Opportunities to Save Energy Now with Intelligent Industrial Buildings

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ABSTRACT

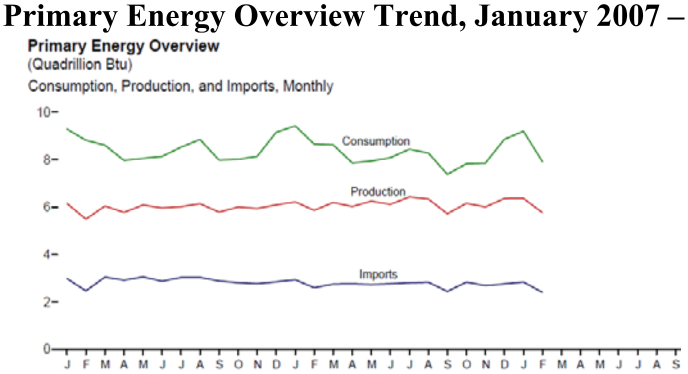
In September 2005, in response to extensive energy infrastructure damage by Hurricane Katrina, the Secretary of Energy initiated a multi-sector plan to reduce energy consumption on a national scale. In the industrial sector, "Save Energy Now" provides an integrated approach to reduce energy consumption. This effort was initially focused on steam and process heating assessments, training, technical assistance, and subsequent implementation tracking. One area, which has not been addressed in these large facilities, is building systems including HVAC, lighting, and building envelope. As a matter of course, these systems are addressed by DOE's Industrial Assessment Centers, (IAC) however, these are primarily for small- and medium-sized establishments (SME). On average, buildings systems represent 5% of industrial energy consumption or 2.1 Quadrillion BTU industry-wide including electrical system losses (DOE 2002). This is roughly equivalent to all energy consumed by the U.S. Food Processing industry (NAICS 311).

Drawing from past and current experience, this paper will attempt to identify, categorize and rank industrial buildings related types of technologies and best practices such as HVAC, lighting, and building envelope insulation and rate their relative applicability to U.S. industry. This paper will highlight a few Industrial Technologies Program (ITP) sponsored technologies that could reduce "building" (HVAC and lighting) energy use in industrial facilities, which is an important but often overlooked component of industrial energy use. The IAC database is used to illustrate the often-untapped potential for industrial buildings energy savings, and to illustrate the magnitude of energy savings and cost-effectiveness of generic strategies.

Introduction

Despite the current economic situation, according to the EIA Monthly Energy Review as of February 2009, U.S. estimated primary energy consumption continues to outpace U.S. energy production.

Figure 1. U.S. Primary Energy Overview Trend, January 2007 – February 2009



Source: U.S. DOE, EIA, Monthly Energy Review, March 2009.

The current economic downturn is seriously affecting the U.S. manufacturing sector, particularly those sub-sectors producing durable goods, (DOC 2009) and their supply chains and the delivery chains. To add to these difficulties, energy security concerns remain and are slowly being addressed by the energy industry, based on lessons learned from the August 2005 Hurricanes and the August 2003 blackout (DOE 2003). Even so, cost-effective opportunities exist for companies to improve their local energy security such as distributed energy production including CHP (Shipley, Hampson, Hedman, Garland, & Bautista 2008) and renewable energy. Several site-based CHP systems operated throughout the 2003 blackout (Carlson, Hedman 2004).

In addition to upward energy price trends and energy price spikes, global energy consumption- and emission-trends in China, India and the rest of the developing world have encouraged governments (ISO 2009) and corporations (U.S. Council for Energy-Efficient Manufacturing 2009) to take new actions to reduce total energy consumption in the near- and long-term. China recently passed the U.S. as the world's largest emitter (McKinsey 2009).

Energy efficiency is an important industrial cost control tool, and a low cost opportunity according to McKinsey & Company analyses regarding a number of low cost carbon reduction opportunities (McKinsey 2007). While some industrial companies have postponed efficiency investments due to economic uncertainty, related limited capital availability or uncertainty regarding cap-and-trade legislation, other companies have strategically continued to make sustainable energy and other investments. Smart investments (Winston 2009) will make their corporations much stronger competitors at the end of the recession.

Similar to the recycling hierarchy of "Reduce, Reuse, Recycle" there is a logical hierarchy in the industrial energy landscape. This hierarchy includes a corporate energy management policy, energy management standards (ISO 2009), process efficiency, non-process efficiency, combined heat and power, and renewable energy. Typically, process efficiency offers greater energy savings, however usually resulting in a temporary loss of accounts receivables, whereas many buildings technologies can be installed during normal operations, providing opportunities to Save Energy Now.

