchmark your building type: identify an initial energy “budget.” For net-zero projects identify maximum kWh from renewables…

ENERGY Star® Target Finder: http://www.energystar.gov/targetfinder
ASHRAE’S Energy Quotient: http://buildingenergyquotient.org/
C. FOCUS ON ENERGY

Pre-Design/ Programming: Benchmark your building type: identify an initial energy “budget.” For net-zero projects identify maximum kWh from renewables…

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<th>Construction Documents</th>
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<td><strong>Program Phase</strong></td>
<td><strong>Schematic</strong></td>
</tr>
<tr>
<td><strong>Design Development</strong></td>
<td><strong>Construction Documents</strong></td>
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</tbody>
</table>

VALUE & OPPORTUNITY

GREATES LEVERAGE

LEAST LEVERAGE

© WBDG.org
C. FOCUS ON ENERGY

**Conceptual Design:** use concept energy modeling tools to test footprint and orientation; estimate a ‘baseline’ EUI; and set initial design energy goals.

- eQUEST, Trane TRACE, Green Building STUDIO, IESVE, Sefaira, NEO Net Energy Optimizer, and others
C. FOCUS ON ENERGY

Schematic Design: More energy modeling: testing assembly options, percent glazing, HVAC system options, lighting power density (LPD) goals, etc.

A good time to start the discussion with clients about their pieces of the consumption ‘pie.’
**DD & CDs:** Use detailed energy modeling as you would a design-phase cost estimating tool – to test if the project is still within the ‘energy budget.’
C. FOCUS ON ENERGY

Bidding / Negotiation: During value engineering use modeling to test the impact of VE choices on the ‘energy budget.’ Using life-cycle cost analysis also key.

Don’t forget that energy efficiency measures in the initial building construction are the least expensive “energy source” a building owner can buy.
**C. FOCUS ON ENERGY**

**Construction phase and Turnover:** “There’s many a slip twixt the cup and the lip” (or twixt construction documents and building operations).

There can be a huge impact on building energy use due to changes made in submittals; failure to perform field testing; lack of BAS set-up and training.
You will need to make a commitment and focus on energy efficiency goals from the earliest possible point in the design process:

And maintain that commitment and focus throughout design, construction, and building operation.

C. FOCUS ON ENERGY

Pre-Design / Programming
Conceptual Design
Schematic Design

Construction Documents
Bidding / Negotiation
Submittals / Coordination

Functional Testing
Training / Turnover

DOES YOUR TEAM HAVE AN ENERGY CHAMPION?
C. FOCUS ON ENERGY

There's many a slip twixt the cup and the lip (or twixt construction documents and building operations).

There can be a huge impact on building energy use due to changes made in submittals; failure to perform field testing; lack of BAS set-up and training.

M&V of recent HPBs; measures to improve performance further (in kBtu/ft²)
D. VERIFY ENERGY GOALS

Verify **Design** Energy Goals:

Whole building energy modeling - early and often
Verify **Design** Energy Goals:
Different models have different functions/intent.
D. VERIFY ENERGY GOALS

Verify Design Energy Goals

Start of Design Phase  ➔ End of Design Phase

LOAD MODEL
- Weather file
- Generic building enclosure properties
- Approximate internal loads (plug loads, lighting, people)
- Generic schedules
- Rough building geometry

COMPLIANCE MODEL
- Actual building enclosure properties (or generic when not known)
- Generic schedules
- Actual building geometry

PARAMETRIC MODEL
- Model is fluid, geometry adapted based on initial analyses of weather, load calculations, and estimated internal loads
- Weather data is manipulated to match site
- Life cycle cost analyses can be derived from the model energy usage estimates
- Systems are sized to match building’s actual internal loads, occupancy, and schedules

GREEN RATING & INCENTIVES MODEL
- Actual schedules
- Minimum process load based on energy cost
- Actual internal loads
- Building geometry and exterior shading accurately modeled
- (depending on incentive) modified basecase model
D. VERIFY ENERGY GOALS

