Existing Building Upgrades

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Smart Energy Design Assistance Center (SEDAC), University of Illinois at Urbana Champaign
SEDAC ILLINOIS K-12 SCHOOL ENERGY USE INTENSITIES

Energy Use Intensity (kBtu/sf/yr)

Electric kBtu/sf    Gas kBtu/sf
New Schools, < 20 years old

- Electric kBtu/sf
- Gas kBtu/sf

Energy Use Intensity (kBtu/sf/yr)
ENERGY STAR QUALIFICATION ≠ ≠
UPGRADES CAN EARN ENERGY STAR QUALIFICATION
EXPECTATIONS

- **Energy Cost Savings**
  - Low Hanging Fruit: 15%
  - Moderate Cost: 30%
  - Capital Intensive: 50%

- **Investment Costs**
  - Low Hanging Fruit
100,000 sf building
$1.00/sf energy costs

Savings from upgrades
~$15,000-$30,000 annually

Over 5 years $75-150k
BUILDING COST BREAKDOWN

- Space Heating: $90,000 (45%)
- Interior Lighting: $40,000 (20%)
- Cooling: $30,000 (15%)
- Plug Loads: $16,000 (8%)
- Fans Pumps: $16,000 (8%)
- Water Heating: $4,000 (2%)

Total: $200,000
BUILDING COST BREAKDOWN

- **Space Heating**: $76,538 (38%)
  - **Exterior Lighting**: $3,200 (2%)
  - **Water Heating**: $4,000 (2%)
  - **Fans Pumps**: $12,800 (6%)
  - **Plug Loads**: $16,000 (8%)
  - **Cooling**: $30,000 (15%)
  - **Interior Lighting**: $34,000 (17%)
  - **Savings**: $29,702 (15%)

- **Space Heating**: $90,000 (45%)
  - **Exterior Lighting**: $4,000 (2%)
  - **Interior Lighting**: $40,000 (20%)
  - **Fans Pumps**: $16,000 (8%)
  - **Plug Loads**: $16,000 (8%)
  - **Cooling**: $30,000 (15%)

**Total Costs Breakdown**

- **Space Heating**: $76,538 (38%)
- **Interior Lighting**: $40,000 (20%)
- **Cooling**: $30,000 (15%)
- **Plug Loads**: $16,000 (8%)
- **Fans Pumps**: $16,000 (8%)
- **Exterior Lighting**: $4,000 (2%)
- **Water Heating**: $4,000 (2%)
- **Savings**: $29,702 (15%)
WHAT YOU CAN UPGRADE

Lighting
- Interior/Exterior
- Exit Signs

Envelope
- Air sealing
- Insulation
- Glazing (Windows Doors)

Mechanical Equipment (HVAC)
- Retro-commissioning (of HVAC equipment)
- Ventilation (controls)
- Temperature Setbacks
- Variable Speed Drives
- Heating (efficient boilers/furnaces)
- Cooling (high-efficiency cooling systems)

Investment Horizons

<table>
<thead>
<tr>
<th>Project</th>
<th>Typical Paybacks (Median-Average)</th>
<th>Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Power Mgt.</td>
<td>&lt;1yr</td>
<td>1 yr</td>
</tr>
<tr>
<td>Programmable T-Stat</td>
<td>0.2-1 yr</td>
<td>5 yrs</td>
</tr>
<tr>
<td>Boiler Tune Up</td>
<td>1 yr</td>
<td>1 yr</td>
</tr>
<tr>
<td>Motion Sensors</td>
<td>2-3 yrs</td>
<td>5 yrs</td>
</tr>
<tr>
<td>Sealing</td>
<td>2-4 yrs</td>
<td>3 yrs</td>
</tr>
<tr>
<td>Lighting</td>
<td>4-3 yrs</td>
<td>10 yrs</td>
</tr>
<tr>
<td>HVAC replacement</td>
<td>7-14 yrs</td>
<td>20+ yrs</td>
</tr>
<tr>
<td>Insulation</td>
<td>7-16 yrs</td>
<td>25+ yrs</td>
</tr>
<tr>
<td>Window Films</td>
<td>8-10 yrs</td>
<td>10 yrs</td>
</tr>
<tr>
<td>Windows</td>
<td>8-21 yrs</td>
<td>25+ yrs</td>
</tr>
<tr>
<td>Renewable Energy</td>
<td>30-20 yrs</td>
<td>25+ yrs</td>
</tr>
</tbody>
</table>
Interior lighting upgrades