Industrial Statistics

The U.S. industrial sector accounts for approximately 30% (DOE/EIA 2008) of total U.S. energy consumption. Roughly 80% of that consumption is process-related, including process heating and steam systems. The remaining 20% represents largely electricity consuming equipment, including motor driven systems such as pumps, fans, compressed air systems, as well as buildings systems such as heating ventilating and air-conditioning (HVAC) systems (often including fuel-based energy consumption) as well as motors and lighting.

EIA data includes combined heat and power (CHP) generation in the non-process energy consumption section of the Manufacturing Energy Consumption Survey (MECS). The following industrial buildings consumption data however, does not include CHP consumption or on-site transportation, rather only HVAC, lighting and the additional EIA category "facility support". Hereafter industrial buildings energy consumption will refer to this grouping of consumption categories.

In 2002, U.S. industrial buildings used an estimated 2 Quadrillion BTU (S) (DOE 2002) (including electric transmission and distribution losses but excluded mining) - more than the entire U.S. Food Processing industry (NAICS 311). The energy used annually by U.S. industrial buildings costs industry about $12 billion and is equivalent to the energy used in 34 million passenger cars or in 11 million homes. According to rough estimates based on EIA and IEA data, international industrial buildings may consume between 6 and 7 Quadrillion BTU/yr[1]. While industrial buildings on average consume about 5% (DOE 2002) (HVAC, Lighting, etc.) of total industrial consumption, several industrial sub-sectors' industrial buildings consume a greater percentage. The following table identifies these sub-sectors. Percentages shown include losses in the generation, transmission and distribution of electricity hereafter identified as Source Consumption and identified with an (S) in parentheses.

Table 1. Industrial Buildings Energy Consumption
Source: U.S. DOE/EIA Manufacturing Energy Consumption Survey 2002

NAICS	*Industrial Sub-sector*	*Number of Facilities*	*Industrial Buildings Consumption (TBtu, S)*	*Industrial Buildings (Avg. Million Btu (S) / Facility)*	*Total Sub-Sector Consumption - Excludes Non-Fuel Feedstocks (TBtu,S)*	*Buildings Consumption as a % of Total Sub-Sector Consumption Excluding Feedstocks (%S,S)*
334	Computer and Electronic	9,238	212	22,949	462	**45.9**
333	Machinery	17,381	121	6,962	343	**35.3**
336	Transportation Equipment	7,653	260	33,974	768	**33.9**
323	Printing and Related	20,220	65	3,215	198	**32.8**
335	Electrical Equip., Appl.	3,886	64	16,469	197	**32.5**
332	Fabricated Metal Products	35,349	151	4,272	709	**21.3**
326	Plastics and Rubber	10,538	138	13,095	710	**19.4**
3315	Foundries	1,715	45	26,239	265	**17.0**
313	Textile Mills	2,247	63	28,037	377	**16.7**

Most of the above sub-sectors are considered non-energy intensive.

[1] EIA, World Total Primary Energy Consumption, 2006 of 472 Quadrillion BTU/yr, OECD/IEA, 2007 from *Tracking Industrial Energy Efficiency and CO2 Emissions*, – "Nearly a third of the world's energy consumption …are attributable to manufacturing industries."), U.S. DOE/EIA–MECS - Industrial buildings consumption as percent of Total Industrial consumption is 5% or 0.05. Therefore, 472 QBtu/yr * 0.3 * 0.05 = approximately 7 Quadrillion BTU/yr.

Table 1 (Continued). Industrial Buildings Energy Consumption Source: U.S. DOE/EIA Manufacturing Energy Consumption Survey 2002						
Plants in the following sub-sectors are more commonly included in DOE's large energy consuming assessments, (manufacturing plants with greater than 0.3 Trillion BTU/year consumption). These sub-sectors typically include plants that are energy intensive.						
NAICS	*Industrial Sub-sector*	*Number of Facilities*	*Industrial Buildings Consumption (TBtu, S)*	*Industrial Buildings (Avg. Million Btu (S) / Facility)*	*Total Sub-Sector Consumption - Excludes Non-Fuel Feedstocks (TBtu,S)*	*Buildings Consumption as a % of Total Sub-Sector Consumption Excluding Feedstocks (%S,S)*
311	Food	15,089	145	9,610	1,576	**9.2**
327	Nonmetallic Mineral	11,593	83	7,159	1,334	**6.2**
325	Chemicals	8,909	273	30,643	4,813	**5.7**
331	Primary Metals	4,166	164	39,366	3,109	**5.3**
322	Paper	4,257	126	29,598	2,807	**4.5**

While several U.S. industrial sub-sectors' facilities consumption fall below 10% of sub-sector consumption (found in the right hand column of Table 1), some of these same plants may find buildings-related potential energy savings attractive. Industrial companies largely operate on thin economic margins in commodity markets. As a result, these companies are very cautious to avoid reductions in production during the installation of any technologies.