Verify **Design** Energy Goals

- Weather file
- Generic building enclosure properties
- Approximate internal loads (plug loads, lighting, people)
- Generic schedules
- Rough building geometry
D. VERIFY ENERGY GOALS

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**PARAMETRIC MODEL**
D. VERIFY ENERGY GOALS

Verify Design Energy Goals

- Actual schedules
- Minimum process load based on energy cost
- Actual internal loads
- Building geometry and exterior shading accurately modeled
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Source: www.GreenDinosaur.org
D. VERIFY ENERGY GOALS

Verify **Design** Energy Goals

- Actual building enclosure properties (or generic when not known)
- Generic schedules
- Actual building geometry

Source: www.GreenDinosaur.org
Verify Performance Energy Goals:

- Building level metering – all utilities
- System sub-metering – primary systems and tenant level metering
- ENERGY STAR Portfolio Manager®

http://www.energystar.gov

- Energy dashboards – real time energy consumption monitoring

Ref: 9/2014 SEDAC Newsletter article on Dashboards
http://smartenergy.illinois.edu/pdf/newsletter14_09.pdf
D. VERIFY ENERGY GOALS

Verify **Performance Energy Goals**: If you cannot measure the energy consumption of your facilities, you will not be able to effectively:

- Verify energy goals
- Manage ongoing energy use
- Improve energy efficiency over time
- Reward excellence in energy performance
Training & Ongoing Verification:

- Staff training cannot be over-emphasized.
- Train facility maintenance and operations staff, but also provide occupant training!
- Plan for incoming O&M staff training, and have a plan in place for continuing education for all staff.
- Don’t rely solely on those big books!

Source: http://www.buildingsystemssolutions.co.uk/o&m.html
Training & Ongoing Verification:

• Ongoing system commissioning.

• Continuous benchmarking.

• Ongoing refinement/adjustment of controls/schedules.

• Scheduled system software/hardware upgrades

• Celebrate energy efficiency accomplishments!
TOP TEN ENERGY EFFICIENCY STRATEGIES

Form & Environment
1. Orientation & Form
2. Insulation
3. Air Sealing

Loads
4. Lighting
5. Loads

Heating, Ventilating, & Air Conditioning
6. Heating
7. Cooling
8. Fans & Pumps
9. Building Automation
10. Commissioning

EXTRA CREDIT:
After implementing all of these, consider renewables such as solar and wind.
1. ORIENTATION AND FORM

Source: http://netzerocourt.com/
1. ORIENTATION AND FORM

Optimized orientation (east-west) with sun control

- Orient buildings on the east-west axis (+/- 10°)
- Reduce west facing glass
- Shade south glazing
- Take advantage of, or block, prevailing winds
- Orientation makes a difference in energy use!
1. ORIENTATION AND FORM

Optimized orientation (east-west) with sun control

- Control glare and overheating with exterior shading
- Where possible, face the broad side of the building to the south...because...
- Shading devices are most effective at keeping out direct sun on south-facing windows.


"h" and "V" are shading overhang dimensions, as a multiple of window height.
1. ORIENTATION AND FORM

Optimized orientation (east-west) with sun control:
Avoid these common pitfalls

- Beware of value engineering! Shading devices are frequently designed to compensate for the heat gain from large banks of windows, only to be eliminated later in order to cut up-front costs. If the windows themselves are not re-designed, the result is visual discomfort from glare and higher energy costs.
Avoid these common pitfalls

- Effective daylighting cannot be achieved without glare control – avoid large expanses of un-shaded windows.
2. INSULATION
Continuous thermal barrier

- Select and detail high performance roof, wall, and foundation assemblies to create a continuous thermal barrier with high thermal resistance (high R-value).

<table>
<thead>
<tr>
<th>Insulation</th>
<th>R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-15 cont. (above deck insul.)</td>
<td>R-24 total assembly</td>
</tr>
<tr>
<td>R-49 Attic insul.</td>
<td></td>
</tr>
<tr>
<td>Beyond-code foundation/ slab insulation</td>
<td>49</td>
</tr>
</tbody>
</table>
Continuous thermal barrier

- “Use less glass, use good glass”

Joseph W. Lstiburek, Ph.D., P.Eng., Fellow ASHRAE
2. INSULATION

R-15 Wall with U-0.35 (R-2.86) Window

Total Assembly U-factor

Source: ASHRAE Journal November 2008
At 20% Glazing, the assembly has an effective overall wall R-Value of ~R-8.
At 40% Glazing, the assembly has an effective overall wall R-Value of ~R-5.5.