✓ Planning upgrades...key steps
  • Identify and meet lighting needs
  • Select energy efficient lighting equipment
  • Control lighting appropriately for use
WHERE IS LIGHTING TODAY

HID

- Current system efficacy 105 lm/W
- Announced 140-150 lm/W

Linear Fluorescent

- Slow but steady increase & longer life

Induction

- Little or no progress. Low-cost products are catching up on lumen maintenance

LED

- Fast improvements. Efficacy difference between lab and products. DOE prognosis 150 lm/W by 2020 and 200 lm/W by 2030
WHAT TO WHAT

T12s

or

T8s 800 Series
or T5s
Interior lighting upgrades

Compare current light levels (fc) with IES recommended levels.*

Too high consider:
  ▪ removing lamps
  ▪ low power ballast
  ▪ low wattage lamps

*IES = Illuminating Engineering Society
EFFICIENT LIGHTING

Controls

- Occupancy/Vacancy (manual on/ auto off) vs (auto on/ auto off)
- Daylight harvesting (photo cells)
- Bi-level switching (stairwells, garages)
- Dimmers
- Timers
Examples:

- **T12 to T8**
  - 48” four-lamp fluorescent fixture
  - 40W T12 to 28W T8
  - Annual cost savings per fixture: $12.75/yr (33% savings)

- Warehouses, gyms, manufacturing, etc.:
  - High-bay lighting one-for-one fixture replacement
  - 400W Metal halide to Six-lamp 32W T8 high-bay fluorescent
  - Annual cost savings per fixture: $60/yr (51% savings)

Vacancy sensors or time clocks can further reduce use/consumption.
Example 1: Delamp Overlit Rooms – Remove 1 of 4 T8 lamps to bring classrooms from 80fc to 50fc.

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh</td>
<td>kW</td>
</tr>
<tr>
<td>64,001</td>
<td>36</td>
</tr>
<tr>
<td>$5,400</td>
<td></td>
</tr>
</tbody>
</table>

Example 2: Gym Lighting Upgrade – Replace 460W MH with 6-lamp T5 high bay fixtures.

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh</td>
<td>kW</td>
</tr>
<tr>
<td>29,484</td>
<td>16</td>
</tr>
<tr>
<td>$23,400</td>
<td></td>
</tr>
</tbody>
</table>

Example 3: LED Exit Retrofit – Retrofit incandescent exit lamps with LED kits.

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh</td>
<td>kW</td>
</tr>
<tr>
<td>18,396</td>
<td>2</td>
</tr>
<tr>
<td>$2,500</td>
<td></td>
</tr>
</tbody>
</table>

Example – 117,000 SF High School built in 2001 code min. construction.
Exterior lighting upgrades

- Assessing what you have
  - Light levels
  - Lamp nominal wattage
  - Ballast type
  - Ballast factor
  - Controls
Exterior lighting upgrades

✓ Planning upgrades…key steps
  • Identify and meet lighting needs
  • Select energy efficient lighting equipment
  • Control lighting appropriately for use
Exterior lighting upgrades

✓ Planning upgrades...key steps

- Select energy efficient lighting equipment
  - High efficacy lamps (high lumens per watt)
  - Long lamp life
  - Whole assembly efficiency (lamp + ballast + fixture)
Efficient Lighting

Exterior lighting upgrades

✓ Planning upgrades...key steps

• Control lighting appropriately for use
  • Motion sensors
  • Astronomical time clocks
  • Partial night lighting (bi-level)

Astronomical Timers
# EFFICIENT LIGHTING - CASE STUDY

## DCEO CASE STUDY
Parking Garage Lighting

<table>
<thead>
<tr>
<th>City of Peoria - Jefferson St. Parking Deck</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Client</strong></td>
</tr>
<tr>
<td><strong>Building type</strong></td>
</tr>
<tr>
<td><strong>Energy measures implemented</strong></td>
</tr>
<tr>
<td><strong>Total project cost</strong></td>
</tr>
<tr>
<td><strong>Projected Annual Cost Savings</strong></td>
</tr>
<tr>
<td><strong>Total DCEO incentive</strong></td>
</tr>
<tr>
<td><strong>Payback period without incentives</strong></td>
</tr>
<tr>
<td><strong>Payback period with incentives</strong></td>
</tr>
</tbody>
</table>