Many of the technologies discussed improve one of more of the following: plant productivity, energy security, or resilience to energy disruptions. Plant productivity (Esty, Winston 2009) will typically be enhanced by reduced errors from improved lighting quality (Romm 1999), or improved worker comfort, or reduced sick leave days from improved air quality.

Efficiency consumption patterns in processes and buildings may highlight cost-effective, synergistic energy opportunities in waste energy recovery or combined heat and power as identified bellow. More than two-thirds of the fuel used to generate power in the U.S. is lost as heat (Shipley, Hampson, Hedman, Garland, & Bautista 2008). Much energy is also lost prior and during industrial processing (Energetics, E3M 2004). Specific savings opportunities can be verified with newly- commercialized secure, industrial, wireless mesh networks (DOE Wireless 2008). This suite of technologies can identify the exact quantity and opportunity of the local process and non-process energy savings opportunities.

Industrial facilities present a unique opportunity to save energy by recovering energy and/or water from industrial processes. Waste heat from processing and/or combined heat and power systems could- and in some cases are used to power, cool, heat, and dehumidify industrial buildings. Energy savings reduce the peak load on natural gas, oil, coal, electric, or water systems thus increasing energy-security and improving the reliability of manufacturing systems.

Table 2. Industrial Sub-Sectors With High Facilities Consumption and Potential for WHR or CHP Source: U.S. DOE/EIA Manufacturing Energy Consumption Survey 2002			
Sub-Sector Buildings(S) consumption as a percent of Sub-Sector Total Consumption(S)	*Sub-Sectors*	*Good Candidate for Waste Heat Recovery (WHR) to Building Heating (or Cooling) Load*	*Good Candidate for Combined Heat and Power (CHP) (and/or Cooling/ Dehumidification)*
40+%	Computer, Electronic Products	WHR – due to Process Heating	CHP - due to temperature / humidity requirements
30+%	Machinery; Transportation Equipment; Printing; Pharmaceutical;	WHR – due to Process Heating	CHP - similar to above or coating systems air exhaust requirements
	Electrical Equip., Appliances and Component; Apparel; Leather	-	Some limited instances will be CHP candidates
20+%	Fabricated Metal	WHR – due to Process Heating	CHP - due to coating systems air exhaust requirements
5+%	Plastics and Rubber Products; Textile/ Product Mills; Beverage/Tobacco; Chemicals; Food;Foundries	WHR – due to Process Heating	CHP – due to consistent and large process- thermal and electric loads

The Industrial Assessment Center Program

The large energy-consuming industrial plant assessments (≥ 0.3 Trillion BTU/yr) conducted as part of DOE's Save Energy Now since 2006 and the prior activity known as Plant Wide Assessments or Targeted Assessments neither included buildings energy savings opportunities, or only did so on a minimal basis.

The Industrial Assessment Center (IAC) program, in contrast, has always conducted integrated assessments including buildings and grounds energy consumption in addition to process energy consumption. The IAC program began operation as the Energy Analysis and Diagnostic Centers program under the Department of Commerce prior to the creation of the U.S, Department of Energy (DOE). DOE subsequently added waste minimization and productivity. IAC Program has been providing energy assessments to the private sector since the late 1970s and has conducted more than 14,000 assessments. Since 2007, the IACs have conducted an increasing quantity of larger energy consuming plants (plants which consume $2+ Million dollars/year in energy). Although energy consumption patterns for small and large manufacturing plants are vastly different, the data presented is still indicative of the types of opportunities that most manufacturing plants experience. Therefore, this paper endeavors to use the IAC data to show intelligent industrial buildings opportunities for the entire U.S. industrial base.

A number of energy experts have said that any expenditure in energy should provide additional energy security (Woolsey 2009) not less energy security (Lovins 2001). Therefore, energy security is just as important to the nation and to industrial companies as energy efficiency.