Source: ASHRAE Journal November 2008
2. INSULATION

But we love our glazing! So let’s make the opaque wall really great (R-40) and keep the glass at 40% and use the best assembly rating we can get (~U-0.30) - without using to triple or quadruple glazing or imported windows.

Source: ASHRAE Journal November 2008
2. INSULATION

OK! Overall Assembly is now a whopping ~R-7.3.
2. INSULATION

You are OK with ~R-7.3? How about we compromise on a buildable wall assembly and readily available commercial glazing assemblies and limit glazing to 25%!!

Source: ASHRAE Journal November 2008

Effective Overall Wall R-Value (hr sf F/ Btu) vs. Window-to-Wall Ratio (WWR) %

Examples of High-Performance Enclosures

Typical Range of Commercial Enclosures

Typical Curtainwall Systems

1. Uwindow=0.5, Rwall=6
2. Uwindow=0.5, Rwall=11
3. Uwindow=0.5, Rwall=16
4. Uwindow=0.35, Rwall=15
5. Uwindow=0.30, Rwall=40
6. Uwindow=0.14, Rwall=20
2. INSULATION

Avoid these common pitfalls

Just say no.
Avoid these common pitfalls

- Misunderstood window performance (center of glass vs. total assembly performance)
  
  **Example** (using 2013 ASHRAE Handbook of Fundamentals)
  
  Double glazing, e=0.20 on surface 2 or 3, 1/2 in., argon-filled: center of glass (CoG) U-Factor = 0.30 (R-3.33)

  Curtainwall assembly with thermal break - 6’-8” x 6’x8” panel: estimated total assembly U-Factor = **0.45** (R-2.22) – 33% reduction compared to CoG thermal resistance

  Assembly would just meet minimum prescriptive requirement for compliance with **ASHRAE 90.1 2010** (U-0.45 max. Metal Framing Curtainwall/ Storefront, Zone 5)
Avoid these common pitfalls

- Misunderstood window performance (center of glass vs. total assembly performance)

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  - Center of glass (CoG) U-Factor = 0.30 (R-3.33)

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  - Estimated total assembly U-Factor = 0.45 (R-2.22) – 33% reduction compared to CoG thermal resistance

  Assembly would just meet minimum prescriptive requirement for compliance with ASHRAE 90.1 2010 (U-0.45 max. Metal Framing Curtainwall/ Storefront, Zone 5)

But fails to meet minimum prescriptive requirement for IECC 2012 (U-0.38 max. Fixed Fenestration, Zone 5)
Avoid these common pitfalls

- Incorrect R-Value for metal stud wall assemblies.

<table>
<thead>
<tr>
<th>WALL COMPONENT</th>
<th>R-VALUE Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUTSIDE AIR FILM</td>
<td>0.17</td>
</tr>
<tr>
<td>4&quot; NOMINAL FACE BRICK</td>
<td>0.80</td>
</tr>
<tr>
<td>1&quot; AIR SPACE</td>
<td>1.00</td>
</tr>
<tr>
<td>1&quot; RIGID INSULATION</td>
<td>5.0</td>
</tr>
<tr>
<td>R-13 BATT INSULATION BETWEEN METAL STUDS @16&quot; O.C.</td>
<td>13.0</td>
</tr>
<tr>
<td>5/8&quot; DRYWALL</td>
<td>0.56</td>
</tr>
<tr>
<td>INSIDE AIR FILM</td>
<td>0.68</td>
</tr>
<tr>
<td>TOTAL R-VALUE</td>
<td>21.21</td>
</tr>
<tr>
<td>Assembly U-Factor</td>
<td>0.047</td>
</tr>
</tbody>
</table>
Avoid these common pitfalls

- Incorrect R-Value for metal stud wall assemblies.

