Non-Residential Energy Efficiency Measures

Introduction

There are a number of cost-effective energy saving technologies, design strategies, construction methods and operational techniques to optimize the energy efficiency of non-residential buildings. For new construction in particular, there is a unique opportunity to incorporate *integrated* design strategies among multiple building systems for maximum overall building efficiency and operating cost reductions.

One of the most important reasons for lower energy use in California buildings over the last 25 years is a result of the *Energy Efficiency Standards* for Residential and Nonresidential Buildings that were established in 1978 in response to a legislative mandate to reduce California's energy consumption. California's Building and Appliance Efficiency Standards have saved more than $20 billion in electricity and natural gas costs over this period. Moreover, it is estimated that the Standards will save $57 billion by 2011[i].

A typical commercial office building in California has a number of distinct end-use energy loads. For example, from highest to lowest energy consumption per square foot this equates to[ii]:

- Indoor Lighting: 33%
- Cooling: 18%
- Miscellaneous Equipment: 17%
- Outdoor Air Ventilation: 10%
- Heating: 10%
- Outdoor Lighting: 6%
- Office Equipment: 3%
- Water Heating: 1%
- Cooking: 1%
- Refrigeration: 1%

Energy Solutions for Businesses

There are several building systems and components common to most commercial facilities that can be investigated for energy efficiency potential:

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[i] http://www.energy.ca.gov/title24/

[ii] Calculated as a combination of a simple average of kWh/sf from the Small Office and Large Office occupancy values from the "California Energy Demand, 2000-2010" report, California Energy Commission, Publication #200-00-002, July 14, 2000.

Building Envelope

The building envelope includes everything that separates the interior of a building from the outdoor environment, including the windows, walls, foundation, ceiling, roof, and insulation. Some specific envelope measures include:

1. Cool Roof: A *light-colored roof membrane or coating* that typically lowers roof surface temperatures by 30-50 degrees Fahrenheit, cooling costs by 20-40%, increases roof life and enhances occupant comfort by using roof materials with a roof reflectance of 65% or more and an emissivity of 80% or more[iii]. *Light-colored walls* also have a lower absorptivity and admit less solar gain to the inside space.

2. Fenestration: *High performance* windows, window walls, structural glazing, glazed doors, atriums and skylights reduce heating and cooling energy costs; improve occupant comfort and enable greater utilization of floor areas on perimeter zones; enhance worker productivity, noise control, and condensation resistance; reduce health patient's recovery times, raise student performance and retail product sales; minimize fading of interior furnishings; and increase the resale value of a property. *Spectrally-selective glazings* use a low-emissivity coating to minimize ultraviolet transmission, maximize the visible light admitted, and reduce solar heat gain in the summer and heat loss in the winter. This type of glazing typically lowers solar gain and heat loss by 25-45% with only a 10-15% reduction in visible light transmission – and tinted glass or reflective coatings can also be used[iv].

3. Shading: *Exterior shading systems* such as overhangs, fins, awnings and operable, louvers, shutters, awnings or weave screens block the solar gain before it enters the fenestration assembly, while *integral and interior shading systems* are secondary options for solar gain, glare and heat loss control. Such shading control can lower the space temperature in spaces adjacent to windows by as much as 20 degrees Fahrenheit on a hot day[v].

4. Insulation: Envelope insulation has a thermal value optimized for the microclimate zone of the facility and encapsulates the entire occupied space that is air-conditioned – either by entirely filling the cavity between the structural system or through the use of an *exterior-applied insulation system* that also reduces air leakage. Stud framing can be omitted entirely with *Structural Insulated Panels* comprised of a foam-core sandwich panel, and have been shown to save 10-15% more in the winter than conventional wood framing assemblies[vi], and as much as 15 times less air leakage in one study[vii]. Finally, the addition of a *radiant barrier*

[iii] Performance values per: http://www.sdenergy.org/docs/CoolRoofPROGRAMGUIDELINESRevisedApril2002.pdf

[iv] Performance values calculated per representative comparison of 1" nominal Guardian Dual-Pane Clear with 1" nominal Cardinal LoE2-172 Clear

[v] http://www.energyloans.org/EnergyReference/body_awnings.html

[vi] http://www.eren.doe.gov/consumerinfo/refbriefs/bd1.html

[vii] http://www.sipweb.com/about/benefits.asp and "New Oak Ridge Tests Verify SIP Performance Advantage" at http://www.sips.org/

under the roof can lower the heat gain another 10-15% by blocking 95-97% of the radiated energy from the roof[viii].