IAC Assessment Data

The IAC program maintains a useful database (http://iac.rutgers.edu) of recommendations and implementations throughout the history of the program. The data is for all U.S. Industry from NAICS 311 - Food Manufacturing through 339 - Miscellaneous Manufacturing (Rutgers NAICS 2009). As of May 27, 2009, the IAC database contains 14,246 Assessments and 106,240 Recommendations (Rutgers IAC Database 2009). This database includes an easily accessible "Recommendations index" that shows implementation and payback data grouped both by categories of recommendations, and by specific recommendations. Upon entering that system and selecting Energy Management, and then Building and Grounds the following categories are presented:

Table 3. IAC Database - Recommendation Index for Buildings

Source: http://www.iac.rutgers.edu/database, Extracted 04-14-2009.

Assessment Recommendation Code (ARC)	*Description*	*Times Recom-mended*	*Average Savings*	*Average Payback (Years)*	*Implementation %*
2.71xx	Lighting	21,167	$4,559	1.6	47.62%
2.72xx	Space Conditioning	5,657	$8,310	1.3	42.86%
2.73xx	Ventilation	572	$9,601	0.9	45.34%
2.74xx	Building Envelope	2,383	$6,609	1.7	44.71%

The IAC centers collect these data by calling the assessed plants to determine implementation and savings experiences and submitting the data to Rutgers University, which maintains the data. This paper includes samples of this average data for various sections including HVAC and Lighting. The database may eventually be normalized to a specific economic year and energy price but at present it is based on various energy prices, for the larger part based on energy price prior to the high prices that occurred in the U.S. after Hurricanes Katrina and Rita.. Therefore, the data is primarily of a conservative nature due to the higher trend of energy prices generally found in these energy-constricted and carbon-constrained days.

I will begin with the category of Ventilation since as you can see from the IAC database table above, that this area has the lowest average payback (years) or the quickest opportunity for positive cash-flow. I will discuss the remaining sections based on increasing average payback (years).

Ventilation Technologies

The Ventilation category noted above is a combination of specific recommendations and computes to an average of 0.9 years payback, based on prior year less expensive energy prices and is therefore somewhat conservative. The following table shows a greater level of detail for this category. I will leave out some of the recommendations that do not address technologies that I will discuss.

Assessment Recommend-ation Code	*Description*	*Times Recom-mended*	*Average Savings*	*Average Payback (Years)*	*Implement-ation %*
2.7312	Minimize Use Of Outside Make-Up Air For Ventilation Except When Used For Economizer Cycle	91	$6,050	0.9	37.18%
2.7314	Reduce Ventilation Air	229	$10,373	0.9	45.63%

Based on the above statistics it seems likely that the following technologies may be both cost-effective and therefore likely candidates to be implemented as compared to other options in the IAC database.

Mobile-zone coating booth – The US Army at Fort Hood, Texas is currently using the technology. The amount of ventilating air entering the spray booth determines the energy usage and scale of the pollution problem. This technology greatly reduces ventilation air in a coating booth by increasing air supply for the operator and reducing it for the rest of the space. This reduces associated heating/cooling/dehumidification costs for the fresh air supply as well as thermal oxidizer fuel consumption and emissions. This one installation saved 7 billion Btu in 2007 alone, as well as 120 Tons of Carbon (DOE IMPACTS 2008).

Intelli-Hood® ***exhaust ventilation controller*** – This is installed in a broad selection of private and commercial kitchens. This technology greatly reduces supply and exhaust fan horsepower for up to 4 hoods with one controller (Bohlig, Fisher 2004). It interlocks with standard fire suppression technology. The controller optimizes airflow to coincide with cooking activity level under the hood by tracking both fume volume and temperature at the opening of the hood. In addition to kitchen installations, there may be opportunities to apply the technology to food processing and other processing streams. More than 2,700 Exhaust Ventilation Controller *(www.melinkcorp.com)* units have saved more than 600 billion Btu since 1994 (DOE Impacts 2008).

HVAC Technologies

The Space Conditioning of HVAC category noted above is a combination of specific recommendations and computes to an average of 1.3 years payback, based on prior year less expensive energy prices and is therefore somewhat conservative. The following table shows a greater level of detail for this category. I will leave out some of the recommendations that do not address technologies that I will discuss.