### Wall Component R-Value

<table>
<thead>
<tr>
<th>Component</th>
<th>R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Air Film</td>
<td>0.17</td>
</tr>
<tr>
<td>4” Nominal Face Brick</td>
<td>0.80</td>
</tr>
<tr>
<td>1” Air Space</td>
<td>1.00</td>
</tr>
<tr>
<td>1” Rigid Insulation</td>
<td>5.0</td>
</tr>
<tr>
<td>R-13 BATT Insulation Between Metal Studs @16” O.C.</td>
<td>13.0</td>
</tr>
<tr>
<td>5/8” Drywall</td>
<td>0.56</td>
</tr>
<tr>
<td>Inside Air Film</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>Total R-Value</strong></td>
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*Appears to meet prescriptive requirement for IECC 2012 (U-0.048 max. Metal Frame Wall, Zone 5)
Avoid these common pitfalls

- Incorrect R-Value for metal stud wall assemblies.

<table>
<thead>
<tr>
<th>WALL COMPONENT</th>
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<th>R-Value Assembly</th>
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</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>TOTAL R-VALUE</td>
<td>21.21</td>
<td>14.21</td>
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</table>

Assembly U-Factor

See: ASHRAE 90.1 Table A9.2.B
Avoid these common pitfalls

• Incorrect R-Value for metal stud wall assemblies.

<table>
<thead>
<tr>
<th>WALL COMPONENT</th>
<th>Outside R-Value</th>
<th>Inside R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUTSIDE AIR FILM</td>
<td>0.17</td>
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<tr>
<td>Assembly U-Factor</td>
<td>0.047</td>
<td>0.070</td>
</tr>
</tbody>
</table>

Actually it **fails** to meet prescriptive requirement for IECC 2012 (U-0.048 max. Metal Frame, Zone 5)
Avoid these common pitfalls:

- Incorrect R-Value for metal stud wall assemblies.

### Table

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<td>0.68</td>
</tr>
<tr>
<td><strong>Total R-Value</strong></td>
<td><strong>31.21</strong></td>
<td><strong>24.21</strong></td>
</tr>
<tr>
<td>Assembly U-Factor</td>
<td>0.032</td>
<td>0.041</td>
</tr>
</tbody>
</table>

The key is more continuous insulation! Shoot for an R-24 total assembly R-Value – or better!
2. INSULATION

Avoid these common pitfalls

- Incorrect R-Value for metal frame wall assemblies.

<table>
<thead>
<tr>
<th>WALL COMPONENT</th>
<th>R-VALUE Material</th>
<th>R-Value Assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUTSIDE AIR FILM</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>4&quot; NOMINAL FACE BRICK</td>
<td>0.80</td>
<td>0.80</td>
</tr>
<tr>
<td>1&quot; AIR SPACE</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>3&quot; RIGID INSULATION</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>R-13 BATT INSULATION BETWEEN METAL STUDS @16&quot; O.C.</td>
<td>43.0</td>
<td>6.0</td>
</tr>
<tr>
<td>5/8&quot; DRYWALL</td>
<td>0.56</td>
<td>0.56</td>
</tr>
<tr>
<td>INSIDE AIR FILM</td>
<td>0.68</td>
<td>0.68</td>
</tr>
<tr>
<td>TOTAL R-VALUE</td>
<td>31.21</td>
<td>24.21</td>
</tr>
<tr>
<td>Assembly U-Factor</td>
<td>0.032</td>
<td>0.041</td>
</tr>
</tbody>
</table>

Beats the minimum prescriptive requirement for IECC 2012 (U-0.048 max. Metal Frame Wall, Zone 5)!
2. INSULATION

Avoid these common pitfalls

• Assemblies with significant thermal bridging
2. INSULATION

Avoid these common pitfalls

• Assemblies with significant thermal bridging
Avoid these common pitfalls

- Missing insulation in installed assemblies

1. What they drew
2. What they got
2. INSULATION

Avoid these common pitfalls

• Underestimated impact of thermal bridging elements in assemblies
  ➢ Example: 20-50% reduction (or higher) in overall component or assembly R-Values due to thermal bridging
  ➢ Significant risk of occupant discomfort, condensation, mold, and moisture related damage.
3. AIR SEALING
3. AIR SEALING

Continuous air barrier

- Air sealing is highly cost-effective
- Reduces a building’s heating and cooling load
- Improves occupant comfort
- Infiltration/ exfiltration can waste up to 5% of a typical office building’s heating and cooling energy (ENERGY STAR®).

