HIGH PERFORMANCE DESIGN

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Trade Ally Rally | Illinois | December 2014
WHAT IS HIGH PERFORMANCE DESIGN?

What will it take to achieve high performance?

A. **Goal Setting**: design & performance energy goals
   
   Know where you are and where you want to go.

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

C. **Focus on energy**: in design & construction
   
   Know the most effective strategies

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

E. **Plan to maintain**: training & ongoing verification
Obtain at least one year’s worth of energy data on the building (two years or more is better).

Plot the energy consumption for each month versus heating degree days and cooling degree days.

Review the graphs for anomalies.

Here is a bank…

www.dgreeedays.net/
**TWO TYPES OF BUILDINGS**

**Envelope Dominated:** energy usage pattern tied to the climate, generally with some base load electrical and natural gas usage.

**Internal Gain Dominated:** energy usage pattern only slightly or not linked to the climate. Cooling load year-round.

Typically, small buildings are envelope dominated and large buildings are internal gain dominated – although this is not cast in concrete.
ENERGY STAR® Target Finder was consulted for a comparison with similar buildings. Target Finder uses a large collection of building energy data to provide an estimate of an average building’s energy consumption, taking into account its location, size and use.


<table>
<thead>
<tr>
<th></th>
<th>Annual Consumption</th>
<th>Annual Costs</th>
<th>Average Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>504,000 kWh</td>
<td>$ 50,249</td>
<td>87%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>8,551 therms</td>
<td>$ 7,236</td>
<td>13%</td>
</tr>
<tr>
<td>Total Facilities Area</td>
<td>15,753 ft²</td>
<td><strong>Total:</strong> $ 57,485</td>
<td></td>
</tr>
<tr>
<td>Electricity Use Intensity</td>
<td>32 kWh/ft²/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas Use Intensity</td>
<td></td>
<td>0.54 Therms/ft²/yr</td>
<td></td>
</tr>
<tr>
<td>Energy Use Intensity</td>
<td>163 kBtu/ft²/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Cost Intensity</td>
<td></td>
<td><strong>$ 3.65</strong> /ft²/yr</td>
<td></td>
</tr>
</tbody>
</table>

Target Finder Results

<table>
<thead>
<tr>
<th></th>
<th>Bank</th>
<th>Average</th>
<th>ENERGY STAR Certified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Performance</td>
<td>31 Percentile</td>
<td>50 Percentile</td>
<td>70 Percentile</td>
</tr>
<tr>
<td>Energy Use Intensity</td>
<td>163 kBtu/ft²/yr</td>
<td>104 kBtu/ft²/yr</td>
<td>82 kBtu/ft²/yr</td>
</tr>
</tbody>
</table>
We know…

- A school
- No summer school
- Heated
- Cooled
- Comfortable

**TYPICAL DATA ANALYSIS – A SCHOOL...**

Remember when you shift a secondary axis you are changing the story you tell.
Base Load is typically lights, fans, pumps, plug loads, etc.

High electric use in air conditioned schools - late spring/ early fall is not unusual as students return to classes and cooling demand can be high.

OR is the baseline electric use closer to ~275,000 kWh?

April is a reasonable “guess” for baseline monthly usage.

REMEMBER

The graph tells only part of the story! A school with minimal summer occupancy...

The graph shows monthly kWh usage and degree days from November 2010 to October 2011. The baseline electric use is indicated by a dashed line, and April is highlighted as a reasonable guess for baseline monthly usage. The graph also includes the information that kWh (3,753,262) and CDD (1,237) are shown.
Correlation with heating degree days likely means electric resistance heating somewhere in the building (i.e. teachers bringing in small space heaters)

Remember to look for the unexpected!
Consider whether or not it is likely the baseline (base utility) natural gas use is ~2,500 Therms/month?

