New & Emerging Energy Efficiency Technologies for C&I Customers

Ken Black
President, E Source

MLGW
Key Accounts Conference
4/25/14
Agenda

- Lighting; LEDs
- Daylight Redirecting Film
- HVAC
- Variable Refrigerant Flow (VRF) Systems
- Condensing Gas RTUs
- Direct-Contact Water Heating
- Fault Detection & Diagnostics
- Energy Data Analytics
- Cloud-based Smart Thermostats
- Plug loads
- Liquid CO2 Textile Cleaning
- Gas Condensing Unit Heaters
- Miscellaneous Potpourri
Lighting
Current Status of LEDs

- High cost; performance and quality getting better
- Increasing number of products
- Good applications today: outdoor, refrigerated cases, warehouses, task lighting, troffers
- Tough applications where thermal management a challenge especially in tight spaces
- Lots of pressure and misleading information from manufacturers and sales reps
- Some dimmer compatibility issues
LEDs: The Big Picture

- LEDs may cut lighting energy use by 1/3 by 2025, and account for >50% of light produced (per DOE)
- Global growth projection for 2014: 68% YoY; 72% in North America
- 70% of lighting business by 2020
- 60-watt replacement lamp cost: was $50, now under $10
- High-bay costs fell 30% to 50% in one year

Source: Philips
LED Performance Up, Costs Down

Since 2009:
• Efficacy doubled
• Costs dropped 85%
• Number installed grew from 400,000 to 49 million
## LEDs in Common Applications

<table>
<thead>
<tr>
<th>Application</th>
<th>2012 penetration (%)</th>
<th>Number installed (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Troffers and tubes</td>
<td>&lt;0.1</td>
<td>0.7</td>
</tr>
<tr>
<td>High-bay</td>
<td>&lt;1</td>
<td>0.3</td>
</tr>
<tr>
<td>A lamps</td>
<td>&lt;1</td>
<td>19.9</td>
</tr>
<tr>
<td>Downlights</td>
<td>&lt;1</td>
<td>5.5</td>
</tr>
<tr>
<td>Parking lots</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>Streetlights</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Directional</td>
<td>4.6</td>
<td>11.4</td>
</tr>
<tr>
<td>MR16</td>
<td>10</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Data from DOE, Adoption of Light Emitting Diodes in Common Applications
LED Troffers Are Coming of Age

Troffers are the most common fluorescent fixture:

- Operate 10.5 hours/day
- Contribute to peak load
- Draw 25 to 113 watts
- Millions of installed fixtures
- 42% of lighting energy
- ~87 terawatt-hours per year
Why LEDs for Troffers?

- Performance improving, prices falling
- Better efficacy than fluorescents
- More controllable, longer life
- 2012: 700,000 installed (40,000 in 2010)
DOE Conclusions

**Troffers**: can compete on efficiency, life, and quality

**Tubes**: have problems with dark spots, glare, efficiency, and safety [but tubes are getting better]
A Wealth of Products

- DesignLights Consortium Qualified Products List (QPL)
  - >900 products
  - http://www.designlights.org/QPL/
- Minimum requirements
  - At least 85 lumens per watt
  - 50,000-hour life
  - 5-yr warranty
**Tubular LED Products**

- **Cree: UR Series**
  - Installs in 10 minutes
    - Magnetic attachment
    - Quick-connect wiring
  - Good light distribution
  - CRI 80, 102 lm/W, 50,000 hour life, 7-year warranty
  - External driver
  - UL label
  - Estimated cost: <$100

Source: Cree
LED Replacement Tube - What We’ve Been Waiting For?

- Philips InstantFit LED
  - Fits in T8 sockets; uses existing instant-start EB
  - 83 CRI; 40,000 hr; 95-116 lm/W
  - $24 to $39

- Concerns
  - Persistence of savings
  - 12.5 to 20 W, only 1300-2100 lm
  - External ballast/driver runs cooler so more output
  - Photometric distribution likely different

Source: Philips
### Comparing Fluorescent T8 with InstantFit

<table>
<thead>
<tr>
<th></th>
<th>High performance T8</th>
<th>InstantFit LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRI</td>
<td>80s</td>
<td>83</td>
</tr>
<tr>
<td>Life, hrs</td>
<td>24,000-75,000</td>
<td>40,000</td>
</tr>
<tr>
<td>Efficacy, lm/W</td>
<td>98</td>
<td>95-116</td>
</tr>
<tr>
<td>Cost, $</td>
<td>5</td>
<td>24-39</td>
</tr>
</tbody>
</table>