Main Sources of Air Pressure Differentials in Buildings

Air Flow Pathways

Continuous air barrier

Reducing air infiltration through the thorough design and construction of a continuous air barrier can also result in:

- Better indoor air quality
- Improved thermal control
- Less potential for mold
- Fewer moisture issues
- Smaller HVAC equipment

Continuous air barrier

The most significant sources of infiltration typical in new buildings are found at these locations:

- Foundation wall to above-grade wall intersection
- Around exterior door and window frames and sills
- Top of wall to roof-framing intersection
- Recessed lighting fixtures
- Roof penetrations including hatches, ducts, electrical conduit, piping, intake/ exhaust dampers, etc.
- Transitions between different building materials (e.g. brick to exterior metal panel system).

3. AIR SEALING

Avoid these common pitfalls

“Typical wall-roof assembly. There is air leakage into and out of everything and everywhere”

“Managing heat flow, airflow, and moisture flow is a multi-part process that requires having a moisture-control layer, thermal-control layer, an air-control layer, and a vapor-control layer.”

Retrofit Magazine Nov.-Dec. 2013

Best Building Envelopes
3. AIR SEALING

Avoid these common pitfalls

AIR SEAL to stop the STACK EFFECT

- Air leaks out the top.
- Hot air rises
- Air sucked in at the bottom

photo: David Keefe, Vermont Energy Investment Corporation
Avoid these common pitfalls

- **Design**: reliance on ‘assumed’ air sealing performance of specific materials without specifying an assembly air leakage maximum rate (CFM/ft²) and/or material air permeance maximum (CFM/ft²).
- **Construction**: construction assemblies/ intersections not sealed before being hidden behind interior finish construction – and no longer accessible for easy application.
- **Design & Construction**: inadequate inspection and testing of assembly installations for compliance with code-required continuous air barrier.
- **Recommendation**: envelope commissioning for large and/or complex projects.
4. LIGHTING AND DAYLIGHTING
4. Lighting and Daylighting

Low LPD and advanced controls

- Identify functional requirements
- Target reduced lighting power density (LPD)
- Coordinate lighting design with envelope design for optimized daylighting
- Coordinate lighting design with HVAC equipment sizing/selection
- Optimize lamp type and fixture selection
- Choose the right lighting controls!
- Include lighting system commissioning
- Train and maintain!
30% better-than-code is incredibly easy for lighting – the standards are lagging the industry revolution.
4. LIGHTING AND DAYLIGHTING

- LED Parking lot fixtures mainly save energy by having better directionality.
- Savings of 50-60% are typical.
- There is also potential for motion sensors, photo cells, and dimming.
- 400W MH = 138W LED fixture
Avoid these common pitfalls

• Dark colored interiors and furniture
• Daylighting controls planned for spaces with high glare
• Light level settings incorrect for daylight control
• Overlit or underlit spaces
• Multiple fixtures connected via one switch
• Too many different lamp types
Avoid these common pitfalls

- Missing or inadequate controls labeling
- Lighting controls too complicated for users & maintenance staff
- Control system not programmed, staff not trained
5. ADDITIONAL LOADS
Reduce plug- and process-loads

Plug loads account for about 10-15% of a typical commercial office building’s electricity consumption.