REMEmber
When you shift a secondary axis you are changing the story you tell.
Or is it more likely that high natural gas use in summer indicates excessive use of ventilation system reheat – and the baseline (base utility) use is closer to 300 Therms/month.

**REMEMBER**

*When you shift a secondary axis you are changing the story you tell.*
Don’t forget the power of interval data analysis when available!

Election Day, school is closed. But some portions are open for polling.
TOP 10 STRATEGIES
NEW AND EXISTING
BUILDINGS
### TOP TEN ENERGY 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. Motors & Pumps
- 9. Building Automation
- 10. Commissioning

**EXTRA CREDIT:**
After implementing all of these, consider renewables such as solar and wind.
- Science & Technology magnet school
- Replaces existing building

### Case Study

<table>
<thead>
<tr>
<th>Component</th>
<th>Baseline Annual kWh</th>
<th>Proposed Annual kWh</th>
<th>Savings Annual kWh</th>
<th>% Saved</th>
<th>% Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>437,167</td>
<td>25,197</td>
<td>411,970</td>
<td>94%</td>
<td>45%</td>
</tr>
<tr>
<td>Cooling</td>
<td>74,963</td>
<td>31,606</td>
<td>43,357</td>
<td>58%</td>
<td>5%</td>
</tr>
<tr>
<td>Pumps/Fans</td>
<td>72,140</td>
<td>166,560</td>
<td>-94,420</td>
<td>-131%</td>
<td>-10%</td>
</tr>
<tr>
<td>Interior Lighting</td>
<td>123,298</td>
<td>104,357</td>
<td>18,941</td>
<td>15%</td>
<td>2%</td>
</tr>
<tr>
<td>Exterior Lighting</td>
<td>18,505</td>
<td>18,505</td>
<td>0</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Plug Loads</td>
<td>200,509</td>
<td>200,509</td>
<td>0</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>926,582</td>
<td>546,734</td>
<td>379,848</td>
<td>41%</td>
<td>41%</td>
</tr>
</tbody>
</table>
ORIENTATION & ENVIRONMENT

- 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!
CASE STUDY ORIENTATION

- East West Axis
- South overhangs
- Northern and southern windows

Costs:
- $70,000
- $72,000
- $74,000
- $76,000
- $78,000
- $80,000
- $82,000

Orientation:
- 0°
- 90°
- 180°
- 270°
ORIENTATION “DON’TS”

Curtain wall…
ORIENTATION “DON’TS”

Curtain wall…

JUST SAY NO!
Beware of value engineering!
Shading devices 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.
Exceed code

- Wall and roof insulation levels
  - Continuous insulation
- Windows
  - Percent of wall area
  - Low-e coating
- Reduced infiltration
  - Air sealing
  - Air barrier
  - Vestibules
- Envelope commissioning
Air infiltration is unwanted air flow into and out of the building caused by leakage paths and pressure differences between inside and outside of the building.

Openings at the top and bottom of the building are the most important to seal.

- plumbing chases
- wiring
- recessed lights
- chimney enclosures
- sill plate
- look above a recessed ceiling
- ducts in unconditioned areas
- surprises that you will find
SEALING THE ENVELOPE

Wall to Roof Junction Air Sealing

Pre-Retrofit

Post Air Sealing

Current condition

From SEDAC report
STACK EFFECT

Don’t let this happen to your building!

Positive pressure (with reference to outside)

Neutral pressure plane

Negative pressure (with reference to outside)

Photo Credit: ©David Keefe, Vermont Energy Investment Corporation
R-18 to R-24 walls
  - 3” continuous insulation (polyiso)
R-37 roof insulation
  - 6” continuous insulation (polyiso)
  - 3” minimum at drains
Windows U-0.27, SHGC-0.31

Vestibules
Designed with heat exchanger to make up for reduced air infiltration
ENVELOPE “DON'TS”

Building in southern Illinois
Built in 2005
Designed to code
ENVELOPE “DON’TS”