Landscaping

By strategically placing *vegetation and trees* immediately adjacent to the building envelope, incoming solar heat gain and glare through fenestration is reduced and cold prevailing winds are obstructed, thereby lowering cooling and heating costs while improving occupant comfort. This practice in conjunction with *light colored hardscape* elements and Cool Roof materials also reduces the "Urban Heat Island Effect" that raises the overall average air temperature of the region.

Lighting

Lighting accounts for 29% of all commercial energy use in California[ix]. Indoor and outdoor lighting fixtures need to be designed in a manner appropriate to the task to prevent illumination levels higher than necessary at any time throughout the day. Efficient indoor lighting systems also reduce heat gain to the space that in turn lowers air conditioning costs. Some specific areas include:

1. Lamps: *High efficacy lamps* offer the highest lumens per watt efficiency possible. For example, *Halogen Infrared Reflecting lamps* have an efficacy improvement of 40% over standard halogen lamps – thereby reducing electrical consumption by a corresponding amount[x]. Exit signs alone cost American businesses more than $1 billion annually, but newer *LED exit signs* use less than one-tenth the energy of an incandescent exit sign, yet have 10,000-30,000 hours of additional life[xi].

2. Ballasts: Ballasts are an essential part of fluorescent, low-pressure sodium and high-intensity discharge lamps – transforming standard voltages into the voltage needed for the lamp. *Electronic ballasts* have the highest efficiencies, and the highest available *Ballast Efficacy Factor (BEF)* possible should be selected[xii], while also selecting lower *Ballast Factors (BF)* as appropriate for each unique application[xiii].

3. Fixtures: An efficient light fixture can be determined by looking at its photometric qualities in order to maximize the amount of lumens exiting the fixture to the area requiring illumination, expressed as its *Luminaire Efficacy Rating (LER)*. The primary method of controlling light from a bare light source via a light fixture is through reflection, transmission and refraction. Secondary design methods include balancing polarization, interference and absorption[xiv]. Using *specular reflectors* makes it possible to remove one-third to one-half the existing fluorescent tubes with no reduction in light levels, decreasing lighting costs by 30-50%.

[viii] http://www.eren.doe.gov/consumerinfo/refbriefs/bc7.html
[ix] http://www.energy.ca.gov/title24/nonresidential_manual/05_Lighting_Systems.pdf
[x] http://www.p2000.umich.edu/energy_conservation/ec1.htm
[xi] Guide to Energy-Efficient Commercial Equipment, ACEEE, page 2-16
[xii] http://www.eren.doe.gov/femp/procurement/pdfs/ballast.pdf
[xiii] http://www.lightsearch.com/resources/lightguides/ballasts.html
[xiv] http://www.lightsearch.com/resources/lightguides/optics.html

4. Controls: Interior *automated lighting controls* typically save 20-40% through the use of *photosensors* to tune the electric lights in response to available daylight from adjacent fenestration systems in the building envelope, *programmable dimming* of the lights for changes in visual tasks, or *occupancy sensors* to turn off the lights when spaces are unoccupied[xv]. Interior lights with *scheduled timeclock control*, and exterior lights with photosensors in conjunction with timeclock control also reduce unnecessary hours of lighting electricity use.

Mechanical

Low energy-consuming mechanical heating and cooling systems are possible through the use of thoughtful building envelope design, siting and orientation, followed by: high efficiency equipment, automated controls, intelligent ventilation, improved duct systems, and various advanced technologies. In addition, energy-efficient domestic water heating combined with water-efficient appliances and fixtures will save water, energy, and money.