43% incentive

*Jefferson Street Parking Deck, Peoria, Illinois*
Reducing air leakage

☑ Assessing current conditions

- All existing buildings… have some infiltration and exfiltration.
- Incoming air needs conditioning
STACK EFFECT INFILTRATION

- Positive pressure (with reference to outside)
- Neutral pressure plane
- Negative pressure (with reference to outside)

Photo Credit: David Keefe, Vermont Energy Investment Corporation
Reducing air leakage

- Assessing current conditions
  - Finding leaks can often be fairly easy.
AIR SEALING / WEATHERIZATION

Reducing air leakage

✓ Planning upgrades

• Fixing leaks is straightforward.
  • Caulking and Spray Foam
  • Weather stripping, thresholds
  • Rigid insulation (faced, taped)
  • Vestibules
INSULATION UPGRADES

Roofs and walls

✓ Assessing current thermal envelope
  • Look for opportunities to upgrade with:
    • Roof replacement
    • Air sealing projects
    • Change of use (e.g. auto shop becomes office space)
    • Locations with easy access (attics, infill spaces)
## INSULATION UPGRADES

### Roofs and walls

- **Planning upgrades**
  - Meet or exceed current prescriptive *total assembly* insulation levels

<table>
<thead>
<tr>
<th><strong>Roofs:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation entirely above deck – R-25.0 continuous</td>
<td></td>
</tr>
<tr>
<td>Attic insulation – R-49.0 (U-0.021)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Walls:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (concrete or masonry) – R-13.3 continuous</td>
<td></td>
</tr>
<tr>
<td>Steel framed – R-13.0 + R-10.0 continuous (U-0.055)</td>
<td></td>
</tr>
<tr>
<td>Walls below grade – R-10.0 continuous</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Slabs:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unheated slabs - perimeter insulation – R-10 for 24 in.</td>
<td></td>
</tr>
<tr>
<td>Heated slabs – perimeter insulation – R-15 for 36 in.</td>
<td></td>
</tr>
</tbody>
</table>

Values from ANSI/ASHRAE/USGBC/IES Standard 189.1-2011 *Standard for the Design of High-Performance Green Buildings*

- Incorporate air sealing to further improve performance
GLAZING UPGRADES

All envelope openings including doors, skylights, overhead doors, etc.

✓ Assessing current openings
  • Look for opportunities to upgrade with:
    • Leaking and/or damaged openings
    • Comfort upgrades
    • Air sealing projects
    • Change of use (e.g. warehouse to office space)
GLAZING UPGRADES

All envelope openings including doors, skylights, overhead doors, etc.

✓ Planning upgrades
✓ Detail and Test for Air Tight Installation
GLAZING UPGRADES

All envelope openings including doors, skylights, overhead doors, etc.

✓ Planning upgrades
  • Meet or exceed current prescriptive **total assembly** performance characteristics
  ✓ Total assembly includes frame, spacers, glazing

<table>
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</tbody>
</table>

Values from ANSI/ASHRAE/USGBC/IES Standard 189.1-2011
*Standard for the Design of High-Performance Green Buildings*

• Emphasize air sealing to further improve performance
TEMPERATURE SETPOINTS AND SCHEDULES

Temperature setpoints are shown for different occupancy states: Unoccupied, Occupied, and Unoccupied. The graph indicates temperature levels and time periods for each state.
TEMPERATURE SETBACKS

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Time</th>
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</thead>
<tbody>
<tr>
<td>56</td>
<td>1</td>
</tr>
<tr>
<td>58</td>
<td>2</td>
</tr>
<tr>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>62</td>
<td>4</td>
</tr>
<tr>
<td>64</td>
<td>5</td>
</tr>
<tr>
<td>66</td>
<td>6</td>
</tr>
<tr>
<td>68</td>
<td>7</td>
</tr>
<tr>
<td>70</td>
<td>8</td>
</tr>
<tr>
<td>72</td>
<td>9</td>
</tr>
<tr>
<td>74</td>
<td>10</td>
</tr>
</tbody>
</table>