Assessment Recommendation Code (ARC)	*Description*	*Times Recommended*	*Average Savings*	*Average Payback (Years)*	*Implementation %*
2.7231	Use Radiant Heater For Spot Heating	397	$15,972	1.9	29.20%

The table expresses several HVAC efficiency options in average payback. Based on the above data, it seems likely that the following commercial or emerging technologies (most developed in part with DOE/ITP funds) may fall into similar payback ranges as applied to industrial buildings.

Radiant heating is usually a better application for spot heating applications, especially is those situations where people must work nearby loading dock doors or in other drafty locations typical of high-bay scenarios or in the path of air supply for large furnaces. This technology allows for heating a person or objects without heating the air space between allowing for setting the space air temperature somewhat lower for heating mode.

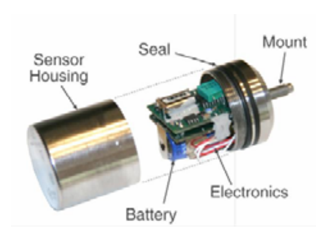
Radiant heating panels – Radiant heating systems transfer heat directly to a person or object in a manner similar to sunlight, eliminating energy consumed by mechanical heat-delivery requirements. These systems can save up to 50% in heating costs compared with baseboard electric-resistance heating and up to 30% compared with heat pumps. Since 1981, more than 375,000 radiant heating panels have been sold, saving more than 1.45 trillion Btu (DOE Impacts 2008).

Assessment Recommendation Code (ARC)	*Description*	*Times Recommend-ed*	*Average Savings*	*Average Payback (Years)*	*Implementation %*
2.7232	Replace Existing HVAC Unit With High Efficiency Model	349	$14,566	2.6	31.03%

Wireless sensors can help address the need for high efficiency units by operating HVAC systems the minimum amount of time, with minimally loaded air filters, with optimally operating motors and therefore at a higher system efficiency.

Industrial wireless sensors and controls enable energy savings especially when combining the data provided with visualization tools that identify specific opportunities rather than combined total system views that tend to hide energy opportunities available at the granular level. These situations might include when a filter is dirty (identified by increased static pressure loss across the filter), or when a steam trap has failed, or when steam/water use exists in an unoccupied space, motor pre-failure indicator, inappropriate system operation for time of day, or the approach of an electrical demand charge. Wireless sensors or wired CO_2 or occupancy sensors may be installed where occupancy patterns vary by combining with simple inflatable shutoff dampers. This would become a Human-Demand Based Ventilation control. In situations where sensors already exist for lighting control such as in bathrooms, stock rooms or warehouses there may opportunities to add-on additional savings by controlling other systems such as ventilation, HVAC and hot-water recirculation. Many wireless sensor manufacturers provide industrial class sensors including GE, Honeywell, Eaton, Sensicast (DOE Impacts 2008).

Distributed wireless sensors for motor efficiency – Motors consume an estimated 63% of all electricity used in industry. To reduce plant power consumption, sensors are often used to monitor the efficiency of 200hp and larger motors used in industrial applications but deploying sensors for continuous monitoring of non-critical motors is costly. Distributed wireless technology offers continuous monitoring to both smaller and less critical motors through low-cost, distributed, multi-measure, wireless sensors. Reducing the cost and complexity of sensor deployment is anticipated to allow continuous monitoring to become pervasive, which will allow industries to better maintain and improve the efficiency of their electric motor assets (DOE Impacts 2008). These energy evaluation and health condition



monitoring results can be very valuable for plant managers in making planning decisions for scheduled maintenance (Gutiérrez, Durocher, Lu, Harley, Habetler 2006).

Vibration power harvesting devices – KCF Technologies commercialized these devices for industrial wireless sensor power applications. Wherever safety or other factors prevent easy access for maintenance, consider self-powered systems. The device functions as an unlimited-life battery, reducing life-cycle cost (KCF Technologies 2009).

Efficient dehumidification technologies improve moisture removal and therefore efficiency during cooling which normally requires overcooling the air supply to force moisture out of the air. Further, there are a number of manufacturing operations where humidity control effects manufacturing productivity and therefore payback analyses should include more than energy savings. Dehumidification capability and control is often difficult in situations where process demands require high ventilation rates and yet this process requirement can lead to costly dehumidification operations. Several options provide flexibility in design and control, and decisions are based on a number of variables including the climate zone of the building, age of existing equipment, access space for renovation, potential peak energy demand costs and potential carbon impacts of the options. These options include: The Cromer Cycle, commercialized as Trane's Cool Dry Quiet Rooftop Unit (DOE Impacts 2008), Heat Pipe Technologies' wrap-around Dehumidification Cooling Coil, as well as CHP systems which may provide Cooling, Heating, Power and Dehumidification. Emerging technologies in this category are also include AIL Research's High Efficiency Liquid-Desiccant Regenerator, and Advantek Inc.'s High Efficiency Variable Dehumidification Control.