1. Primary Heating Systems: Should be properly zoned, sized and installed. Smaller furnaces, heaters and air-source heat pumps should meet or exceed California's *Appliance Efficiency Standards*[xvi]; while packaged terminal heat pumps, water source heat pumps, boilers and larger furnaces should meet or exceed California's *Building Energy Efficiency Standards*[xvii]. *Sequence* multiple pieces of equipment to come on in stages according to heating load demands. Reclaim furnace and boiler exhaust flue waste heat as well as excess heat from computer data centers with *heat recovery systems* for combustion air, domestic hot water or space heating preheat. Also use *ceiling fans* to reduce stratification and increase task-level space temperatures without increasing the thermostat setting.

2. Primary Cooling Systems: Should be properly zoned, sized and installed. Smaller air conditioners and air-source heat pumps should meet or exceed California's *Appliance Efficiency Standards*; while packaged terminal heat pumps, water source heat pumps, chillers, cooling towers and air cooled condensers should meet or exceed California's *Building Energy Efficiency Standards*. Also utilize *evaporative cooling systems* in lieu of compressor-based refrigerant air conditioning systems wherever possible. Other central plant measures also include *variable speed drives* on the cooling tower fans and pumps, as well as chillers in conjunction with *condenser water temperature reset*. Design for *high differentials* (or "Delta T") between chilled water supply and return temperatures to maximize chiller and chilled water pumping energy savings. *Sequence* multiple pieces of equipment to come on in stages according to cooling load demands. *Reclaim* chiller waste heat with double-bundle condensers or heat off the hot refrigerant gas lines of air-cooled condensers for use in domestic hot water systems or terminal zone reheat loads. Also use *ceiling fans* to reduce stratification and decrease task-level space temperatures without decreasing the thermostat setting.

[xv] http://www.energy.ca.gov/title24/nonresidential_manual/05_Lighting_Systems.pdf, Table 5-10
[xvi] http://www.energy.ca.gov/efficiency/appliances/index.html
[xvii] http://www.energy.ca.gov/title24/standards/index.html

3. Distribution Systems: Consist of supply and return fans required to deliver cooled or heated air throughout the building. Use *variable air volume systems* for spaces with varying space loads, *maximize airflow efficiency* with proper fan selection and duct design principles, and *avoid simultaneous heating and cooling system* designs. Ensure that *air cleaners are cleaned or replaced regularly* – as excess loading on the filter raises the static pressure and decreases their filtration effectiveness, therefore increasing fan energy. Also incorporate *low static pressure air filters* for ongoing energy savings. For additional energy savings, consider chilled water *radiant cooling systems* commonly located in ceiling tiles, or *modular raised floor systems* for underfloor air distribution.

4. Ventilation: These systems provide fresh, outside air to a conditioned space.

    - *Night Ventilation* utilizes cool air to flush the space in the evening hours, reducing the air conditioning load on the system when it starts in the morning.

    - *Demand Controlled Ventilation (or "DCV")* is a concept in which the amount of outdoor air used to purge one or more offending pollutants from a building is a function of the measured level of the pollutant(s). DCV reduces energy use since outdoor air is now provided *proportional* to the amount of people or pollutants in the establishment – instead of at a fixed rate over the time the HVAC system is scheduled to operate. Annual electricity savings are on the order of 10-15%, while gas energy savings (assuming gas-fired heating equipment) are typically 60-90% for intermittent use spaces.

    - *Dedicated Outdoor Air Systems (DOAS)* condition the outdoor ventilation make-up air separately from the return air coming from the conditioned space, and have been shown to save 10-20% over conventional systems[xviii].

    - Use *ventilation air heat recovery* through the use of air-to-air heat exchangers. These systems preheat the colder incoming winter ventilation air with the outgoing warmer air exiting the air handling system – lowering heating costs; likewise, they precool the warmer incoming summer air with the outgoing cooler air exiting the air handling system – lowering cooling costs.