Note: different definitions of “life” for LEDs, fluorescents

Source: E Source
LEDs replace CFLs in recessed cans

- The Helen Lamp, Lunera
- Replaces pin-base CFLs (26, 32 or 42 W)
- Uses existing 4-pin e-ballast
- No dimming
- Specs:
  - 13W/900 lm
  - 84 CRI
  - 50,000 hr. life
  - 2700, 3000, 3500, or 4000 K
More About Helen

- **Cost:** $40-45
- **Several utilities have paid prescriptive rebates**
  - E.g. PG&E, happy university user
- **Concerns:**
  - No dimming: coming soon
  - Persistence of savings
  - Quantity of light
  - Limits on compatible ballasts: more coming
  - No DLC category, but LDL listed
Look ma, no fins!

- Philips SlimStyle
- Ring of LEDs distributes light and dissipates heat
- 60W eq: 10.5W/800 lm
- Low price ($9.97)
- 80 CRI, 2700 K
- Dimmable
- 25,000 hrs
- Less shelf space; less shipping volume and weight
## Comparing 60W Equivalent Lamps

<table>
<thead>
<tr>
<th></th>
<th>Cree</th>
<th>Philips SlimStyle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (W)</td>
<td>9.5</td>
<td>10.5</td>
</tr>
<tr>
<td>Efficacy (lm/W)</td>
<td>84</td>
<td>76</td>
</tr>
<tr>
<td>Life (hrs)</td>
<td>25,000</td>
<td>25,000</td>
</tr>
<tr>
<td>Color Temp (K)</td>
<td>2700</td>
<td>2700</td>
</tr>
<tr>
<td>CRI</td>
<td>82</td>
<td>80</td>
</tr>
<tr>
<td>Dimmable</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Price ($)</td>
<td>12.97</td>
<td>9.97</td>
</tr>
<tr>
<td>Warranty</td>
<td>10 yr</td>
<td>3 yr</td>
</tr>
<tr>
<td>Shape</td>
<td>bulb</td>
<td>disk</td>
</tr>
</tbody>
</table>

Source: E Source
LEDs with Advanced Controls

LEDs easier to control than HID or fluorescent

- A new approach to wireless lighting control
- Instant response
- Lamp life not decreased by frequent on/off cycling
- Options for individual control
- Easy to dim; dimming may increase lamp life
  - Check for compatibility; some problems with incandescent dimming
- Can change color temperature
  - Mimic incandescent dimming
  - Health and productivity impacts
LEDs: Big Savings with Controls

- Daylight dimming, occupancy sensing, task tuning, scheduling by zone, flexible zones, monitoring status, demand response
- kWh: 50% to 90% reduction
- kW: 50% to 80% reduction
- Best paybacks with long hours, little existing controls, and big savings per fixture; good in industrial/warehouse
- Longer paybacks in office buildings (shorter hours, already doing daylight dimming, occupancy sensing)
LEDs: Good Application for Industrial & Warehouse Facilities

- Many 250W to 400W HID systems
- Long operating hours (6,000 to 8,760 hrs/year)
- Few have occupancy sensors or daylight harvesting due to re-strike requirements associated with HIDs
- Individual fixture control easier to justify
- Original lighting system often does not align with current facility usage patterns
- Expected savings over 80%
LED High-Bay Case Study: Ace Hardware

- 44,800 sq ft section of warehouse
- Baseline: metal halide, no automatic controls
- Installed: Intelligent LED fixtures
  - Networked, software, sensors, wireless communications
- 93% energy savings (50% light source, 43% controls)
- 3.6 yr payback

Source: Digital Lumens

Project with PG&E, CA ETCC; Digital Lumens

Report available online at:
Putting Light Where It’s Needed

Digital Lumens

Light into the Aisle
71% vs. 18%

400W MH

Doubling the light since no foot-candles are wasted

15 fc

8 fc

LM-79 Absolute Photometry

Courtesy: Digital LUmens
Daylight Redirecting Film
What’s the Matter with Daylighting?

