Email r2s2@ppe.com and BDCJ@ppe.com
If you do not have the email with the class instructions.

Time for a Poll
Web: PollEv.com/ryanstroupe526
Or
Text: ryanstroupe526 to 22333, then text answer option
Where are you?

If you are currently located in this area, mark your location on the map. If not, note your location in California here...

Do not mark here

If you are not in California, note your location here...

Do not mark here

and if you are not in the US, click on the image of the earth.

If you are currently located in this area, mark your location on the map. If not, note your location in California here...
Energy Efficiency Update:
May 13, 2020 as a Webinar
Agenda

- Energy usage analysis
- Exercise: working with interval data
- Setting energy and emissions goals
- Scoping a facility
- Operating efficiently at part load
- Top retrofit opportunities
- HVAC controls
- Lighting retrofits
- Lighting controls
- O&M opportunities
- Deep energy retrofits
- 2020 utility incentives
- On-bill financing
- Financial return calculations
- Exercise: calculating financial return
- Other strategies including occupant behavior programs, renewables, thermal storage and demand response
Energy Usage Analysis
Billing Analysis: Electric Service

San Francisco High School

Average KWHR/Day

Billing Period End Date

Above 1400

1200

1000

800

600

400

200

0

20-Sep
18-Oct
17-Nov
19-Dec
18-Jan
20-Feb
21-Mar
19-Apr
21-May
21-Jun
22-Jul
20-Aug
19-Sep
18-Oct
Billing Analysis: Gas Service

2011-2012 Average Daily Gas Use

Average Therms/day

Billing Period End Date

Oct-11  Nov-11  Jan-12  Mar-12  Apr-12  Jun-12  Jul-12  Sep-12  Nov-12
Interval Energy/Climate Data Scatter Plot 1

Hourly Usage (kWh and Temp)
Interval Energy/Climate Data Scatter Plot 2

Meter 1 - kWh vs Temp (Sept 1st 2013 - Aug 31st 2014)
Daily Avg OSA Temp vs. Daily Therm Use

\[ y = 0.3037x^2 - 48.891x + 2035.5 \quad R^2 = 0.8853 \]

\[ y = 0.294x^2 - 40.692x + 1537.9 \quad R^2 = 0.0156 \]
Project Type: Interval Data Analysis

- **Purpose:** identify operational patterns from interval data.
- **Data required:** a year’s worth of interval smart meter data
  - Acquire from customer
  - Acquire from utility if given third-part authorization
- **Collect data for each fuel type.**
  - Electricity
  - Natural gas
  - Steam
  - Chilled water
- **Will also need coincident climate (OSA temp) data for same location**
  - [National Oceanic and Atmospheric Administration site](#)
  - [National Weather Service site](#)
- **Will need ability to filter data by time of day and day of week.**
- **Processing tools**
  - Excel
  - ECAM
  - Universal Translator
Interval Energy/Climate Data Scatter Plot 5

Stockton Meter 1
All Data

Stockton Meter 1
Weekday, evening data

Stockton Meter 2
All Data

Stockton Meter 2
Weekday, evening data
Day of the Week Chart
Exercise: Working with Interval Data
Setting Energy and Emissions Goals
Energy and Emissions Reduction Goals

Examples:

• Stop all increases in consumption of energy from fossil fuels no later than 2015.
• Drop emissions from fossil fuels to 20 percent below 1990 levels by 2020.
• Drop emissions from fossil fuels to 40 percent below current levels by 2030.
• Further decrease fossil fuel consumption to 80 percent below current levels by 2050.

Reductions are easier for poorer-performing facilities.

Scoping a Facility
Motor
Lights

•

.
Packaged Unit

•
Fryer
# EEM Summary Table

## NRG Geeks Inc.

<table>
<thead>
<tr>
<th>Measure Number</th>
<th>Measure Description</th>
<th>Annual Energy and Cost Savings</th>
<th>Payback with Incentive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Peak Savings (kW)</td>
<td>Electricity Savings (kWh)</td>
</tr>
<tr>
<td>Lightning Measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EEM-1</td>
<td>Reduce Garage Lighting to Half Overnight</td>
<td>0.0</td>
<td>34,465</td>
</tr>
<tr>
<td>EEM-2</td>
<td>Install Photocell To Control Lobby Lights</td>
<td>1.4</td>
<td>4,047</td>
</tr>
<tr>
<td>EEM-3</td>
<td>Install Photocell to Control Outdoor Lights and Schedule</td>
<td>0.0</td>
<td>15,257</td>
</tr>
<tr>
<td>EEM-4</td>
<td>Re-Commission Lighting Controls</td>
<td>0.0</td>
<td>109,102</td>
</tr>
<tr>
<td>EEM-5</td>
<td>Install Bi-Level LED Fixtures in Garage</td>
<td>6.3</td>
<td>84,765</td>
</tr>
<tr>
<td>Kitchen Measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EEM-6</td>
<td>Kitchen Hood and Fan Upgrade</td>
<td>0.0</td>
<td>138,763</td>
</tr>
<tr>
<td>EEM-7</td>
<td>Install Controls to Schedule Two Pan Chillers in Savory</td>
<td>0.0</td>
<td>9,907</td>
</tr>
<tr>
<td>EEM-8</td>
<td>Kitchen AC-G - Expand Outside Air Intake Area</td>
<td>2.2</td>
<td>5,192</td>
</tr>
<tr>
<td>EEM-9</td>
<td>Install Controls to Schedule Temperature Setbacks for Kitchen AC-G</td>
<td>0.0</td>
<td>1,019</td>
</tr>
<tr>
<td>Main Air Handler Measures (Occupied Hours Only)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EEM-10</td>
<td>Repair Ecomonizers and Convert to Dry Bath Temperature Control</td>
<td>0.0</td>
<td>155,576</td>
</tr>
<tr>
<td>EEM-11</td>
<td>Supply Air Temperature Optimization and Duct Static Pressure Reset</td>
<td>1.4</td>
<td>178,563</td>
</tr>
<tr>
<td>EEM-12</td>
<td>Install VPDs on Exhaust Fans</td>
<td>(4.7)</td>
<td>31,858</td>
</tr>
<tr>
<td><strong>SUB-TOTALS</strong></td>
<td></td>
<td>6.5</td>
<td>768,505</td>
</tr>
</tbody>
</table>

**TOTALS (Recommended Measures)**

|                        | 0.5 | 768,505 | 6,896 | 82,368 | 482.3 | $225,630 | $54,772 | $171,058 | 12% | 2.1 |

Slide courtesy of Jim Kelsey, kW Engineering
## Stacked Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>kW saved</th>
<th>Energy saved</th>
<th>$ saved</th>
<th>Cost measure</th>
<th>Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupancy</td>
<td>0</td>
<td>5,333.33</td>
<td>$800.00</td>
<td>$1,200.00</td>
<td>1.5</td>
</tr>
<tr>
<td>T-8 lighting-LED</td>
<td>4.04</td>
<td>20,200.00</td>
<td>$3,030.00</td>
<td>$10,000.00</td>
<td>3.3</td>
</tr>
<tr>
<td>Combined/blended</td>
<td>4.04</td>
<td>15,433.33</td>
<td>$2,315.00</td>
<td>$11,200.00</td>
<td>4.83</td>
</tr>
</tbody>
</table>

The table above illustrates the energy savings, cost savings, and payback periods for different measures. The payback period for combined measures is calculated as the sum of individual payback periods.
Operating Efficiently at Part Load
Part Load Efficiency

Vary AHU cfm
Reset supply air temperature
Vary chilled water flow
Reset chilled water temperature
Variable speed chillers
Vary condenser water flow
Vary cooling tower fan speed
Demand control ventilation
Add dedicated cooling systems for 24/7 loads
1. Schedule all lighting zones (non-emergency lights) off.
2. Schedule all HVAC zones off. Make sure zones have setbacks in place.
3. Make sure outside air economizer dampers are closed.
4. Shut down restroom exhaust fans.
5. Make sure boilers, chillers, fans and pumps for hydronic loops are controlled off but will cycle on to maintain zone setback temperatures under extreme hot/cold conditions.
6. Make sure that hot water loops are not leaking in off mode.
7. If cooling towers can be taken offline, consider draining cooling tower basins.
8. Turn off copiers, printers and monitors that draw power in the stand-by mode.
9. Turn off exterior signage.
10. Close blinds to limit heat gain and loss through windows.
11. Make sure security systems and critical HVAC system alarms are in place and working.
12. Take notes on all shut down procedures so that these can be referenced during system start-up.