    - Parking garage ventilation fans can also take advantage of *Carbon Monoxide Sensing Systems* as an indicator of vehicle exhaust levels to save fan energy by removing exhaust-contaminated air only as necessary, instead of continuously.

5. Economizing: use *integrated air economizers* to normally utilize 100% incoming outside air, but can also simultaneously utilize a refrigerant compressor and outside air mix at lower percentages of outside air to cool the air in the most efficient manner. Likewise, use *water-side economizers* for direct or indirect cooling with chilled water systems when cost-effective. Also consider *natural ventilation* through the use of operable windows when combined with appropriate HVAC controls.

[xviii] Energy Consumption Characteristics of Commercial Building HVAC Systems Volume III: Energy Savings Potential, Building Technologies Program, *July, 2002, Sec. 4.2*

6. Control Systems: turn off equipment when unoccupied or no longer necessary; utilize occupancy controls on intermittent use spaces, such as meeting rooms and assembly areas, restrooms, storage areas and small offices; and provide other additional monitoring and control capabilities. *Variable speed drives* allow motors with varying loads to significantly reduce energy usage by matching their speed to the *actual* building load – common to air conditioning systems that are at part load a majority of the time, thereby saving energy and extending equipment life. Variable pumping systems typically result in 20-50% savings over fixed speed pumps, and variable flow air systems commonly save even more. Use *electronic variable voltage motor controllers* for constant speed AC induction motors such as elevator motors with variable loads, offering reduced voltage start, improved power factor, and reduced operation costs of 10-40%[xix]. Utilize *Direct Digital Control (DDC)* systems with *electric actuators* instead of pneumatic air control for more precise control, lower energy costs, improved building operator productivity, increased occupant comfort, and lower overall equipment costs. *Energy Management Control Systems* or *"Building Automation Systems"* allow enhanced control in the form of nighttime temperature setback; multi-schedule on/off programming; optimal start and stop; chiller and boiler lockout settings; and seasonally adjusted chilled water, hot water and supply air temperature setpoints.

   Through the use of enhanced building automation systems in conjunction with *Energy Information Systems*, building managers are provided with an additional layer of information encompassing system-wide facility performance, energy use and utility pricing. These systems are an integral part of enabling participation in peak electrical *demand-responsiveness* activities to take advantage of lower utility rate periods, while saving kilowatt-hours in the process. These activities can include such actions as demand limiting, peak load shifting and scheduling, duty cycling, and load curtailment – whether to meet internal kilowatt demand goals, participate in dynamic pricing programs from electricity and fuel providers, or to respond to emergency calls for demand responsiveness actions[xx].

7. Motors: Motor-driven equipment accounts for 64% of the electricity consumed by U.S. industries. *Premium Efficiency motors* can cut this energy use by at least 12%[xxi]. Energy-efficient motors offer other benefits as well. Because they are constructed with improved manufacturing techniques and superior materials, energy-efficient motors usually have higher service factors, longer insulation and bearing lives, lower waste heat output, and less vibration – all of which increase reliability[xxii]. *Brushless DC motors* are well suited to small air handling systems and maintain their high efficiency over a wide speed range, and can provide continuous fan circulation at low speed with only modest energy consumption[xxiii]. They can also be powered directly by photovoltaic systems, which provide direct current output.

[xix] http://www.powerefficiencycorp.com/home/welcome.shtml

[xx] Enhanced Automation: Technical Options Guidebook, California Energy Commission, Publication No. 400-02-005f, Page 3

[xxi] http://www.eren.doe.gov/EE/industry.html

[xxii] http://www.oit.doe.gov/bestpractices/motors/factsheets/mc-0382.pdf

[xxiii] http://www.advancedbuildings.org/_frames/fr_t_motors_low_energy_elevators.htm

8. Water Heating: Use *high-efficiency* water heaters and boilers, *low-flow* fixtures and appliances, *sufficient insulation* on storage tanks and pipe runs, *demand controlled hot water circulation systems* for end uses that are at extended distances from the water heater, and *instantaneous or tankless water heaters* at the point-of-use to avoid piping and storage tank thermal losses.