Courtesy: National Renewable Energy Laboratory
Old Solution: Light Shelves

- Sunlight
- Clerestory glazing
- Light shelf
- Blinds
- View glazing
New Solution: 3M Daylight-Redirecting Film

Source: Sacramento Municipal Utility District
How It Works

Source: 3M
Cheaper and Deeper

Source: Sacramento Municipal Utility District
## Looks Like a Winner

<table>
<thead>
<tr>
<th>Metric</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost ($ per square foot)</td>
<td>$30</td>
<td>$35</td>
</tr>
<tr>
<td>Energy savings (%)</td>
<td>39%</td>
<td>43%</td>
</tr>
<tr>
<td>Simple payback period (years)</td>
<td>1.5</td>
<td>4.5</td>
</tr>
</tbody>
</table>

© E Source; data from Lawrence Berkeley National Laboratory and 3M
Tubular Skylights

- Daylighting without heat or glare
- Clear plastic dome, reflective tubes, diffusers
- Used with daylight sensors to dim electric lights
HVAC
Turbocor Chiller Compressor

Courtesy: Danfoss Turbocor
Turbocor Uses Magnetic Fields to Levitate the Compressor Shaft

No contact between radial bearings and shaft

Courtesy: Turbocor
## Benefits

### 33% Improvement in IPLV
- IPLV: Integrated Part Load Value
- Reduced friction
- Variable speed operation

### Reduced Maintenance/Installation Costs
- No mechanical bearings so no oil is needed
- Smaller, lighter, generates less noise
- Modular; retrofit and OEM

### Reduced Startup current
- 2 amps instead of 100-500 to startup
- Much quieter startup
## Example Rough Paybacks

<table>
<thead>
<tr>
<th>Citya</th>
<th>Miami, FL</th>
<th>Phoenix, AZ</th>
<th>Stockton, CA</th>
<th>Minneapolis, MN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent full-load cooling hours</td>
<td>3,931</td>
<td>2,141</td>
<td>1,148</td>
<td>662</td>
</tr>
<tr>
<td>Energy use of an average screw (kWh)</td>
<td>339,049</td>
<td>184,661</td>
<td>99,878</td>
<td>57,098</td>
</tr>
<tr>
<td>Energy use of McQuay WMC-150 (kWh)</td>
<td>221,119</td>
<td>120,431</td>
<td>65,138</td>
<td>37,238</td>
</tr>
<tr>
<td>Savings (kWh)</td>
<td>117,930</td>
<td>64,230</td>
<td>34,740</td>
<td>19,860</td>
</tr>
<tr>
<td>Simple payback period (years)</td>
<td>1.6</td>
<td>2.9</td>
<td>5.3</td>
<td>9.3</td>
</tr>
</tbody>
</table>

Notes: IPLV = Integrated part load value
a. These examples assume a screw chiller cost of $280/ton, a cost premium of 35 percent for the WMC-150, and an electricity rate of $0.08/kWh.

Source: E SOURCE; data from manufacturers
Variable Refrigerant Flow (VRF) Systems
Variable Refrigerant Flow (VRF) Systems

- Circulate refrigerant instead of water or air
- Promise lower operating cost, greater comfort, and several other benefits over conventional HVAC systems
- Even looks like traditional AC

Courtesy: Daikin AC
www.daikinac.com
Mitsubishi Hyper-Heat Line

<table>
<thead>
<tr>
<th></th>
<th>Commercial (variable refrigerant flow)</th>
<th>Residential (ductless heat pump)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>City Multi</td>
<td>P-Series</td>
</tr>
<tr>
<td>Tested to (°F/°C)</td>
<td>–13 / –25</td>
<td>–13 / –25</td>
</tr>
<tr>
<td>Operation limit (°F/°C)</td>
<td>–18.4 / –28</td>
<td>–33 / –36</td>
</tr>
<tr>
<td>Cooling capacities (tons)</td>
<td>6, 8, 12, 16</td>
<td>2.5, 3</td>
</tr>
<tr>
<td>Heating capacities (kW at 47°F)</td>
<td>23, 32, 47, 63</td>
<td>9.4, 11</td>
</tr>
<tr>
<td>Number of indoor units</td>
<td>41</td>
<td>1 or 2</td>
</tr>
</tbody>
</table>

© E Source; data from manufacturers

At 0°F/ –18°C, traditional heat pumps can lose half or more of their capacity and net (heat pump + backup heat) COPs approach 1.0.
Fault Detection & Diagnostics (FDD) for Commercial HVAC

Rapidly emerging low cost minimalist diagnostics that work
Minimalist Approach: Using Sound

Virtjoule

- Monitors sound for faults and degradation
- Savings: 5 to 8 percent kW and 15 to 20 percent kWh (vendor-reported)
- $150 to $300 installed
Fault-Finding Made Easy

- Runtime outside business hours
- Economizer opportunities
- Short cycling
- Condenser fan failure
- Compressor failure
- Refrigerant leaks
- High head-pressure faults