---

Covid-19 response

1. Schedule lighting zones (non-emergency lights) off in unoccupied areas. Make sure switches allow lights to be turned on if people use these spaces.
2. Schedule unoccupied HVAC zones off. Make sure zones have setbacks in place and that occupant overrides work.
3. Shut down restroom exhaust fans on unoccupied floors.
4. Make sure turn-down strategies are in place for boilers, chillers, pumps, fans and cooling towers.
   A. Boiler temperature resets are in place and working.
   B. Chilled water temperature resets are in place and working.
   C. Variable flow controls for variable flow pumps are working.
   D. Variable speed cooling tower fans are operating properly.
   E. Supply air temperature resets are working.
   F. Duct static pressure resets are working.
5. Verify that copiers, printers and monitors that draw power in the stand-by mode are turned off in unoccupied areas.
6. Close blinds to limit heat gain and loss through windows in unoccupied areas.
7. Make sure security systems and critical HVAC system alarms are in place and working.
8. Take notes on all operation adjustments so that these can be referenced when systems are returned to normal.

---

1. Insure that social distancing best practices are maintained by allowing staff to spread out to conference rooms and other underutilized spaces if possible.
2. Make sure minimum ventilation requirements are being met as per ASHRAE Standard 62.1.
3. Sanitize commonly used surfaces (handrails, door handles, elevator buttons) routinely throughout each work day.

---

Is facility vacant?

Yes/no?

Yes

Is facility under-occupied?

Yes/no?

Yes

No

No

No
Top Retrofit Opportunities
Top Retrofit Opportunities

1. Replace with higher efficiency at end of life
2. Condensing boilers and furnaces
3. Light-emitting diodes
4. Advanced HVAC controls
   1. Resets
   2. Dual max terminal unit airflow
   3. Trim and respond
5. Layered lighting controls
6. Integrate open ADR
7. Eliminate on-site fuel combustion
8. Integrate on-site renewables
9. Integrate on-site storage
10. Retrocommissioning
### Incremental Cost Opportunities

<table>
<thead>
<tr>
<th><strong>Packaged Unit Retrofit:</strong></th>
<th><strong>Packaged Unit End-of-Life Replacement:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>$ cost of standard equipment</td>
<td>$ cost of standard equipment</td>
</tr>
<tr>
<td>$ cost of electrician</td>
<td>$ cost of electrician</td>
</tr>
<tr>
<td>$ cost of plumber</td>
<td>$ cost of plumber</td>
</tr>
<tr>
<td>$ cost of sheet-metal worker</td>
<td>$ cost of sheet-metal worker</td>
</tr>
<tr>
<td>$ cost of roofer</td>
<td>$ cost of roofer</td>
</tr>
<tr>
<td>$ cost of crane</td>
<td>$ cost of crane</td>
</tr>
<tr>
<td></td>
<td>$ additional cost of high efficiency equipment</td>
</tr>
</tbody>
</table>
Optimizing HVAC Controls
System-Level Operating Modes

Occupied Mode
- Terminal units maintain “occupied” setpoints
- Outdoor-air damper delivers proper amount of ventilation air
- Air is cooled or heated to desired setpoint
- Supply fan operates continuously, modulating to maintain system static-pressure setpoint

Unoccupied Mode
- Terminal units maintain “unoccupied” setpoints
- Outdoor-air damper is closed
- Supply fan, cooling coil, and heating coil operate only as needed
Morning Warm-Up

occupied setpoint

unoccupied setpoint

occupied hours

system on

system off

zone temperature

6 AM  Noon  6 PM
Variable Frequency Drives

- Many systems use variable flow distribution
- Fan and pump power laws dictate that power is roughly proportional to the flow rate cubed
- VFD quality/reliability have improved greatly over time
- VFD costs have dropped significantly with wider adoption
- Now required by code for many applications in new construction
- Recommend minimum speed as low as possible. (Overheating is not a problem.)
Why Fans with VFD’s Save Energy

This relationships between fan energy and fan flow are taken from the California Energy Commission Guide to Preparing Feasibility Studies and the 1998 Nonresidential ACM Approval Manual. Note that a typical system curve, DOE2 default, is assumed and these relationships are not applicable to all systems.
## Some VFD Applications

<table>
<thead>
<tr>
<th>Application</th>
<th>Basis of Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply air fans</td>
<td>Duct static pressure</td>
</tr>
<tr>
<td>Relief fans</td>
<td>Building static pressure</td>
</tr>
<tr>
<td>Hydronic loops</td>
<td>Differential pressure at end of loop</td>
</tr>
<tr>
<td>Chillers</td>
<td>Cooling load (delta T across chiller)</td>
</tr>
<tr>
<td>Cooling tower fans</td>
<td>Condenser water temperature</td>
</tr>
<tr>
<td>Condenser water pumps</td>
<td>Condenser water temperature</td>
</tr>
<tr>
<td>Variable refrigerant flow systems</td>
<td>Load at compressors</td>
</tr>
</tbody>
</table>
Cooling Tower Staging

100% capacity

100% power

OFF

OFF

33% capacity

33% capacity

33% capacity

12% power

12% power

12% power

Total capacity: 1 unit at 100%

Total power: 1 unit at 100%

Total capacity: 1 unit at 100%

Total power: 1 unit at 36%

Larger heat rejection surface area
Increase Cooling Tower Size

• Larger cooling towers allow reduction of approach temperature from 12°F to 5°F.
• This improves the effectiveness of the cooling tower.
• Cooling-tower energy is very small, compared to the chiller energy.
• Unlike oversizing other equipment, there is no energy penalty associated with oversized cooling towers.
Conventional VAV Box Operation
Dual Maximum VAV Box Operation

- Lower fan energy
- Lower heating energy: avoids high minimums which can drive zone into heating
- Lower reheat energy
- Control of supply air temperature reduces stratification
- Better modulation of HW valve and less SAT overshoot
- HW circuit is self-balancing with 2-way valves
Trim & Respond Setpoint Reset

• Used to reset setpoints based on zone demand, e.g.
  • static pressure
  • supply air temperature
  • HW and CHW supply temperature

• Zones issue “requests” based on zone temperature, or damper/valve position
  • E.g. “Generate 1 request when damper position exceeds 95%”
  • Extra requests can also be generated based on error from setpoint

• Multiply “requests” by zone Importance Multiplier
  • IM=0 means ignore the zone
  • IM=1 default
  • IM>1 for critical zones to get past “Ignores”

• Send to AHU controller to adjust setpoint
  • Every time-cycle setpoint is reduced (“trim”)
  • But setpoint is increased (“respond”) proportional to number of zone “requests” (up to a maximum change)
Trim and Respond Example
A rogue zone is one that is always requesting more (more static pressure, colder CHW, or hotter HHW)

Example causes
- Load larger than anticipated in design
- Poor duct design/construction
- Extreme setpoint adjustments
- Equipment failure (broken damper, valve)

This drives the reset loop to extremes and prevents energy savings.

Finding Rogue Zones
- Finding rogue zones requires operator attention.
- BAS calculates Request-Hours for each zone, and alarms on high cumulative %-Request-Hours.