9. Elevators: The most efficient elevators utilize a *gearless drive system with axial synchronous AC motors* that reduce energy consumption by up to 50% when compared to traction elevators and up to 75% when compared with hydraulic elevators. They also reduce operating costs; eliminate hydraulic fluid; reduce the size of wiring, switch gear and emergency generators; simplify the design and construction; and reduce noise levels[xxiv].

Electrical

1. Transformers: Most commercial and industrial transformers convert at least 95% of the electricity received into usable output power. Transformer power losses amount to about 2% of total US electricity generation or 61 billion kilowatt-hours of wasted electricity each year[xxv]. Since the transformers are in constant use, any improvement can lead to significant energy savings as well as reduced utility bills for building owners and occupants. Many utility distribution transformers now operate at efficiency levels exceeding 98%. Look for ENERGY STAR rated transformers that incorporate the highest available efficiencies.

2. Power Factor: Power factor measures how effectively electrical power is being used. A high power factor means that electrical power is being utilized effectively, while a low power factor indicates poor utilization of electrical power and payment for electricity you're not using. The simplest way to improve power factor is to add power factor correction capacitors to your plant distribution system[xxvi].

3. Investigate for Overheating: Loose connections, load imbalances, and corrosion cause hot spots in electrical systems – causing unnecessary energy losses as well as the risk of unplanned failures and fires. Infrared thermography is a very useful method of inspecting components such as motor control centers, breaker panels, disconnect switches, and transformers[xxvii]. The June 2001 issue of *Maintenance Technology* magazine reported a $4 return on investment in for every $1 spent on infrared inspection.

Office Equipment

Purchase ENERGY STAR office equipment and ensure that they are configured properly for maximum savings. For example, ENERGY STAR labeled copiers are equipped with a power management feature that automatically turns them off after a set period of inactivity,

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xxiv http://www.advancedbuildings.org/_frames/fr_t_motors_low_energy_elevators.htm

xxv http://yosemite1.epa.gov/estar/consumers.nsf/content/transformers_gateway_page.htm#what

xxvi http://www.comsprague.com/power2.htm

xxvii http://www.flirthermography.com/success/pdfs/pm_article.pdf and have been shown to reduce a copier's annual electricity costs by over 60%[xxviii]. Optionally, use occupancy controlled plug controllers that turn off equipment and task lighting after a set period of inactivity.

There are 2.5 million vending machines in the United States consuming approximately 7.5 billion kWh per year, costing American businesses nearly $600 million annually to power – with two-thirds of the energy going to cool the machine for those that are chilled[xxix]. Use occupancy sensors on chilled beverage and snack machines to achieve a mean annual savings per machine of about 46%[xxx]. Also add timers to chilled drinking water dispensers, and turn off any equipment that does not need to stay on after hours.

Data Centers

Newer blade servers and low-voltage dual processing have high CPU densities and energy efficient processors that offer high performance, simpler cabling, run cooler, and save space compared to standard servers and processors. For example, 20 blade servers can fit into a 3U space normally reserved for only 3 rack-mount servers, and each server uses less than 50 watts[xxxi].

Commissioning

Also called "Performance Verification," it is the application of targeted inspection checks, as well as functional and performance testing conducted to determine whether specific building components, equipment, systems, and interfaces between systems conform to the criteria set forth in the plans, specifications and/or building codes[xxxii]. In addition to helping reduce energy costs by ensuring the building performs to design intent, other benefits often valued even *higher* by building owners are provided by this post-construction process: such as improved occupant comfort and air quality, lower tenant turnover and reduced employee absenteeism.