- Unoccupied
- Occupied
- Unoccupied

WINTER
TEMPERATURE SETBACKS

- **Temperature Setbacks**

  - **Unoccupied**
  - **Occupied**
  - **Unoccupied**

  - **Summer**

  - Graph showing temperature changes over time:
    - Temperature range: 72°F to 81°F
    - Time scale: 12 hours

  - Thermostat settings:
    - **70°F**
    - **71°F**
    - **72°F**

  - Images of thermostats and control panels.
Basics

- Up in the summer & down in the winter
- Optimize the schedules by zones

Advanced (BAS Users)

- Using optimum start/stop controls logic
- Using optimum start/stop *experiential* logic.
Steam Boilers

✓ Planning upgrades
  • Steam trap maintenance
  • Boiler tune-up – clean, fuel/air adjustment
  • Spark ignition
  • Energy-efficient burners - induced draft
  • Controls upgrades
  • Automatic flue dampers
  • Stack economizers
  • Pipe insulation
  • Boiler replacement:
    ✓ Consider age
    ✓ Right-sizing
    ✓ High efficiency steam boilers (80-83%)
    ✓ Consider system conversion to use higher efficiency hot-water boiler(s) (92%+)
    ✓ Advanced controls (O2 trim, auto blow down).
HEATING

Hot Water Boilers

✓ Planning upgrades
  • Boiler tune-up
  • Energy-efficient burners
  • Hot water reset
  • Automatic flue dampers
  • Burner control upgrades
  • VFDs on pumps
  • Boiler replacement:
    ✓ Right-sizing
    ✓ Modular
    ✓ Condensing
    ✓ High Efficiency (92%+)
    ✓ Advanced controls –O2 trim
Condensing boilers

Example

Add a Condensing Boiler – Supplement the two original boilers with a high efficiency modular condensing unit. This will run at peak efficiency during most of the low-load heating hours.

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh</td>
<td>kW</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Gas for heating ≥ $75,000/yr

- Full engineering analysis is necessary.
- Isolate the two old boilers with valves.
- AKA: Shoulder Boiler or Front-Loaded Boiler
- Full upgrade is always an option if funds allow.
COOLING

Chillers

✓ Planning upgrades
  • Chiller tune-up
  • Temperature resets
  • VFDs on pumps
  • Controls upgrades
  • Chiller replacement:
    • Right-sizing
    • Larger systems: Water Cooled Centrifugal ≥ 5.9 COP (≤ 0.6 kW/ton) Full Load
    • Smaller systems: Air Cooled Chillers ≥ 2.9 COP (≥ 10.0 EER)
    • Advanced controls–desuperheating, floating head pressure, condenser heat recovery
BUILDING COST BREAKDOWN

- Space Heating: 45%
- Interior Lighting: 20%
- Cooling: 15%
- Fans Pumps: 8%
- Plug Loads: 8%
- Water Heating: 2%
- Exterior Lighting: 2%
- Water Heating: 2%

TOTAL: 100%
VENTILATION

- Exterior Lighting: 2%
- Fans: 8%
- Plug Loads: 8%
- Cooling: 15%
- Interior Lighting: 20%
- Water Heating: 2%
- Ventilation: 25%
- Envelope: 20%
- Heating: 45%
Modulate ventilation rates

- Assessing current ventilation
  - Are current ventilation rates appropriate?
  - Measure/ trend CO2 levels
  - How is ventilation currently controlled?
  - Incoming air typically needs conditioning
Modulate ventilation rates

✓ Planning upgrades
  • Modulate ventilation rates using demand-based control (based on occupancy) using:
    • Sensed CO2 levels
    • Occupancy tracking (in security controlled buildings)
Modulate ventilation rates
✓ Planning upgrades
  • Modulate ventilation rates using economizer control to:
    • Reduced cooling load
      * Conditioning outside air is more energy efficient than conditioning recirculated air when the enthalpy (heat + humidity) of the outside air is less than the enthalpy of recirculated air.
    • Free cooling
      * When the outside air is both sufficiently cool and sufficiently dry (depending on the climate) no additional conditioning may be needed.
  • Use economizer control year-round when appropriate for significantly reduced mechanical cooling energy use.
Ventilation energy recovery

- Planning upgrades
  - Consider ventilation exhaust energy recovery for new air handling equipment.