Once identified rogue zones can be...
- Repaired
- Locked out of the T&R control loop if non-critical (“Importance Multiplier” set to 0)
VAV2-9 is a rogue zone.
Relief Fan Logic

- Building static pressure setpoint is maintained by
  - First modulating exhaust damper open
  - Then resetting RF DP setpoint very low value to that required to exhaust design return fan airflow (with return damper closed)
**Water-side Economizer**

- Enables facilities with cooling towers to bypass chiller for first stage of cooling.
- Requires heat exchanger to keep particles in condenser water loop from entering chilled water loop.
- Provides redundancy for chiller.
- Best where the wet bulb temperature is lower than 55°F for 3,000 hours or more.*
- Also called “Strainer Cycle”

* Energy Star
Demand Control Ventilation

- Reduces ventilation air based on measured CO2 levels.
  - Saves cooling and heating energy
  - For VAV systems saves fan energy
- Savings greater in milder climates (SF vs. Stockton)
- T-24 DCV
  - Space must maintain 600 ppm difference between inside and outside CO2.
  - If OSA CO2 is unknown, it is assumed to be 400 ppm.
- DCV in kitchens based on temperature and smoke in hood.

DCV: CO₂ and Ventilation Rates

The Relationship Between CO₂ Inside/Outside Differential And Ventilation Rates
(Assumes 400 ppm outside concentration)

- Unacceptable: 5 cfm/person
- Very Poor: 8 cfm/person
- Poor: 10 cfm/person
- Under-Ventilated: 15 cfm/person
- Marginal: 20 cfm/person
- Ideal: 25 cfm/person
- Over Ventilated: 30 cfm/person

Prepared By: Telaire
Contact: Mike Schell 6489 - Calle Real - Goleta, Ca 93117 - 1-800-472-6075
DCV Savings

Table 1: Savings vary with location
For a given temperature, measured cooling energy savings at the site in Sacramento were greater than those at Bay Area sites because occupancy rates were lower.

<table>
<thead>
<tr>
<th>Daily average temperature (Fahrenheit)</th>
<th>Bradshaw Road (Sacramento)</th>
<th>Milpitas (Bay Area)</th>
<th>Castro Valley (Bay Area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>Not applicable (fan only)</td>
<td>26%</td>
<td>15%</td>
</tr>
<tr>
<td>70</td>
<td>46%</td>
<td>16%</td>
<td>11%</td>
</tr>
<tr>
<td>80</td>
<td>28%</td>
<td>12%</td>
<td>9%</td>
</tr>
<tr>
<td>90</td>
<td>20%</td>
<td>10%</td>
<td>8%</td>
</tr>
</tbody>
</table>
ASHRAE Guideline 62: Ventilation for Acceptable Indoor Air Quality

- Minimum ventilation rates
- Based on cfm/person
- For different building types

<table>
<thead>
<tr>
<th>Occupancy Category</th>
<th>People Outdoor Air Rate $R_p$ (cfm/person)</th>
<th>Area Outdoor Air Rate $R_a$ (L/min/m²)</th>
<th>Notes</th>
<th>Combined Outdoor Air Rate (see Note 72)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Buildings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office space</td>
<td>5</td>
<td>2.5</td>
<td>6</td>
<td>85</td>
</tr>
<tr>
<td>Reception areas</td>
<td>5</td>
<td>2.5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Telephone/data entry</td>
<td>5</td>
<td>2.5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Main entry lobbies</td>
<td>5</td>
<td>2.5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bank, vaults/doors</td>
<td>5</td>
<td>2.5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Computer (not printing)</td>
<td>5</td>
<td>2.5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Electrical equipment areas</td>
<td>–</td>
<td>0.06</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Elevator machine rooms</td>
<td>–</td>
<td>0.06</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Pharmacy (dispensing area)</td>
<td>5</td>
<td>0.10</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Phone station</td>
<td>5</td>
<td>0.12</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Shipping/receiving</td>
<td>5</td>
<td>0.12</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Telephone switch</td>
<td>5</td>
<td>0.12</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Transportation area</td>
<td>5</td>
<td>0.12</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>5</td>
<td>0.12</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Public Assembly Spaces</td>
<td>5</td>
<td>0.12</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

Note: This table is not valid in isolation; it must be used in conjunction with the accompanying notes.
Demand Ventilation Controller

CO₂ Differential

CO₂ in PPM

0 200 400 600 800 1000

06/23/02 06/25/02 06/27/02 06/29/02 07/01/02 07/03/02 07/05/02
Parking: CO Ventilation Controls
### Enforceable and/or Regulatory CO levels

**TABLE B-1 Comparison of Regulations and Guidelines Pertinent to Indoor Environments**

(The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.)

<table>
<thead>
<tr>
<th>Enforceable and/or Regulatory Levels</th>
<th>Canadian (Ref. B-8)</th>
<th>WHO/Europe (Ref. B-11)</th>
<th>NIOSH (Ref. B-13)</th>
<th>ACGIH (Ref. B-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NAAQS/EPA (Ref. B-4)</strong></td>
<td>5000 ppm</td>
<td>3500 ppm [L]</td>
<td>30,000 ppm [15 min]</td>
<td>5000 ppm</td>
</tr>
<tr>
<td><strong>OSHA (Ref. B-5)</strong></td>
<td>10,000 ppm [1 h]</td>
<td>30,000 ppm [15 min]</td>
<td>30,000 ppm [15 min]</td>
<td></td>
</tr>
<tr>
<td><strong>Carbon monoxide</strong></td>
<td>50 ppm</td>
<td>50 ppm [1 h]</td>
<td>50 ppm [1 h]</td>
<td>25 ppm</td>
</tr>
<tr>
<td><strong>Formaldehyde</strong></td>
<td>30 ppm</td>
<td>25 ppm [1 h]</td>
<td>25 ppm [1 h]</td>
<td>20 ppm [1 h]</td>
</tr>
<tr>
<td><strong>Lead</strong></td>
<td>0.3 ppm [L]</td>
<td>0.1 ppm [L]</td>
<td>0.1 ppm [L]</td>
<td>0.1 ppm [L]</td>
</tr>
<tr>
<td><strong>Nitrogen dioxide</strong></td>
<td>0.1 ppm [L]</td>
<td>0.05 ppm [L]</td>
<td>0.05 ppm [L]</td>
<td>0.3 ppm [L]</td>
</tr>
<tr>
<td><strong>Ozone</strong></td>
<td>0.05 ppm [1 yr]</td>
<td>0.05 ppm [1 h]</td>
<td>0.05 ppm [1 h]</td>
<td>0.05 ppm [1 h]</td>
</tr>
<tr>
<td><strong>Particles</strong></td>
<td>0.02 ppm [1 yr]</td>
<td>0.02 ppm [1 yr]</td>
<td>0.02 ppm [1 yr]</td>
<td>0.02 ppm [1 yr]</td>
</tr>
<tr>
<td><strong>Radon</strong></td>
<td>50 ppm [1 yr]</td>
<td>50 ppm [1 yr]</td>
<td>50 ppm [1 yr]</td>
<td>50 ppm [1 yr]</td>
</tr>
<tr>
<td><strong>Sulfur dioxide</strong></td>
<td>0.00 ppm [1 yr]</td>
<td>0.00 ppm [15 min]</td>
<td>0.00 ppm [15 min]</td>
<td>0.00 ppm [15 min]</td>
</tr>
<tr>
<td><strong>Total Particles</strong></td>
<td>15 mg/m³</td>
<td>15 mg/m³</td>
<td>15 mg/m³</td>
<td>15 mg/m³</td>
</tr>
</tbody>
</table>
Lighting Retrofits
Identifying Opportunities

- Lighting opportunities boil down into three broad categories:
  - Shutting off lights when not needed
  - Providing just enough light (i.e. light levels) to be productive
  - Using efficient light sources to provide light
- Order of consideration matters
  - If we installed an efficient light source before we considered reducing the light levels, we may have to buy two new light sources instead of doing it right the first time.
- Identifying opportunities in each of these categories can lead to significant energy savings at your facility
Typical Lighting Improvement Measures

• Fluorescent retrofits
  – T12 to T8
  – 32W T8 to 28W T8 or 25W T8
• HID retrofits
  – HPS or Probe-Start Metal Halide to Pulse-Start Metal Halide
• LED retrofits
  – Replace Linear Fluorescent Lamps with LED Tube Lamps
  – Replace CFL/HID Lamps with LED Lamps
  – New Luminaires or Luminaire Retrofits
• Medium Base Lamps Retrofits
Providing the Right Amount of Light

The table below represents recommended practices in a common areas for most buildings.