- Sends you a text or email
Best Applications

- Performance monitoring for HVAC equipment with limited or antiquated energy management systems
- Attractive option for monitoring tenant HVAC
- Critical-system monitoring for large HVAC, server rooms, and refrigeration

Courtesy: Virtjoule
RTU Retrofit with Big Savings
### VFD Retrofit Devices for RTUs: What’s Under the Hood

- Designed for existing single speed, single zone RTUs
- Packaged rooftop units (RTU) are used in 46% of all commercial buildings in the US
- Site energy consumption of 230 Trillion Btus annually

<table>
<thead>
<tr>
<th>Product</th>
<th>VFD – Evaporator Fan</th>
<th>VFD – Compressor</th>
<th>DCV</th>
<th>Economizer controls</th>
<th>FDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalyst</td>
<td>Y</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>Some</td>
</tr>
<tr>
<td>Enerfit</td>
<td>Y</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>Some</td>
</tr>
<tr>
<td>Digi-Rtu</td>
<td>Y</td>
<td>Y</td>
<td>IP*</td>
<td>IP*</td>
<td>IP*</td>
</tr>
</tbody>
</table>

*IP = in progress
Newest Results Continue to be Positive - PNNL Study

- PNNL Study published July 2013:
  - 66 Catalyst units
  - 8 different buildings (retail, shopping mall, office, food sales, healthcare)
  - 4 climate zones (warm coastal, mixed humid, mixed marine, cool moist)

- Average savings of 57%!
- Mostly due to fan energy
- Average simple payback of 3 years at $0.10/kWh
Newest Results Continue to be Positive – SCE Study

- SCE Study published November 2013:
  - 4 different manufacturers – kept anonymous
  - 1 installation per manufacturer
  - 1 building in San Diego, CA

- 2 units were duty cycling controllers!
- 1 unit modulated supply fan speed (mostly)
- 1 unit modulated compressor speed (mostly)
- 24-27% savings
VFD Retrofit Devices Are Ready for Prime Time

- Proven, significant savings
- Compressor modulation not shown to be any more effective than fan speed modulation
Condensing Gas RTUs
Gas Heating Rooftop Units (RTUs), a.k.a. “gasPACs”

The workhorses of commercial buildings

Source: U.S. National Archives and Records Administration

Source: Wikimedia Commons
The Problem:

GasPACs are only 80% efficient!

Help is on the way....

Source: Open ClipArt Library
### The (Emerging) Solution:

<table>
<thead>
<tr>
<th>Condensing Gas RTUs (gasPACs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recover latent and sensible heat from flue gas</td>
</tr>
<tr>
<td>Can deliver 90+ percent efficiency</td>
</tr>
</tbody>
</table>
What’s Held It Back So Far?

- Technical challenges with condensing RTUs
  - Freezing condensate
  - Acidic condensate
- Economic challenges—increased costs for:
  - Condensing heat exchanger
  - Fan energy penalty from increased pressure drop
  - Maintenance (acid-neutralizing agent)

Net operating cost savings are key, so need to be selective with applications
Available Products

- **Engineered Air**
  - RTU with condensing gasPAC
  - 90 percent efficiency
  - DJX series

- **Modine**
  - RTU/dedicated outdoor air system (DOAS) with condensing gasPAC
  - 90 percent efficiency
  - Atherion line with Conservicore

- **Munters**
  - DOAS with condensing gasPAC
  - Not officially released yet
Identifying Cost-Effective Applications

- Gas Technology Institute (GTI) and Consortium for Energy Efficiency (CEE) joint research project
- Monitored more than 105 gasPAC units in 11 Chicago-area commercial buildings
  - RTUs serving perimeter run more than those for core
  - Runtime patterns were repeated in big-box retailers with similar RTU layout
- Two big-box store tests are underway in Chicago and Minnesota; expect energy and cost savings data next year
Best Opportunities for Upgrading

- Northern US and Canada (5,000 or more annual heating degree days)
- High-runtime RTUs (likely serving perimeters, vestibules, or 24/7 operations)
- DOASs
- High-make-up air volumes
- Variable or 2-speed fan units (reduces pressure drop losses)
Time to Replace the Water Heater?
Direct-Contact Water Heating

No heat exchanger
- Water comes into physical contact with combustion gases

Hot water produced as needed
- Minimal standby loss

Up to 99.7 percent efficient!
- Can yield energy savings of up to 60 percent in the right applications