Select total energy recovery – enthalpy wheel (sensible and latent heat transfer, can provide dehumidification in summer, humidification in winter).
Modulate ventilation rates

Example:

**Demand Control Ventilation** – Reduce the amount of outdoor air brought into the building by monitoring need with CO2 sensors.

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh</td>
<td>kW</td>
</tr>
<tr>
<td>71,248</td>
<td>0</td>
</tr>
</tbody>
</table>

- Scheduling ventilation typically only closes ventilation louvers at night and on weekends.
- Modern CO2 sensors are self-calibrating.
- Typically ≤ 1,100 ppm avoids odors.
- Occupancy override buttons in space can allow for more aggressive scheduling.

Example – 117,000 SF High School built in 2001 code min. construction.
PLANNING UPGRADES

- Fans and pumps with variable torque loads
  - Significant energy savings
  - Soft start potential
  - Manual override recommended
  - Lower motor maintenance
  - Extended motor life
  - Training recommended
Variable Frequency Drives (Variable Speed Drives)

Example:

**VFDs on Heating Loop Pumps** – Reduce the speed of the heating loop pumps with VFDs. Control the VFD based on pressure in the line.

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh</td>
<td>kW</td>
</tr>
<tr>
<td>36,829</td>
<td>0</td>
</tr>
</tbody>
</table>

- To control based on pressure, valve bypass loops must be removed. (i.e. Replace three-way valves with two-way valves.)
- VFDs are not useful unless you are going to turn down the flow, or replace flow restrictors.

Example – 117,000 SF High School built in 2001 code min. construction.
### City of Decatur - Civic Center

<table>
<thead>
<tr>
<th>Client:</th>
<th>City of Decatur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Type:</td>
<td>Civic Center</td>
</tr>
<tr>
<td>Energy Measures Implemented:</td>
<td>High Efficiency Lighting Occupancy Sensors, Boiler Pump Controls, Chiller Water Pump Sequencing</td>
</tr>
<tr>
<td>Projected Annual Energy Savings:</td>
<td>682,383 kWh</td>
</tr>
<tr>
<td>Projected Annual Cost Savings:</td>
<td>$60,000</td>
</tr>
<tr>
<td>Total Energy Incentive:</td>
<td>$25,496</td>
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<tr>
<td>EECB Grant:</td>
<td>$283,054</td>
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<tr>
<td>Project Cost:</td>
<td>$308,550</td>
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<tr>
<td>Payback Period with Incentives:</td>
<td>0.45</td>
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</tbody>
</table>

**Retrofit Savings Potential & Incentives**
**Case Studies - Multiple Retrofits**

**Kenwood Elementary**

<table>
<thead>
<tr>
<th>Client:</th>
<th>Champaign Unit 4 School District</th>
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</thead>
<tbody>
<tr>
<td>Building Type:</td>
<td>Elementary School</td>
</tr>
<tr>
<td>Project Goals:</td>
<td>Reduce operating costs</td>
</tr>
<tr>
<td></td>
<td>Provide year-round comfort</td>
</tr>
<tr>
<td>Energy Measures Implemented:</td>
<td>Air sealing</td>
</tr>
<tr>
<td></td>
<td>Window replacement</td>
</tr>
<tr>
<td></td>
<td>Condensing boilers</td>
</tr>
<tr>
<td></td>
<td>High efficiency lighting</td>
</tr>
<tr>
<td>Projected Energy Savings:</td>
<td>$16,933 per year</td>
</tr>
<tr>
<td>Projected Capital Cost:</td>
<td>$138,801</td>
</tr>
<tr>
<td>Total DCEO Incentives:</td>
<td>$21,165</td>
</tr>
</tbody>
</table>

**Retrofit Savings Potential & Incentives**
FREE SEDAC Building Energy Assessment includes:

- Bill analysis
- Current energy cost breakdown
- Benchmarking
- Site visit
- Quick list of potential measures
- Analysis of potential incentives
- Final report with quantified recommendations
  - L3 reports also include an economic analysis
- Follow-up assistance
- Implementation tracking
✓ Start with our 1 page application
  • Include square footage, account numbers, annual energy cost totals
✓ Then the client provides:
  • 24 months of gas & electric bills
  • Building plans, layout, mechanical schedules as available
  • Site visit with appropriate personnel (2-4 hrs)
  • An energy champion to get things done
UP NEXT: RETROCOMMISSIONING

Web site: www.sedac.org
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1-800-214-7954

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