<table>
<thead>
<tr>
<th>Space</th>
<th>Light level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hallway</td>
<td>5 fc, average</td>
</tr>
<tr>
<td>Stairwell</td>
<td>10 fc, average high activity</td>
</tr>
<tr>
<td></td>
<td>5 fc, average</td>
</tr>
<tr>
<td></td>
<td>1 fc, minimum</td>
</tr>
<tr>
<td>Break Room</td>
<td>10 fc</td>
</tr>
<tr>
<td>Exterior</td>
<td>1 fc, average</td>
</tr>
<tr>
<td></td>
<td>3 fc, high security</td>
</tr>
<tr>
<td>Lobby</td>
<td>10 fc, average daytime</td>
</tr>
<tr>
<td></td>
<td>5 fc, average nighttime</td>
</tr>
<tr>
<td></td>
<td>15 fc, reception area</td>
</tr>
<tr>
<td>Elevator</td>
<td>5 fc, average</td>
</tr>
<tr>
<td>Private Office</td>
<td>50 fc, average</td>
</tr>
<tr>
<td>Open Office</td>
<td>30 fc, average</td>
</tr>
<tr>
<td></td>
<td>50 fc, with task light on</td>
</tr>
<tr>
<td>Conference</td>
<td>30 fc, average</td>
</tr>
<tr>
<td></td>
<td>3 fc, for AV presentation</td>
</tr>
<tr>
<td>Copier Room</td>
<td>10 fc, average</td>
</tr>
<tr>
<td></td>
<td>30 fc, on machinery</td>
</tr>
<tr>
<td>Restrooms</td>
<td>15 fc, on fixtures</td>
</tr>
<tr>
<td></td>
<td>5 fc, average</td>
</tr>
<tr>
<td>Equipment Room</td>
<td>20 fc, average</td>
</tr>
</tbody>
</table>

Image(s) Courtesy of: kW Engineering
Smaller Control Groups Independent of Electrical Circuiting

- Historically, lighting control groups have been tied to electrical circuiting
  - Lights on the same switch were on the same electrical circuit
- Addressable fixtures or fixture groups may be controlled as part of multiple control groups and multiple electrical circuits.
LOW COST MEASURES
Recommissioning

- Re-testing the systems and equipment
- Repeat past testing
- Systematic way to assess and fix issues
- Usually done after hours
Night-Time Walk

- Timeclock-related issues
  - Interior lighting
  - Exterior lighting
- Occupancy sensors
  - Interior
  - Exterior
- Interior Daylighting

Image Courtesy: kW Engineering
Daytime Walk

- Exterior lighting – should be OFF.
- Interior lighting
  - Daylighting Controls Functioning
    - Dimming or Shutting Off Lighting
  - Occupancy Sensors Functioning
    - Occupancy sensors don’t pick-up people walking by
    - Occupancy sensors respond
      - Auto-on 100%
      - Auto-on 50%
      - Manual-on (vacancy sensing)
Tuning of Existing Fixtures

- Lighting is over-designed (on purpose)
  - Accounts for light loss as products age
- Measure at night
  - Alternatively, draw the window shades
- Place your light meter
- Adjust the maximum output to meet desired light level on meter
Maintain and Fix

- Energy savings only persist because of maintenance
- Installation & Operation Manuals (IOMs) are golden
- Systems Manual and initial Cx Functional Tests are too!
- Keep a log of setpoint changes
Lighting Controls
Timeclocks (aka Timeswitches)

- Timeswitch (up to 24%)
  - Hours of operation
  - Sweeps, interval, warning
  - Zones
  - Janitor Overrides
- Astronomic Timeswitch
  - Sunrise/sunset by location
  - On/off times after/before sunset/sunrise
  - Curfew
Occupancy Sensors

- 24% energy savings
- Types:
  - PIR (Passive InfraRed)
  - Ultrasonic
    - Human hearing: 20Hz – 20kHz
    - Ultrasonic: >34kHz
  - Microphonic
  - Dual Technology
- Delay to Off (Dwell)
- Occupancy/Vacancy
- Trigger/Retrigger

Tyrannosaurus Rex colored. Wikimedia creative commons re-use
Microphone. Iconfinder https://cdn0.iconfinder.com/data/icons/Free-Icons-Shimmer-01-Creative-Freedom/256/microphone.png
Occupancy sensors, cont’d

- Technology recommendations
- Coverage range
- Mounting location
- Integration with HVAC

THANKS TO THE CLOUD ALL MY DEVICES ARE IN SYNC... IT’S ONLY MY BRAIN THAT DOESN’T KNOW WHAT’S GOING ON.
Photocells/Daylight Sensors

- Types
  - Open loop
  - Closed loop
  - Combo
  - Skylight
- Technology
  - Placement
  - Cost
- Coverage range
  - Closed vs open loop
- Up to 28% savings (1)
Lighting and Title 24
Title 24 & Lighting

Title 24-2019 mandates many lighting controls in new construction and they often impact retrofit, too

There are five distinct interior control requirements

- **Area Controls**: All spaces must have a manual light switch in the space. The switch must control the lights in the space
- **Multi-level Controls**: Depending on the lighting technology, each light source has a minimum number of light levels it must provide. This effectively requires dimming
- **Scheduling Controls**: All spaces have a scheduling device to control operating hours. No fixtures can be on 24/7 (except for 0.05W/ft² in office buildings). Some spaces must have occupancy sensors or partial-on sensors
- **Daylighting Controls**: All spaces with more than 120W of light in the daylit area or more than 24-ft² of windows must have daylighting controls
- **Demand Responsive Controls**: All new buildings must be able to shed 15% of the connected lighting load in normally occupied spaces
Area Controls require controls that allow occupants to shut off controls in their space.

The requirements do not exceed normal practice:
- The switch must be accessible
  - There are exceptions for public areas where this could be problematic
- The switch must have line-of-sight with the controlled luminaires
  - There are exceptions for public areas where this could be problematic; however, the switch must be permanently labeled and include a light to indicate it’s on
- The switch cannot interfere with any of the other required controls
Title 24-2019 – Multi-level Controls

- Multi-level Controls is code for dimming
- Requirements vary by technology type, see table
- Requirements set based on typical performance of system hardware at the time code was written.
- If dimming controls are provided, the controls must be used
  - Usually a manual switch
  - Others controls available