Occupants were cold
No continuous insulation
Don’t underestimate the impact of thermal bridging
Avoid these common pitfalls

- Assemblies with significant thermal bridging
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
LIGHTING
30% better-than-code is incredibly easy for lighting – the standards are lagging the industry revolution.
Lighting power usage
- Reduce ASHRAE numbers <0.9 W/sf

Occupancy & vacancy sensors
- Manual On / Auto OFF (after less than 30 minutes)

Multi-level switching or dimming

Daylighting controls

Solar tubes

Outdoor lighting
- Reduce by 50% after closing
- Turn off 30 minutes after sunrise
MULTI-LEVEL CONTROLS AND SWITCHING

ENERGY SAVING
Standby mode when unoccupied

100% BRIGHTNESS
for safety upon occupancy

Image: LaMar Lighting
HID TO FLUORESCENT RETROFIT (OR LED)

Existing System:
- 400watt High Pressure Sodium and 400watt Metal Halide
- Each fixture uses 455 watts (400 for lamp, 55 for ballast)

Retrofit:
- Each fixture uses 234 watts (lamps and ballast combined)
- Light levels increased 10-20%
- Instant on is a huge benefit for schools
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.
LED EXIT SIGNS

- Payback is quick: $30 / $30/yr = 1yr
- Rebates available
- Very basic lighting energy savings measure
- Chicago requires more expensive versions
- Be sure to match LED color to fixture. i.e. if existing lamp is white, new lamp should be white
Avoid these common pitfalls

- Missing or inadequate controls labeling
- Lighting controls too complicated for users & maintenance staff
- Control system not programmed, staff not trained

LIGHTING “DON'TS”
CASE STUDY
LIGHTING

- Lighting Power Density = 0.9 W/sf
- Daylighting controls on perimeter windows
- Vacancy sensors and occupancy sensors throughout
- Controllable solar tubes
CASE STUDY
SOLAR TUBES

- Natural light for interior rooms
- Better insulated than skylights

50 fc 1 fc 6 fc
Use design to reduce loads

Data Centers
- Cold Aisle
- Server Virtualization
- Thin Client
- Economizers

General Plug Loads
- Smart strips

Process:
- Equipment efficiency
- Equipment interaction (i.e. reclaim heat)

ENERGY STAR® equipment
VENDING ENERGY MANAGEMENT

- Turns off equipment when no one is present
- Cycles compressors to keep beverages cold
- Available for snack machines and merchandizers
- Less than 1 year payback
CASE STUDY
PLUG LOADS

- Data center houses thin client servers for district
- ENERGY STAR equipment
- Elevator only usable as needed
- Computer energy management district-wide
- Vending energy management contractually obligated by vendors
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
Reduce loads from ventilation

- Demand control ventilation
Reduce loads from ventilation

• Total energy recovery

A diagram of a rotary heat exchanger, or "heat wheel" (From Uptime Technology BV)
Ground source heat pumps
- EER 13.5
- COP 4.5

Server room cooling tied to heat pump loop

Dedicated outside air VAV with GSHP & heat recovery

Demand control ventilation

Economizers

User control thermostats with +/- 2°F adjustment

VFDs on water pumps
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
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.
BUILDING AUTOMATION SYSTEM (BAS)

- Ability to control and document systems and settings
- **Design to the level of ability of operating personnel**
- Assure adequate training and ability to manipulate
- System should
  - Allow owner to set schedules for equipment and lighting
  - Optimal equipment start with adaptive learning
  - Time and respond capabilities based on demand in zones
  - Monitor and meter energy use
  - Trend data
  - Reset schedules for systems
  - Send alarms
CASE STUDY
BUILDING AUTOMATION

- Full building automation system (BAS)
- Allows minimal control at each space
- Provide district-wide control from central office
BUILDING AUTOMATION “DON’TS”

Avoid these common pitfalls

• All control points – no status points
• Too complex

Sometimes people need/want this:

Not this:
**BUILDING AUTOMATION “DON'TS”**

- Community college in southern Illinois
- Had a BAS, were never trained on how to use it
- Needed to call BAS contractor anytime there was a malfunction – so, typically didn’t bother to call.