Courtesy: Ludell Manufacturing
How It Works

Water spray

Flame

Falling water

Hot water

© E Source
Minimal Maintenance Requirements

- No heat exchanger
- Available in all-stainless-steel construction
- Little calcination or scale buildup
- Long life expectancy

Source: Department of Agriculture
Some Important Differences

Hot water is unpressurized
- Differs from a standard boiler or tank heater
- Requires pumping to the end use

Capacities of up to 54 million Btu per hour
- Can produce lots of hot water very quickly

Incomplete combustion can hurt water quality
- However, several models do meet bottled water and food ingredient water standards for direct use without additional filtration

Low-temperature exhaust
Industries That Could Benefit

Pharmaceuticals
Textiles
Laundry
Greenhouses
Warehouses

Materials production
- Metals
- Molded plastics
- Synthetic rubber
- Synthetic fibers
- Concrete

Food processing
- Meat
- Dairy
- Beverages
- Sugar refining
- Raw food

Courtesy: EC Systems
Case Study: Cambridge Towel Corp.

Background
- Located in Ontario, Canada
- Makes terrycloth towels
- Operates four days a week, employing over 200 people

Retrofit details
- Replaced an inefficient steam water-heating system with a direct-contact water heater
- Cost for the water heater: approximately $150,000

Results
- Went from a thermal efficiency of 60.0 percent up to 99.7 percent
- Savings of $8,400 per month ($100,800 annually)
- Simple payback period of 1.5 years
- Resulted in the shutdown of one of the plant’s two boilers
Who Makes Them?

- Armstrong International
- Heatec
- Kemco Systems
- Ludell Manufacturing
- QuikWater
- Sofame Technologies
- Thermal Engineering of Arizona

Courtesy: Ludell Manufacturing
New Simple Building Energy Analytics: Turning Big Data into Savings

Source: Xcel Energy

Source: 123RF.com
How They Work

Analytical engine

- Utility bills
- Dashboard
- Recommendations
- Economic analysis
- Ranking
- Weather station
- Digital controls
- End-use meters
No-Touch Audits

This building uses approximately 23% more energy than an efficient peer building. Estimated Energy Savings Potential: $561,821 per year.

<table>
<thead>
<tr>
<th></th>
<th>This Building</th>
<th>Peer Building</th>
<th>Efficient Peer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$2,444,510 per year</td>
<td>$2,705,687 per year</td>
<td>$1,882,689 per year</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Savings</th>
<th>% kWh Reduction</th>
<th>Seasonal Peak kW Reduction</th>
<th>Dollar Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual</td>
<td>Lifetime</td>
<td>During Peak (8am-11pm)</td>
<td>Summer Peak (1-5pm)</td>
</tr>
<tr>
<td>2,675,336 kWh</td>
<td>21,402,691 kWh</td>
<td>22.98%</td>
<td>80.90%</td>
</tr>
</tbody>
</table>

Courtesy: Retroficiency
Minimal Data Inputs Needed

Courtesy: FirstFuel
End-Use Benchmarking

Courtesy: FirstFuel
Many Products to Choose From!
But Do They Save Energy?

- Vendors claim up to 30% energy reduction

<table>
<thead>
<tr>
<th>Site</th>
<th>EIS used</th>
<th>Action/observation</th>
<th>Energy impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>UC Merced</td>
<td>Automated Logic Corp.'s WebCTRL</td>
<td>Excessive overnight gas use due to nonzero pressure at steam boilers</td>
<td>30% reduction in average daily gas use; avoided cost of $4,500/month</td>
</tr>
<tr>
<td>Sysco</td>
<td>NorthWrite's Energy WorkSite</td>
<td>Retrocommissioning and refrigeration tune-ups</td>
<td>36% reduction in site energy use</td>
</tr>
<tr>
<td>UC Berkeley</td>
<td>No central EIS</td>
<td>Lighting retrofit and ventilation schedule change</td>
<td>30% reduction in whole-building energy use</td>
</tr>
</tbody>
</table>

Depends on:
- Skill/motivation/ability/authority of users
- Building type
- Building performance before energy analytics

Source: CKSinfo.com
Cloud Thermostats:
“Poor Man’s Energy Management System”

Source: photoeverywhere.co.uk
Here’s How They Work

- Internet
  - Ethernet cable or Wi-Fi connection
- Internet-connected thermostat
  - Ethernet cable or Wi-Fi connection
  - Copper wire
- HVAC equipment
- Web-enabled devices