<table>
<thead>
<tr>
<th>Technology</th>
<th>Level Requirements</th>
<th>Compliance Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear Fluorescent &gt; 13W U-Bend Fluorescent &gt; 13W</td>
<td>4-steps, roughly 100%/80%/60%/30%</td>
<td>Continuous dimming, Three dimming steps Switching (4) lamps</td>
</tr>
<tr>
<td>Pin-Based/GU-24 CFL &gt; 20W</td>
<td>Continuous dimming, 20% to 100%</td>
<td>Continuous dimming</td>
</tr>
<tr>
<td>Linear Fluorescent ≤ 13W U-Bend Fluorescent ≤ 13W Pin-Based CFLs ≤ 20W GU-24 CFL ≤ 20W Track Lighting</td>
<td>Bi-level, between 30-70%</td>
<td>Continuous dimming, One dimming step, Switching (2) lamps</td>
</tr>
<tr>
<td>Line-voltage, med-base Low-voltage incandescent LED</td>
<td>Continuous dimming, 10% to 100%</td>
<td>Continuous dimming</td>
</tr>
<tr>
<td>HID &gt; 20W Induction &gt; 25W Other</td>
<td>Bi-level, between 50-70%</td>
<td>Continuous dimming, One dimming step, Switching (2) lamps</td>
</tr>
</tbody>
</table>
Title 24-2019 – Shut-off Controls

- Shut-Off controls target turning off the lights when not needed
- Unless another shut-off control is used, all spaces need a timeclock control of some type.
  - The timeclock has to have a battery back up
  - The timeclock has to capture each day of the week and holidays
    - Exceptions are available for a few building types
  - The overrides (for custodial staff or after hours use) must be set at 2 hours or less
- Some spaces (small offices, conference rooms, multipurpose rooms, restrooms) need occupancy sensors
- Some spaces need (hallways and stairs, warehouse aisles, library stacks) need partial-off sensors & timeclocks, which dim the lights by 50% when unoccupied
- Some spaces only need partial-off sensors (common areas of hotels/high-rise res & parking garages)
Title 24-2019 – Daylighting Controls

- Daylighting requires any light near a skylight or nearest the windows be controlled with a daylighting sensor
  - Contractor or lighting designer should indicate the zones on plans
  - Zones should be controlled separately
- Many exceptions and caveats
  - Low energy daylit zone (<120 W) exempt
  - Spaces with small windows (<24 ft²) exempt
  - Low W/ft² spaces (<0.3 W/ft²) on-off okay
- Parking garages have special rules
- Secondary daylit zone only required in new construction or where lighting power is increased
Title 24-2019 – Demand Responsive Controls

- All buildings larger than 10,000 ft² must be able to shed 15% of lighting power
- The shed must be accomplished using the multi-level control steps/dimming discussed earlier
- Total quantity of lighting power that must be shed calculated as follows:
  - \[
  \text{Total Shed Watts} = \left( \frac{\text{Total Lighting Watts}}{\text{Total Lighting Watts}} \right) - \left( \frac{\text{Nonhabitable Lighting Watts}}{\text{Nonhabitable Lighting Watts}} \right) \times 0.15
  \]
- Non-Habitable Space Lighting includes hallways, stairwells, and closets
- Low LPD spaces are any space with a W/ft² less than 0.5 W/ft²
- Shed doesn’t need to be used, but the system must be capable of using DR communication protocols (i.e. OpenADR)
Title 24-2019 & Existing Buildings

Title 24 provides a special compliance path for replacing the lighting in existing buildings -- §141.0 (b) 2 I

**Option i: Meet New Building Code**
- Manual Controls
- Multi-level Controls
- Shut-off Controls
- Daylighting Controls
- Demand Response Controls

**Option ii: 20% Lower than New Building Code**
- Manual Controls
- Shut-off Controls

**Option iii: Reduce power by 40% vs. existing with a project area ≤ 5,000 ft²**
- Manual Controls
- Shut-off Controls

---

**Table 141.0-F – Control Requirements for Indoor Lighting System Alterations**

<table>
<thead>
<tr>
<th>Control Specifications</th>
<th>Projects complying with Section 141.0(b)2ii</th>
<th>Projects complying with Sections 141.0(b)2ii and 141.0(b)2iii</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Area Controls</td>
<td>130.1(a)1 Required</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>130.1(a)2 Required</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>130.1(a)3 Only required for new or completely replaced circuits</td>
<td>Only required for new or completely replaced circuits</td>
</tr>
<tr>
<td>Multi-Level Controls</td>
<td>130.1(b) Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>Automatic Shut Off Controls</td>
<td>130.1(c)1 Required, 130.1(c)1D only required for new or completely replaced circuits</td>
<td>Required, 130.1(c)1D only required for new or completely replaced circuits</td>
</tr>
<tr>
<td></td>
<td>130.1(c)2 Required</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>130.1(c)3 Required</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>130.1(c)4 Required</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>130.1(c)5 Required</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>130.1(c)6 Required</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>130.1(c)7 Required</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>130.1(c)8 Required</td>
<td>Required</td>
</tr>
<tr>
<td>Daylighting Controls</td>
<td>130.1(d) Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>Demand Responsive Controls</td>
<td>130.1(e) Required</td>
<td>Not Required</td>
</tr>
</tbody>
</table>
Title 24-2019 & O&M Replacements

Things that don’t trigger code:

- Burn-out or on-failure replacement of fixtures
  - Provided the input watts do not change
- Replacements that do not involve rewiring (a straight lamp replacement)
- The first 50 replacement fixtures installed per year in one of the following applications
  - Per building
  - Per floor of a building
  - Per tenant area
Exterior Lighting Controls

Title 24 has two code requirements

• Shut off the lights during the day
  • Astronomic Timeclock
  • Photocell Control
• Partial-Off Controls
  • Bi-level vacancy sensors dim lights when no one is present
  • Part-night lighting controls shut off the lights early, (e.g. midnight)

Check for photocells on top of luminaires or controlling entire circuits
Bi-Level Vacancy for Exterior Lighting

- Exterior areas are not occupied all the time
- Lighting necessary for safety/security
- Uses vacancy sensors to dim lights when no one is present

Setting yourself up for success

• Transitioning from a successful project to successful operation
  – Request Owner’s Manuals
  – Receive training
    • At occupancy
    • 3 and/or 6 months later
  – Part number inventory – get all the makes/model numbers

• Prepare for the next project:
  – Establish an Owner’s Project Requirements (OPR) or Current Facilities Requirements (CFR)
  – Sole-source lighting controls
O&M Opportunities
Top 10 Non-Retrofit Audit Findings

10. Replace worn or broken weather-stripping and caulking.
9. Recalibrate thermostats.
8. Straighten or eliminate flex-duct.
7. Inspect pipes for broken or missing insulation.
6. Reset set-points and zone temperatures seasonally.
5. De-lamp in over-illuminated or day-lit areas
4. Tune occupancy sensors.
3. Verify economizer operation.
2. Clean condenser coils.
1. Verify equipment operating schedules.
O&M Opportunities

• Run time opportunities
• Broken economizers
• Bad zone control
• Inability to maintain set-point
• Refrigerant charge
• Limited ventilation air
• Broken control logic
• Simultaneous heating & cooling
Basement Tech Staff: Before

![Bar chart showing hours worked by Basement Tech Staff from January 1, 2009, to March 31, 2009.](image-url)
Air Handler Run-time Data

Before

After
Scheduling Issues

Fan motor running 24/7

Fan motor cycling off
Data from Timer Controls

Retail Example
Verify Lighting Controls

Garage Example
Compressor Over-Cycling

18 Ton 2 Stage Gaspack Unit
Deep Energy Retrofits
## Typical Line Item Analysis

13,000-ft² Denver office

<table>
<thead>
<tr>
<th>Energy Measure</th>
<th>Incremental Cost</th>
<th>Incremental Savings</th>
<th>Payback Period (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daylighting</td>
<td>$4,900</td>
<td>$1,560</td>
<td>3.14</td>
</tr>
<tr>
<td>Glazing</td>
<td>$5,520</td>
<td>$1,321</td>
<td>4.18</td>
</tr>
<tr>
<td>Energy Efficient Lighting</td>
<td>$1,400</td>
<td>$860</td>
<td>1.63</td>
</tr>
<tr>
<td>Energy Efficient HVAC</td>
<td>$3,880</td>
<td>$739</td>
<td>5.25</td>
</tr>
<tr>
<td>HVAC Controls</td>
<td>$2,900</td>
<td>$506</td>
<td>5.73</td>
</tr>
<tr>
<td>Shading</td>
<td>$4,800</td>
<td>$325</td>
<td>14.77</td>
</tr>
<tr>
<td>Economizer Cycle</td>
<td>$1,200</td>
<td>$165</td>
<td>7.27</td>
</tr>
<tr>
<td>Insulation</td>
<td>$1,600</td>
<td>$101</td>
<td>15.84</td>
</tr>
</tbody>
</table>
Bundled Whole-Building Analysis