- Typical building uses 0.5-1.0- W/sf for plug loads.
5. ADDITIONAL LOADS

Reduce plug- and process-loads

Plug loads account for about 10-15% of a typical commercial office building’s electricity consumption

- Typical building uses 0.5 to 1.0 W/sf for plug loads.
- Those new offices of the Iowa Utilities Board and Office of Consumer Advocate, Des Moines, IA – are consuming just 0.25 W/sf in plug loads!
Reduce plug- and process-loads

Data center efficiency strategies

- Virtualize! Typical server utilization rates < 5%
- Use hot aisle, cold aisle layout
- Use cold aisle containment
- Minimize distance air has to travel for cooling
- Raise temperatures (for newer equipment)
- Recover waste heat for building space- or water- heating
- Use high-efficiency (≥ 90%) computing equipment power supplies and uninterruptable power supply (UPS)
- Install variable frequency drives on air handler fans
Plug loads in a net zero building in Seattle

Avoid these common pitfalls

- Lack of staff awareness/training
- Poor thermal control leading to the proliferation of personal comfort devices (fans, space heaters).
- Information management staff unaware of computer management energy saving tools
6. & 7. HEATING & COOLING
Minimize loads first, then select & size equipment

- Adding quality to envelope and loads reduces the final HVAC size and cost.

Choose High efficiency systems/ equipment

- Air source heat pumps
- Condensing boilers
- Chilled beams
- Variable refrigerant flow (VRF)
- Modular equipment
Choosing the right system(s)

An efficient system:

- Integrates with the design concept
- Matches planned use and zone control
- Has a manageable level of complexity
- Is scalable for varying demand
- Is easy to maintain
- Is easy to control
Choosing the right system(s)

- System selection can impact required building floor-to-floor heights, ceiling heights, acoustics, occupant comfort, site planning…and of course operational energy use.
- The best choice will depend on:
  - building use type and schedules
  - level of system control needed
  - complexity of system requirements
  - availability/skill level of O&M staff
Choosing the right system(s)

- Three main ways to provide space heat & cooling:
  - Direct air heating/cooling via gas-fired furnace and direct expansion (DX) cooling equipment.
  - Indirect heating/cooling of supply air through hydronic coils in a central air handler or terminal unit – served by boiler / chiller.
  - Radiant heating and/or cooling.
- Then there is the choice between using a centralized heating/cooling plant or distributed heating/cooling equipment.
Combined systems

- Ground source heat pumps (GSHP) use the ground as a source/sink for heat.
- Water-source heat pumps and variable refrigerant flow (VRF) systems transfer heat from an overheated area of a facility into another area calling for heat.
- Air-source heat pumps use ambient air as a heat source and heat sink.
Optimal Systems

- High-efficiency radiant heating and cooling for people comfort
- Dedicated outdoor air units for conditioned ventilation-air
- Displacement air distribution for cooling (supply low)
- Appropriate zone control
- Waste heat recovery from large process loads (data centers, refrigeration, process steam, etc.)
6. & 7. HEATING & COOLING

Reduce loads from ventilation

• Demand control ventilation

Graphic from: EnergyCodes.gov
6. & 7. HEATING & COOLING

Reduce loads from ventilation

- Total energy recovery
Avoid these common pitfalls

- Equipment selection based on first-cost only
- Failure to right-size equipment based on final building envelope configuration and energy efficiency measures implemented
- Lack of system commissioning
- Cramped mechanical rooms
- Inadequate operator training
- Poor system zoning
8. FANS AND PUMPS
Variable speed drives (VSD)

- AKA: adjustable speed drives (ASD), variable-frequency drives (VFD), etc.
- Use variable speed drives on electric motors with variable loads.
- Use premium efficiency equipment.
- Include training!
Avoid these common pitfalls

• Use variable speed drives on electric motors without variable loads.
• System stuck at 100%
• Incorrect system logic
• Sensors not installed correctly or not connected
9. BUILDING AUTOMATION
Great potential

- No other system has greater potential to determine the success (or failure) of an energy-efficient building project than the selection, installation, and commissioning (or lack of commissioning) of HVAC controls. Code-required and recommended beyond-code energy-saving control strategies all rely on functional sensors and controls that operate as intended. Without this the energy consumption of the building will almost certainly be adversely affected.
9. BUILDING AUTOMATION