© E Source
## Costs and Benefits

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>First costs</td>
<td>$500 to $1,000 per thermostat installed</td>
</tr>
<tr>
<td>Annual costs</td>
<td>$36 to $75 per thermostat</td>
</tr>
<tr>
<td>Energy savings</td>
<td>10% to 50% of overall energy costs</td>
</tr>
<tr>
<td>Other benefits</td>
<td>Reduced O&amp;M costs</td>
</tr>
</tbody>
</table>

© E Source
Cloud Thermostats Go to School(s)

Metered Electricity Use vs. Historical Heating Degree-Days

Source: Quantum Energy Services and Technologies
The Thermostats

Vendors:
• Proliphix
• Bay Controls
• Radio Thermostat
• Viconics

Courtesy: Proliphix
Thermostat Features

- Built-in web server
- Wired or wireless connectivity
- Multiple stages (3 heat, 2 cool)
- Password protected
- Automatic daylight savings time correction
- 366 day programming
- 5-year holiday scheduling
- Humidity and other additional sensing (3 sensor inputs)
- 2 auxiliary relays
- Intelligent recovery
- Built-in alarms
The Auxiliaries

Source: Xytronix Research and Design, Inc.
Application Features

- Access from any web connected browser, including smart phones and tablets
- Data storage
- Graphing
- Alerts
- Thermostat programming and scheduling
- Reporting
- Demand response
Now, the Fine Print

- Few independent savings analyses
- Ability of vendors to manage quality and reliability undetermined
- Ability of building staff to use systems undetermined
- Potential savings vary widely depending on baseline conditions

Source: CKSinfo.com
Plug Loads
Why Care About Plug Loads?

- Plug loads are huge!
  - As much as 15% of the electricity consumed in homes
  - Up to 20% of electricity consumed in commercial offices
  - Phantom power accounts for 3% to 10% of all electric consumption

- Largely underserved by utility programs, nor a focus of many customers
Commercial Plug Loads Are a Big Deal!
Plug loads: One of the Largest and Fastest Growing End-Uses

Source: Graph created by Ecova with data from EIA 2008 Annual Energy Outlook
What’s Left On Most Often?

- Water dispensers: 100%
- Coffee makers: 50%
- Desktop computers: 30%
- Printers/copiers/MFDs: 10%
- Computer monitors: 10%
- Laptops: 10%

Percent of the time left on after-hours
Smart Power Strips Are Supposed to Help, But They Can Present Challenges

- Difficult to determine the best strategy for a given plug load
- Companywide installation can be challenging
- Tough to determine savings
- Employees can change settings or unplug the smart strip altogether
- Little to no demand-response capabilities
Enmetric Systems
What Makes It Different?

- Multiple control strategies for up to four plugs
  - Scheduled and load-sensing control options
- Communicates wirelessly
  - Uses a centralized web portal
  - All settings can be adjusted in one place
  - Easy monitoring and reporting
  - Simplifies installation and setup of power strips
- Can intelligently reduce peak load
  - OpenADR-compliant for use with demand response
- Designed to monitor and control hundreds of plug loads in commercial settings!
Modlet

- No mere smart strip
  - WiFi-enabled smart plug
  - Highly controllable
  - Built-in power meters
- For residential and commercial applications
  - Something tenants can do to reduce energy use!
- Four main benefits
  - Individualized feedback
  - Automated savings
  - Behavior change
  - Smart demand response

Courtesy: ThinkEco, Inc
Some Independent Test Data

- National Renewable Energy Laboratory (NREL) tested the Enmetric smart strips in eight buildings
  - Baseline was a standard “dumb” power strip
  - Studied nearly 300 devices

- Control strategies used included:
  - Submetering only
  - Schedule timer
  - Load-sensing
  - Schedule timer and load-sensing

Source: Wikimedia Commons
Measured Savings

Controlled Device

- Laptop
- Monitor
- Printer
- Under-Cabinet Light
- Kitchen Equipment
- Misc Equipment

Percent Savings

- Scheduled Timer
- Load-Sensing
- Both

© E Source
Economics

- Installed costs vary
  - Estimated $100 per strip
- Simple payback periods can vary widely
  - Can range from <1 to nearly 50 years

Source: Wikimedia Commons
Lessons Learned

- Plug loads comprise 10%-40% of electricity use in small offices.
- Smart controls can reduce consumption by up to 10%.
- Modlet and Enmetric can be used to turn stuff off during DR events.
  - Something that tenants can do to reduce energy use!
- Corporate leadership, culture shift, and behavior change are vital to realizing savings.
- Gamification can help spur education and make it fun to reduce energy consumption.
Liquid CO$_2$ Textile Cleaning
How Does Liquid CO$_2$ Clean?