$180/hr * 4-6 hrs = proposal

$180/hr * 4-11 hrs = work completed

$1,440 - $3,000!
COMMISSIONING

- A quality assurance process
  - Occurs between early design phase through occupancy
- Ensures that the building operates as intended
  - Building staff are prepared to operate and maintain
- Why is it needed?
  - Increasing complexity of building control systems
  - Lack of contractual coordination between trades
  - Technical staff in the field who looks out for the owner
CASE STUDY
COMMISSIONING

- Commissioning agent brought on to project during schematic design phase
- On-site commissioning of all equipment
- Trained staff on equipment and control operation
COMMISSIONING “DON’TS”

- Back to our poor building
- Designed with a BAS but was never commissioned
- Uses 3x energy as planned
RETRO-COMMISSIONING
EXAMPLE SITE AND BILLS

2001 High School
- Standard construction
- Constant volume system
- Standard efficiency boilers
- Ran out of money on the energy budget

<table>
<thead>
<tr>
<th></th>
<th>Sep09-Aug10</th>
<th>Annual Consumption</th>
<th>Annual Costs</th>
<th>Average Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>2,041,200 kWh</td>
<td>$106,176</td>
<td>31%</td>
<td>$0.05 $/kWh</td>
</tr>
<tr>
<td>Electric</td>
<td>304 - 712 kW (min-max)</td>
<td>$88,812</td>
<td>26%</td>
<td>$16 $/kW</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>165,094 therms</td>
<td>$145,097</td>
<td>43%</td>
<td>$0.88 $/therm</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>$340,085</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Floor Area</th>
<th>117,000 sf</th>
<th>Occupants</th>
<th>300 Students, 55 Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>17.4 kWh/sf/yr</td>
<td>Gas Use Intensity</td>
<td>1.41 therms/sf/yr</td>
</tr>
<tr>
<td>Energy</td>
<td>201 kBtu/sf/yr</td>
<td>Energy Cost Intensity</td>
<td>$2.91 $/sf/yr</td>
</tr>
</tbody>
</table>

Bar chart showing EUI from Sept 07 to Sept 09 with "Targe Finder" at 50 KBTU/SF/YR
**BILL ANALYSIS**

**SBHS: Monthly Electricity Usage**

- 2008 had summer school
- Some anomalies in 2007
- Fairly high spring and fall baseload

**SBHS: Monthly Gas Usage**

- HDD line is a relative indicator of gas use
- Notice pretty good seasonal dependency
Then, things went crazy.
• Note, this case is extreme but it’s not alone.
• It’s roughly 2.5 times the average use and cost.
Only consider renewables after implementing all of the previous ideas.

The cost per unit energy saved of high efficiency equipment and improved design is less than the cost per unit of energy of wind or solar.

Renewables do, however, make great marketing and educational opportunities and can be more affordable when incentives are available.
Renewables:

- Plan the **infrastructure** now for future
- Select **site-appropriate** technologies
- Use to take last step to net-zero
Savings from renewables not shown in savings table
3 kW solar array funded through ICECF
Program to put panels on all schools
This site does not have sufficient wind resources to consider educational level turbine
TOTAL INCREMENTAL COST $546,120

Incentives $340,508

Final Incremental Cost $205,612

Annual Utility Savings w/o solar $33,037

Simple Payback 6.2 years

IRR (5% acceptable) 10.3%

Net Present Value (10 yr, 5%) $53,952
How SEDAC can help with new construction...

- **Design Assistance**
  - Public sector
  - Private sector
- **Incentive Review**
  - Public Sector
- **Services are funded by DCEO or Utility at no charge to the project or owner**