Operation & Maintenance Optimization

Establish operations and maintenance protocols and conduct routine maintenance of all building systems. These protocols should include: regular filter changes; verifying that all belts, compressors, and dampers are operational; cleaning of cooling and condenser coils, fans, drains, and flues; calibrating controls; checking and adjusting fluid levels; and adjusting the fuel to air ratio of any gas or oil burning equipment[xxxiii]. Finally, conduct ongoing onsite performance measurements and utility bill analyses of energy consumption for pro-active energy management.

[xxviii] http://yosemite1.epa.gov/estar/consumers.nsf/content/copier.htm#Copier
[xxix] Guide to Energy-Efficient Commercial Equipment, ACEEE, page 5-13
[xxx] http://www.bayviewtech.com/html/vendingmiser_savings_informati.html
[xxxi] http://www.polywell.com/us/rackservers/poly3u20.asp
[xxxii] http://www.cacx.org/projects/documents/NQRAREPORT.PDF
[xxxiii] Guide to Energy-Efficient Commercial Equipment, ACEEE, page 3-34

Self Generation

For buildings that are already designed with energy efficient features, the strategy of "self-generation" should be considered.

"Self-generation" refers to clean, distributed generation technologies such as microturbines, small gas turbines, wind turbines, photovoltaics, fuel cells, internal combustion engines and combined heat and power systems that are installed on the customer's side of the utility meter to provide electricity for a part or all of a customer's electric load. This offsets the energy consumed from traditional utility sources, thereby reducing net operating costs and offering additional flexibility. Several cost-effective technology options exist for small-scale power generation:

1. Microturbines: Microturbines are a new class of small gas turbines used for distributed generation of electricity. They are compact in size, have low emissions and therefore exempt from air-pollution permit requirements, are very reliable and have low maintenance costs.

2. Small Gas Turbines: These larger systems are typically less than 1.5 MW in size, and have additional control requirements to address air pollutants.

3. Wind Turbines: Wind turbine technology captures the wind energy in order to turn a generator that in turn produces electricity, and is a very cost effective way to generate electricity in areas with a reliable wind source.

4. Photovoltaics: PV systems take advantage of the "photovoltaic effect" by converting the sun's energy directly into electricity by these solar cells. PV is a viable and increasingly attractive method of generating power.

5. Fuel Cells: Fuel cells are energy conversion devices that continuously transform the chemical energy of a fuel and an oxidant into electrical energy, with a by-product of waste heat and potable water. Due to their very low air emissions, fuel cells are typically exempt from air pollution control permit requirements – resulting in thousands of dollars saved annually in air permit fees and emission source test costs.

6. Internal Combustion Engines: Reciprocating internal combustion (IC) engines are reliable, efficient and inexpensive self-generation technologies that are relatively easy to install, operate, and maintain. The two primary types of IC engines used for Combined Heat and Power applications are four cycle-spark-ignited engines (Otto cycle) and compression-ignited (diesel cycle) engines.

7. Combined Heat and Power (CHP): For buildings with heating or cooling needs, a "CHP" system may be the best option. With these systems, waste heat from the power generation process is used to create hot water or steam – which can then be used for building heat. Through a device known as an absorption chiller, hot water can also be used to make chilled water for building cooling. Reuse of waste heat can increase system efficiencies from 30% to 80% or higher…ensuring the best use

of precious natural gas resources. Fuel cells, microturbines, and internal combustion engines are typically used in combined heat & power systems.

Conclusion

With thoughtful consideration regarding the energy impacts of design and equipment decisions, many benefits are possible. Enhanced automation technologies and efficient systems reduce operating costs, lower environmental impacts, increase occupant comfort and well-being, provide additional information on building conditions for better control and decision-making, increase flexibility in building operations, and enhance property values.

Next Steps

To learn more about how to ensure that the highest efficiency goals for your facilities are met, tap into the numerous resources available to you from the *San Diego Regional Energy Office*. Don't let these opportunities pass you by, act today!

Stephen L. Kapp, CEM
Energy Engineer
San Diego Regional Energy Office
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