Carbon-dioxide (CO$_2$) solvent properties compared to water:

- Lower viscosity and surface tension
- Improved small pore penetration
- Cleans better and more quickly

<table>
<thead>
<tr>
<th>Gas at room temperature</th>
<th>Liquid at higher pressures</th>
<th>Solid at atmospheric pressure and below (-)109° F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonation</td>
<td>Liquid</td>
<td>Dry ice</td>
</tr>
</tbody>
</table>

Courtesy (left to right): Quinn Dombrowski, Mr. Thomas, and Michael Melgar
How the Process Works

1. Cleaning chamber purged of air
2. Liquid CO\textsubscript{2} pumped into cleaning chamber
3. Wash – liquid is recirculated
4. Distillation – residual body oils, detergent, other soils are captured for disposal
5. Clean liquid moved back to storage and ready for next cycle
Liquid CO$_2$ Cleaning Process

Benefits

- CO$_2$ is recycled, recaptured, and reused
- No water, no hazardous chemicals, no secondary waste stream
- Particulates/organic wastes are captured and recycled
- Clothing comes out clean and dry
- Increased garment life
- 20 minute cycle times
- High throughput (100-300 lbs/hour)
- CO$_2$ is non-toxic; non-hazardous; non-flammable; cheap & inexhaustible
Liquid CO₂ Cleaning Process

Processing advantages

- Continuous filtration throughout washing cycle
- High penetration capacity into textile
- Less abrasive = Increased Fabric/Garment life
- Clothing comes out clean and dry
- No Shrinkage / No Color Bleeding

Cleans a wide variety of fabrics

- Kevlar
- Oil rags
- Wool / Uniforms
- Fabrics with Special Coatings / Treatments
### Savings vs. Incumbent Water-based System

#### Process Consumption

<table>
<thead>
<tr>
<th></th>
<th>Water-based system</th>
<th>CO2-based system</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>4M gallons</td>
<td>0 gallons</td>
<td>100%</td>
</tr>
<tr>
<td>Energy</td>
<td>4000 GJ</td>
<td>1800 GJ</td>
<td>55%</td>
</tr>
<tr>
<td>Chemicals</td>
<td>30,000 lbs (disposed in municipal water system)</td>
<td>9000 lbs</td>
<td>70%</td>
</tr>
<tr>
<td>Garment Life</td>
<td>50+ cycles</td>
<td>2-3 x longer life</td>
<td></td>
</tr>
</tbody>
</table>

© E Source: Data from CO2Nexus, Inc

Based on 1.2 million lbs of garments throughput /year
Current CA Energy Commission Pier Project: Garment Cleaning for Cleanrooms

Cleanroom requirements

- Cleanrooms classified based on particles in the air
- Static-charge control is critical
- Minimal biological contamination

CO$_2$ system advantages versus a water-based system

- 60 percent fewer particles
- Reduces static buildup
- 25 percent less bio-burden

Current field testing

- Aramark Cleaning Services in LA
- Testing to be completed March 2014
Gas Condensing Unit Heaters
Gas Condensing Unit Heaters

- **Applications**
  - Warehouses
  - Industrial facilities
  - School/government garages
  - Greenhouses

- **Benefits**
  - Energy efficient
  - Easy to install (no ductwork)
  - Durable in corrosive environments

- **Drawbacks**
  - Requires a condensate drain and noncorrosive venting
# Unit Heater Efficiency

<table>
<thead>
<tr>
<th>Heater type</th>
<th>Thermal efficiency (%)</th>
<th>Seasonal efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity vented</td>
<td>80</td>
<td>65</td>
</tr>
<tr>
<td>Power vented</td>
<td>80</td>
<td>78</td>
</tr>
<tr>
<td>Condensing</td>
<td>91 to 93</td>
<td>~91</td>
</tr>
</tbody>
</table>

© E Source; data from Focus on Energy
## Unit Heater Economics

### Simple payback period example

<table>
<thead>
<tr>
<th>Building type</th>
<th>MBh required</th>
<th>Condensing unit heater incremental additional cost</th>
<th>Annual natural gas savings (therms)</th>
<th>Annual energy cost savings</th>
<th>Simple payback period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto garage</td>
<td>(2) 241</td>
<td>$7,200</td>
<td>2,772</td>
<td>$3,049</td>
<td>2.4</td>
</tr>
<tr>
<td>Warehouse</td>
<td>109</td>
<td>$2,850</td>
<td>698</td>
<td>$768</td>
<td>3.7</td>
</tr>
<tr>
<td>Greenhouse</td>
<td>260</td>
<td>$3,600</td>
<td>1,386</td>
<td>$1,524</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Note: MBh = thousand Btu per hour.