System scheduling, resets

- Turn systems off and shut dampers when not needed (nights, weekend, holidays)
- Avoid simultaneous heating and cooling
- Optimize ventilation when building is occupied
- Use outside air when it will save energy
- Boiler and chiller supply temperature resets
- Duel control strategies for VAV
Lots of code-required capabilities*

- Zone thermostatic control
- Dead band control
- Setpoint overlap restrictions
- Off-hour controls
  - Automatic shutdown
  - Setback controls
  - Optimum start controls
  - Zone isolation
- Ventilation system controls

*ASHRAE 90.1-2010
9. BUILDING AUTOMATION

System scheduling, resets

• Controls are indeed the elephant in the living room.
Avoid these common pitfalls

• Use of proprietary systems resulting in high component replacement costs.
• Unlimited access to the system given to untrained personnel.
• Failure to match system complexity with available staff and/or consultant support
• Initial system programming/ scheduling/ setup incomplete
• Inadequate staff training
• Lack of planning for regular system maintenance and upgrades
Avoid these common pitfalls

- All control points – no status points
- Too complex

Sometimes people need/ want this:

Not this:
10. COMMISSIONING

3 PHASES OF COMMISSIONING

- Design Phase Commissioning
  - Create OPR and BOD
  - Construction Docs Cx
  - Develop Cx plan

- Construction Phase Commissioning
  - Schedule Cx
  - Execute Cx plan
  - Start-up testing
  - Training

- Operational Commissioning
  - Final Cx report
HVAC, lighting, and envelope commissioning

• Involving a commissioning agent early-on helps to ensure a fully optimized building that is both efficient and comfortable.
10. COMMISSIONING

Design Phase

The phases of commissioning during design parallel the recommended energy modeling process through design and construction.
Avoid these common pitfalls

- Engaging commissioning agent too late in the process.
- Failure to heed commissioning agent recommendations.
- Inadequate scope of work and contingency fund to encompass functional testing and retesting for systems that fail initial sample testing.
- Single season commissioning
Renewables:

- Plan the **infrastructure** now for future
- Select **site-appropriate** technologies
EXTRA CREDIT

The diagram illustrates the relationship between construction cost and energy consumption or production. The y-axis represents construction cost ($/sf), and the x-axis represents energy consumption/production (kBtu/sf/yr).

- **Minimum Total Cost**: The point where the total cost is minimized.
- **Total Cost**: The line representing the total cost, which includes both construction cost and energy costs.
- **Energy Production**: The line indicating energy production.
- **Energy Demand**: The line indicating energy demand.

The graph shows that there is an optimal point where the total cost is minimized, which is between energy consumption and production levels.
EXTRA CREDIT

Net Zero Walgreens

425 MWh

340 MWh

315 MWh

260 MWh

250 MWh

200 MWh
EXTRA CREDIT

Net Zero Walgreens, Evanston IL
PV Costs

Cost per watt decreases with capacity.

Typical range: $2 to $4 per watt:

- Can be as low as $1.0/watt for the collectors.
- Thin film might costs less, but is less efficient.
- New technology may be as low as $0.87/watt.

Total installed costs:

- Installation (contractor hours)
- Include racking, etc.
- $2,500-$5,000/kW
- $2.50-$5/kW
- Cost per watt decreases with capacity.
- **Typical range: $2 to $4 per watt:**
  - Can be as low as $1.0/watt for the collectors.
  - Thin film might costs less, but is less efficient.
  - New technology may be as low as $0.87/watt.
- **Total installed costs:**
  - Installation (contractor hours) will always costs the same
  - Include racking, etc.
  - $2,500-$5,000/kW
  - $2.50-$5/kW

Solar power panels
Credit: Courtesy of SunEdison
Avoid these common pitfalls

- Spending dollars up front for renewables that could better be used to achieve high levels of energy efficiency in the building envelope, lighting, and HVAC – reducing building consumption.
- Selecting technologies that do not fit available renewable resources (e.g. wind turbines in low-wind or areas of high potential turbulence)
Illinois Energy Now | 1-800-214-7954
www.ILEnergynow.org