13,000-ft² Denver office

<table>
<thead>
<tr>
<th>Energy Measure</th>
<th>Incremental Cost</th>
<th>Savings</th>
<th>Payback Period (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daylighting</td>
<td>$4,900</td>
<td>$1,560</td>
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<tr>
<td>Energy Efficient Lighting</td>
<td>$1,400</td>
<td>$860</td>
<td>1.63</td>
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<td>5.25</td>
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<td>$325</td>
<td>14.77</td>
</tr>
<tr>
<td>Economizer Cycle</td>
<td>$1,200</td>
<td>$165</td>
<td>7.27</td>
</tr>
<tr>
<td>Insulation</td>
<td>$1,600</td>
<td>$101</td>
<td>15.84</td>
</tr>
<tr>
<td></td>
<td><strong>$26,200</strong></td>
<td><strong>$5,577</strong></td>
<td><strong>4.70</strong></td>
</tr>
</tbody>
</table>

Fewer E & W Windows            | -$4,160          |         |                     |
Small & Different HVAC         | -$17,700         |         |                     |
Total Cost                     | **$4,340**       |         |                     |

Added construction costs: $26,200
Capital cost reductions: $21,860
Incremental construction cost: $4,340
Energy savings (70%): $4,500/year
Simple payback: about 1 year
ROI: about 100%
**Energy Saving Measures**

- **Lighting Measures:** high efficiency lighting, integrated daylighting, and lighting controls
- **HVAC:** advanced systems, radiant heating/cooling, evaporative cooling, energy mgmt. controls, motorized ventilation dampers, demand controlled ($CO_2$) ventilation
- **Daylighting:** integrated lighting controls, automated blinds, exterior shades, skylights
- **Envelope:** operable windows, increased insulation, improved glazing
- **Controls/Monitoring/Cx:** whole building monitoring, tenant-level metering, ongoing tracking, continuous commissioning

Source: NBI

http://newbuildings.org/meta-report-search-deep-energy-savings
The Empire State Building’s pre-retrofit performance was average.

Annual utility costs:
$11 million ($4/sq. ft.)

Annual CO2 emissions:
25,000 metric tons (22 lbs/sq. ft.)

Annual energy use:
88 kBTU/sq. ft.

Peak electric demand:
9.5 MW (3.8 W/sq. ft. inc. HVAC)

But…. 102 stories and 2.8 million sf and 4.0 million visitors per year!
The Retrofitted Empire State Building Is a Landmark

Energy and cost savings:

• Save 38% of energy use with a 3-year payback
• Remanufacturing 6,500 windows onsite into super windows
• Installing better lights and equipment
• Envelope improvements and reduced internal loads allowed for a smaller cooling system
Energy and CO2 savings in the optimal package result from 8 key projects.
# Digestible Business Case:
## Capital Costs & Energy Savings for Each Measure

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Projected Capital Cost</th>
<th>2008 Capital Budget</th>
<th>Incremental Cost</th>
<th>Estimated Annual Energy Savings*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows</td>
<td>$4.5m</td>
<td>$455k</td>
<td>$4m</td>
<td>$410k</td>
</tr>
<tr>
<td>Radiative Barrier</td>
<td>$2.7m</td>
<td>$0</td>
<td>$2.7m</td>
<td>$190k</td>
</tr>
<tr>
<td>DDC Controls</td>
<td>$7.6m</td>
<td>$2m</td>
<td>$5.6m</td>
<td>$741k</td>
</tr>
<tr>
<td>Demand Control Vent</td>
<td>Inc. above</td>
<td>$0</td>
<td>Inc. above</td>
<td>$117k</td>
</tr>
<tr>
<td>Chiller Plant Retrofit</td>
<td>$5.1m</td>
<td>$22.4m</td>
<td>-$17.3m</td>
<td>$675k</td>
</tr>
<tr>
<td>VAV AHUs</td>
<td>$47.2m</td>
<td>$44.8m</td>
<td>$2.4m</td>
<td>$702k</td>
</tr>
<tr>
<td>Tenant Day/Lighting/Plugs</td>
<td>$24.5m</td>
<td>$16.1m</td>
<td>$8.4m</td>
<td>$941k</td>
</tr>
<tr>
<td>Tenant Energy Mgmt.</td>
<td>$365k</td>
<td>$0</td>
<td>$365k</td>
<td>$396k</td>
</tr>
<tr>
<td>Power Generation (optional)</td>
<td>$15m</td>
<td>$7.8m</td>
<td>$7m</td>
<td>$320k</td>
</tr>
<tr>
<td><strong>TOTAL (ex. Power Gen)</strong></td>
<td><strong>$106.9m</strong></td>
<td><strong>$93.7m</strong></td>
<td><strong>$13.2m</strong></td>
<td><strong>$4.4m</strong></td>
</tr>
</tbody>
</table>

24 yr payback 3 yr payback
THE ESB ANALYSIS IN FOUR STEPS...

1. Identify Opportunities
2. Model Individual Measures
3. Create Packages of Measures
4. Model Iteratively

Outcome:
Package of measures with best economic & environmental benefits
Remanufacturing Existing Windows

—Remanufacture existing insulated glass units (IGU) within the Empire State Building’s approximately 6,500 double-hung windows to include suspended coated film and gas fill.
HALF THE SAVINGS EXIST WITHIN TENANT SPACES

Energy Savings: Base Building vs. within Tenant Space

- Retrofit chiller
- Balance of DDC
- Tenant DCV
- Radiative Barrier
- Tenant energy management
- Building windows
- VAV AHU's
- Tenant daylighting
- Lighting/plugs

Measures that only affect the base building
Measures within tenant space

Annual energy savings (kBtu)
PG&E Incentives

• If measure qualifies for deemed rebates, one must apply for deemed program.
• Calculated incentives vary by measure type.
• Calculated incentive is one amount up to code and a larger amount to exceed code.
• Minimum incentive for calculated program:
  • $3,000 for non-residential heating, ventilation, and air conditioning (HVAC) measures
  • $2,000 for lighting control (LC) measures
• PG&E must inspect and approve project before old equipment is removed.

<table>
<thead>
<tr>
<th>Measure</th>
<th>kW</th>
<th>kWh</th>
<th>Therms</th>
</tr>
</thead>
<tbody>
<tr>
<td>To code/Standard practice</td>
<td>$75.00</td>
<td>$0.06</td>
<td>$0.50</td>
</tr>
<tr>
<td>Above code/Standard practice</td>
<td>$150.00</td>
<td>$0.12</td>
<td>$1.25</td>
</tr>
<tr>
<td>Whole building using normalized metered energy consumption (NMEC)</td>
<td>$200.00</td>
<td>$0.12*</td>
<td>$1.75</td>
</tr>
</tbody>
</table>
Normalized Meter Energy Consumption (NMEC)
Rebates

- Eligible LED rebates
  - Highbay/Lowbay Lighting
- HVAC
  - Variable Frequency Drives for HVAC Fans
  - Advanced Digital Economizer Control Systems for Packaged HVAC Units
  - Demand Controlled Ventilation for Packaged HVAC Units
  - Enhanced Ventilation Control for Packaged HVAC Units
- Refrigeration
- Insulation
- Water Heating
- Laundry equipment
- Food Service
On-Bill Financing
On-Bill Financing