© E Source; data from Focus on Energy
For More Information

- **Modine** Effinity 93 High Efficiency Natural Gas-Fired Unit Heaters

- **Reznor** Ultra High Efficiency Condensing Gas Fires Unit Heaters
Here are a Potpourri of Other Technologies
Ultrasonic Leak Detectors

- Compressed air system leaks waste 20% to 30% energy
- Use acoustic sensors to detect sounds in the ultrasonic frequency range and can identify & locate leaks
- Portable and easy to use
- Cost $1,000 to over $15,000
- Payback typically measured in weeks

<table>
<thead>
<tr>
<th>Facility</th>
<th>Annual energy savings (kilowatt-hours)</th>
<th>Annual dollar savings ($)</th>
<th>Simple payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rochelle Foods</td>
<td>308,602</td>
<td>22,951</td>
<td>0.40</td>
</tr>
<tr>
<td>Chrysler Transmission Plant</td>
<td>227,483</td>
<td>17,737</td>
<td>0.60</td>
</tr>
<tr>
<td>Southern Clay Products</td>
<td>170,745</td>
<td>11,952</td>
<td>0.80</td>
</tr>
<tr>
<td>Superior Graphite</td>
<td>155,804</td>
<td>7,728</td>
<td>0.97</td>
</tr>
</tbody>
</table>

© E Source; data from the U.S. Department of Energy
Electrochromic Windows

Before

After

Source: Sage Electrochromics
A Problem Solver but not a Great Energy Efficiency Measure

Colorado State University Morgan Library

Source: glassmagazine.com

Kimmel Center for the Performing Arts in Philadelphia

Source: sageglass.com

W Hotel in San Francisco

Source: forbes.com
Wireless Charging: Convenience at the Expense of Energy Consumption

- No wires = useful for charging consumer electronics
  - Electric toothbrushes
  - Smart phones
  - Tablets
- BUT typical transmission efficiency is only ~70%
- For comparable performance, input power must be increased by almost 1.5 times compared to a wired system!

Image courtesy: LGEPRI, via Wikimedia Commons
Beware Wireless EV Charging

- Bosch and others are touting wireless electric vehicle charging systems
- Is the convenience really worth it?
  - Upfront costs of ~$3,000
  - Significant increase in power draw—at 7 kW for a normal Level 2 charger, this is a big deal
- EV owners should know what they’re getting into
Liquid Submersion Cooling for Computers

- Liquid submersion cooling for data center servers from Green Revolution Cooling
- Liquid similar to mineral oil. Pump circulates the hot oil to either a coolant-to-water heat exchangers or an air radiator system
- 10%-20% reduction in server power use
- 90%-95% reduction in cooling energy use
Have a Gas Cooktop? Consider a Turbo Pot!

The problem
![Image of a gas cooktop with flames]

The solution
![Image of a Turbo Pot with improved heat transfer]

- A pot with fins
  - More heating surface area
  - Better heat-transfer efficiency
  - And, it boils water faster!
- Can increase cooktop efficiency by 49% to 80%

Images courtesy Eneron Inc.
Next Generation Demand-Controlled Ventilation (DCV) in Commercial Kitchens

- Saves 40% to 70% on hood fan energy
- Saves an additional 15% to 40% in building HVAC losses
- Unobtrusive design
- Less fan noise
- Decreased fire risk
- No sacrifice to indoor air quality

Sources: Melink, PG&E Food Service Technology Center
Drain Water Heat Recovery

Energy savings: 30% to 50% per shower

Doubles the first-hour rating of water heater

**No** moving parts

Use in homes, motels/hotels, dormitories, health clubs

Payback: 2 to 6.5 years in new Construction

Retrofits also possible
Thermal: The Other On-Site Storage

- Lightweight construction reduces thermal mass
  - Increases heat transfer
  - Heating/cooling loads go up

- Thermal storage options
  - Phase-change material
  - Water or ice storage
  - Seasonal thermal storage

- What’s holding it back?
  - Industry standards
  - Cost and performance
  - Invisible; lacks “sexiness”

Source: Wikimedia Commons
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