- The loans offered by PG&E under OBF are interest free (0%) and free of any fees, pre-payment penalties, or other charges.
- Financing is available to fund energy efficiency measures that are installed through an eligible PG&E rebate or incentive program.
- Loan payed back as part of monthly utility bills.
Financial Return Calculations
Whole Building Pre and Post Retrofit Data

Avg. KW

0 50 100 150 200 250 300

9/2 9/7 9/12 9/17 9/22 9/27 10/2 10/7 10/12
Developing a Blended Rate

• Information required:
  • Cost in electricity per year in dollars
  • Total kWh usage for the year

• Calculate $/kWh by dividing cost by annual energy

• Does not factor in variability of energy cost
  • Night operation is cheaper
  • Day operation is more expensive
  • Summer day operation is most expensive
  • *Not ideal for determining value of cooling strategies*
## Blended Rate Example

<table>
<thead>
<tr>
<th>kWh</th>
<th>Therms*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>June</strong></td>
<td></td>
</tr>
<tr>
<td>kWh</td>
<td>78561.05</td>
</tr>
<tr>
<td>$</td>
<td>$12,041.05</td>
</tr>
<tr>
<td>$/kWh</td>
<td>$0.15/kWh</td>
</tr>
<tr>
<td><strong>December</strong></td>
<td></td>
</tr>
<tr>
<td>kWh</td>
<td>76742.78</td>
</tr>
<tr>
<td>$</td>
<td>$8662.78</td>
</tr>
<tr>
<td>$/kWh</td>
<td>$0.11/kWh</td>
</tr>
</tbody>
</table>

| **June** |         |
| Therms   | 2808 |
| $        | $3393.79 |
| $/Therms | $1.21/Therms |

| **December** |         |
| Therms      | 3601 |
| $           | $4707.21 |
| $/Therms    | $1.31/Therms |

*Natural gas is a market entity with a varying rate.*
Pay Back Period

• Calculate cost of retrofit
• Subtract cost of incentive
• Divide by annual energy savings
  \[
  \frac{\text{retrofit cost ($)} - \text{rebate ($)}}{\text{savings ($)/year}} = \text{Payback years}
  \]

A \textbf{three year payback equates to a 33\% return on investment}
A \textbf{five year payback equates to a 20\% return on investment}
Rate of Return vs. Payback

Investors who limit themselves to simple payback periods of four years or less are limiting themselves to investments with a rate of return better than 12 percent. As a result, they may be depriving themselves of some attractive long-term opportunities. Even projects with simple payback periods as long as 15 years can produce a rate of return of about 7 percent.

Note: Calculations are based on a 6 percent discount rate, 15-year financing with 3 percent real interest rate, and a 15 percent tax rate.

Courtesy: Platts; data from Architectural Energy Corp.

Energy Design Resources
Annual Building Operation Costs

Data from Statistical Abstract of the United States 1991
Exercise: Calculating Financial Return
Example Project

5-ton packaged unit replacement

**Existing:** 8 EER

**Standard:** 14 EER, $7,100.00

**Proposed:** 17 EER, $8,000.00

**Location:** Sacramento

**Facility type:** Retail

https://www.pnnl.gov/uac/costestimator/main.stm
Existing Building Commissioning
What Is Building Commissioning?

Commissioning is a quality assurance strategy.

Commissioning is a systematic process of ensuring that all building systems perform interactively according to the contract documents, the design intent and the building owner’s operational needs.
Why Commission?

- Owners do not typically receive fully functional building systems
- Owners face increasing numbers of performance problems
- Buildings have more complex life safety, security, communication, and comfort control systems
- Building systems are becoming increasingly specialized and integrated
- Many problems are masked by energy-wasting process
- Multiple trades and contracts are involved (fragmentation)
- Conflicting loyalties and objectives
- Increasing costs (change orders, call backs)
- Emphasis on fast track
- Design fees do not reflect reality
- Requirements – LEED, CHPS, Title 24
Commissioning is *Quality Assurance*

- A coordination process to optimize building performance (comfort, reliability, safety, energy)
- Articulating/verifying energy-related design intent
- Construction observation; warranty enforcement
- Controlling first cost
- Training operators
- Enhancing safety and risk management
- Creating more cohesion among team members
A Common Industry Perspective;
Commissioning; A Bandage for a Broken Process

An Emergency Response

- Treating the wound
- Add-on process
- Last-ditch effort
  - Resurrect quality
  - Identify deficiencies
  - Force accountability

Images courtesy www.talkingproud.us
Building problems (a.k.a. “deficiencies”) are *pervasive*

- These include *Design flaws; Construction defects; Malfunctioning equipment; Deferred maintenance*

<table>
<thead>
<tr>
<th>EXISTING BUILDINGS</th>
<th>NEW CONSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simultaneous heating+cooling</td>
<td>Oversized equipment</td>
</tr>
<tr>
<td>Mis-sized valves/dampers, chillers</td>
<td>Unnecessary components (valves)</td>
</tr>
<tr>
<td>Low-quality or clogged filters</td>
<td>Construction debris blocking ventilation</td>
</tr>
<tr>
<td>VFD or economizer overridden/stuck</td>
<td>Specified equipment not installed</td>
</tr>
<tr>
<td>Dumb alarms (false; ignored)</td>
<td>Wrong set points or control sequences</td>
</tr>
<tr>
<td>Circuitous duct or piping runs</td>
<td>Wrong sensors (inappropriate sensitivity)</td>
</tr>
<tr>
<td>Bad or inaccurate sensors</td>
<td>Improper startup (e.g. daylighting sensors)</td>
</tr>
<tr>
<td>Supply fans running; return not (or visa-versa)</td>
<td></td>
</tr>
</tbody>
</table>
First-cost savings alone can pay for cost of Cx!

Evan Mills: The Cost-Effectiveness of Commercial Buildings Commissioning, 2004
Payback Times: New Construction

Payback times not always attractive (if NEBs excluded)

Median Payback Time = 4.8 years

Outliers: (390,575;165,130), (661,752;149,513 ), (1,126,000;308,344)
RCX Payback Times for Existing Buildings

Median Payback Time = 0.7 years

Excluding NEI’s
N=100

Attractive payback times across a range of Cx costs
PEC: Pre and Post Commissioning Data

Average Daily Electrical Consumption
PG&E Pacific Energy Center

- April 2000 - March 2001
- April 2002 - March 2003
- April 2003 - March 2004
Other Strategies

including occupant behavior programs, renewables, thermal storage and demand response
Load Profiles, Peak Demand and Rates

Consider that utility rates vary by time of day and year
Duck Curve

Net load - March 31

Ramp need
~13,000 MW in three hours

Potential over generation

Manipulate the scale of the x-axis to provide context.
California Population Growth
Peak Demand Projections

Source: California Energy Commission, Demand Analysis Office, 2013
The Last Decade

• Manage Peak Capacity During Hot Summer Days
• Improve Affordability and Reliability of Electricity

Slide courtesy of Mary Ann Piette, Lawrence Berkeley National Laboratory
Demand Response Dispatched on June 20, 2016

- On June 20, 2016, temperatures peaked at 101 degrees in Los Angeles (114 in Riverside) while SCE’s demand was nearing all-time peak levels of over 23,000 MW.
- All of SCE’s DR programs were dispatched that day with the exception of BIP and API.
- Nearly 600 MW of SCE-managed demand response responded to system conditions.
Frequency of DR Strategies

- Global temp. adjustment
- Duct static pres. increase
- SAT increase
- Fan VFD limit
- CHW temp. increase
- Fan qty. reduction
- Pre-cooling
- Cooling valve limit
- Turn off light
- Dimmable ballast
- Bi-level switching

Legend:
- Fully-Automated
- Manual or Semi-Automated
Global Temperature Adjustment:

GTA is Intuitive - During DR events:

- Turn cooling setpoint up
- HVAC systems “coast” to provide savings
Case Study 7 – Retail Store Results

IKEA: Oct-25

Whole Building Power [kW]

Actual
LBNL Baseline
CPP Baseline
DR Services Span Time Scales

Shape
- Incentivize EE and Behavior Change

Shift
- Mitigate Ramps and Capture Surplus Renewables

Shed
- Manage contingency events and coarse net load following

Shimmy
- Fast DR to smooth net load and support frequency

Years | Seasons | Days | AM/PM | Hours | Minutes | Seconds
DR Shed Reduces and Shift Moves Load

**Shed** Service Type: Peak Shed DR

**Shift** Service Type: Shifting load from hour to hour to alleviate curtailment/overgeneration

Slide courtesy of Mary Ann Piette, Lawrence Berkeley National Laboratory
Shape is Price Response, Shimmy is Fast

**Shape** Service Type as modeled: Accomplishes Shed and Shift with prices and behavioral DR.

**Shimmy** Service Type: Load Following & Regulation DR

*Illustrative pricing profile*

Slide courtesy of Mary Ann Piette, Lawrence Berkeley National Laboratory
# Grid Services Mapping

<table>
<thead>
<tr>
<th>Service Type</th>
<th>Description</th>
<th>Grid Service Products/Related Terms</th>
<th>Analysis Unit</th>
<th>Shape (TOU/GPP) Included in service type analysis?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift</td>
<td>Demand timing shift (day-to-day)</td>
<td>Flexible ramping DR (avoid/reduce ramps), Energy market price smoothing</td>
<td>kWh-year</td>
<td>Yes</td>
</tr>
<tr>
<td>Shed</td>
<td>Peak load curtailment (occasional)</td>
<td>CAISO Proxy Demand Resources/Reliability DR Resources; Conventional DR, Local Capacity DR, Distribution System DR, RA Capacity, Operating Reserves</td>
<td>kW-year</td>
<td>Yes</td>
</tr>
<tr>
<td>Shimmy</td>
<td>Fast demand response</td>
<td>Regulation, load following, ancillary services</td>
<td>kW-year</td>
<td>No</td>
</tr>
</tbody>
</table>
Peak Day Pricing (PDP)

- Rate has lower costs for most of year
- Has increased cost during 9-15 events/year
  - Event duration is 2-6 pm (12-6 pm is option)
  - Notification about event occurs on previous day
  - Based on avg. projected temperature > 98°F in 5 North-California cities
  - Price during peak event will increase $0.60/kWh over normal rate

- Financial impact/risk
  - PDP is revenue neutral for PG&E
  - Is a “no lose” proposition for customers in first year of program
  - Lucrative for customers that can shed power during peak events

- Optional rate
- Most impacted customer type is retail facilities in valley

www.pge.com/PDP
Intent of Peak Day Pricing

• Energy costs are reduced across the board on non-event days.
• Customers benefit by reducing peak power during event days.
Open Automated Demand Response – Open ADR

- open standardized DR interface
- Allows electricity providers to communicate DR signals directly to customers
- Uses XML language and existing communications e.g., Internet

Slide courtesy of Mary Ann Piette, Lawrence Berkeley National Laboratory
Batteries can be of various sizes and modular, depending on size and location.
PV with Energy Storage for Commercial Buildings

Diagram:
- **A**: Solar PV Panels
- **B**: PV Inverter
- **C**: Energy Storage
- **D**: Controls
- **E**: Building Loads
- **F**: Smart Meter & Connection to Grid
PV with Energy Storage for Commercial Buildings

Best value situations involve peak shaving and lowering of demand charges.
Thermal Storage
Full Storage vs. Demand Limiting
Thermal Storage Issues

- Peak demand reduction (saves $)
- More efficient operation at night
- Smaller electrical service required

- Requires space
- Requires knowledgeable facility engineers
- Efficiency losses as cooling is stored and retrieved
Additional Resources

Tool Lending Library, Universal Translator and Other Resources
PG&E TLL – free energy measurement tool loans and technical assistance

- Over 5,500 tools in our inventory
- 173,000 tool loans over our 25-year history
- Two locations – San Francisco and Stockton
- Pickup in person or ship to borrower
- Equipment tutorials
- Assistance with data downloading and analysis
- Equipment troubleshooting
- Field support
- Application notes explaining use of tools
Save money! Borrow from our library of specialized tools and books for your next energy-related project. To learn more, visit our front desk or go to https://www.sdge.com/energy-innovation-center/tool-and-book-lending-library.

We have a library of books, publications, and more than 100 energy-measuring tools that are available on loan to the general public. Search the library and make reservations online.

All lending is on hold now, but when we open again, you can pick them up and take them home.
Tool Lending Library

Tool Catalog

Borrower Request Form
https://www.sce.com/apps/forms/

Contact Us at 1-800-772-4822
https://www.sce.com/apps/forms/
Universal Translator (utronline.org)

- **Data Management Tools**
  - Trend and logger data
  - Re-sampling
  - Time corrections
  - Slope and offset corrections
  - Calculated channels
  - Schedule and data filters

- **Data Analysis Tools**
  - Economizer
  - Run time of equipment
  - Lighting controls
  - Plug load controllers
  - Psychrometrics
  - Set-point analysis
Future PEC Classes

RCx101: Identifying and Assessing Common Retro-Cx Opportunities
May 20, 2020 as a webinar

June 15, 2020, as a webinar

A Class for Control Freaks: Getting the Most from your Building Automation System
June 18, 2020 as a webinar

Chilled and Condenser Water Systems: Design, Performance, and Commissioning
June 24, 2020 as a webinar

Existing Building Commissioning Workshop Series – year 16
Starts on June 25, 2020 at PEC in San Francisco (meets 14 times over a one-year period)

The Quest for Performance and California Code Commissioning Requirements
June 29, 2020

Basic Excel for Energy Auditors
September 18, 2020

Graphic Representation of Data: Making Charts that Matter
November 20, 2020
Virtual Facility Walk-through
Ryan Stroupe  
Building Performance Program Coordinator  
PG&E Pacific Energy Center  
851 Howard Street  
San Francisco, CA 94103  
P: 415.973.7257  
E: r2s2@pge.com  
www.pge.com/pec

THANK YOU
Appendix
Motor

- Capture nameplate data
- Place a data-logger on motor
- Measure motor speed (to calculate %-load)
- Look up efficiency of motor and possible replacement
- Determine age of motor
- Determine basis of control (VFD)
- Look for noise and vibration
- Find maintenance records
Lights

- Determine lamp and ballast type
- Count # of fixtures
- Determine control strategy
- Leave data-logger for run-time
- Measure light levels
- Look-up recommended light levels
- Determine type of space
- Look-up actual wattage
- Calculate LPD (watts/sf)
- Measure color of light
- Clean fixtures
Packaged Unit

- Look up nameplate data
- Look up full-load hours
- Identify facility type
- Determine facility schedule
- Put data-logger on supply fan
- Gather trends from BMS (if available)
- For thermostat...
  - Find location
  - Determine if schedule is set
  - Determine if setbacks are set
  - Calibrate thermostat
- Determine age of equipment
- Look up efficiency (online)
- Look-up min SEER in T-24
- Check refrigerant type.
- Look at refrigerant site glass

O&M:
- Check for service log
- Determine if belts are tight
- Look for duct leakage and missing insulation.
- Check condensate drain
- Check condenser coils
- Check cleanliness of filters
- Straighten bent fins
- Check economizer
- Check combustion efficiency
Fryer

- Gather nameplate data
- Determine usage rate (bags of product/month)
- Look up energy rate based on usage rate.
- Determine equipment age
- Check heating elements
- Look up in LCC calculator
- Look-up replacement at FSTC
- Find maintenance records
- Test temp control sensor