The Cromer Cycle: Trane's cool dry quiet rooftop unit – This technology is well suited for hot and humid climates (ASHRAE 2006) or for industrial buildings where internal processes cannot be sealed and therefore add humidity to the internal space. The technology reduces the amount of cooling, eliminating reheat used in many systems to dehumidify, and improves the efficiency of the cooling needed by maintaining higher evaporator coil temperatures than standard systems. The system removes excessive moisture in the air, which can contribute to indoor air quality problems in buildings (DOE Impacts 2008).

High efficiency liquid-desiccant regenerator (www.ailr.com) (emerging technology) **–** The use of desiccants, which have a high affinity for moisture, can greatly reduce the energy required for typical drying and dehumidification. A new generation of liquid desiccant technology was developed that lowers overall cost and size, while improving the performance characteristics of existing dehumidification technologies. This new regenerator has the potential nearly to double the efficiency of liquid-desiccant systems (DOE Impacts 2008). This system could be coupled with solar water heating systems (Lowenstein, Slayzak, Kozubal 2006) such as mentioned below to deliver a solar-based combined heating, air conditioning and power system.

High efficiency variable dehumidification control for air conditioners (www.advantekinc.com) (emerging technology) – This technology combines several technologies to provide systems efficiency improvement. The technology consists of an extremely simple and reliable variable damper mechanism, together with a few additional refrigeration system components. This technology scenario could be broadly applicable to many different markets including industrial scale HVAC (DOE Impacts 2008).

Ice-energy air conditioning units (www.ice-energy.com) – This modular system shifts 95 % of AC load from peak to off-peak periods. This type of technology can provide responsiveness to process-energy related, peak-HVAC-demand or dehumidification demand since it can also be run in an additive mode if the designed with an additional set of evaporator cooling coils. This technology may provide sufficient demand load reductions for billing reductions beyond those based on energy savings. The technology was commercialized by Ice Energy, Inc. in 2005. Total installations saved 1 billion Btu in 2007 alone, as well as 10 Tons of Carbon (DOE Impacts 2008). Ice Energy reported that a large number of resources provided through the U.S. DOE Inventions and Innovations program were critical ingredients to their product's current success (Moore, Weakley, Butters 2004). This technology reduces energy consumption directly by eliminating the common practice of sub-cooling refrigerant at the condensing unit.

Variable speed controllers reduce energy consumption of motor driven systems due to the affinity laws. Power is proportional to the cube of the shaft speed. This provide for roughly 7/8 energy savings for 50% speed reduction.

Variable speed, electronic motor controller – Developed by Opto-Generic Devices, Inc. (www.ogd3.com), these controllers are commercially available with over 2500 units in use. The device controls single-phase motors up to 240 VAC and 12 amps full load, including HVAC and other system motors found in data centers, fan coils, unit ventilators, and exhaust fans. In HVAC systems, the controller enhances thermal energy exchange from the coils as it gradually ramps down fan speed in response to the supply air temperature as it settles into the setpoint temperature even after the thermostat has closed the valve that brings in steam/heated or chilled water. Thus, the coil thermal energy transfer with the room continues even after the water valve has closed, allowing for additional electrical savings in chillers and fuel savings in boilers (DOE Impacts 2008). This scenario also has a positive impact on humidity control.

Selective zone isolation for HVAC systems (www.retrozone.com) – This system selectively controls air flow from a central HVAC system and can now fit into ducts that cannot accept conventional dampers because of poor access. The flexible dampers can save 20% to 30% of a typical heating and cooling bill in a commercial building by sealing off unoccupied rooms. More than 4000 systems have been sold and have cumulatively saved 305 billion Btu (DOE Impacts 2008). This technology may be most applicable in instances where occupancy varies widely, such as in the case of storage zones of larger industrial buildings. This technology could be controlled either with CO_2 sensors or by using a signal from any existing occupancy sensors controlling the lighting system in the same zone. However, if the airflow volume in a proposed installation of these dampers represents more than a small fraction of the total air supplied by the HVAC unit it would be more efficient to include a variable speed drive for the supply fan as well.

Geothermal (or ground-coupled or geoexchange) heat pumps are a proven (DOE States 2009) and widely available though underutilized technology (ASE, DOE/FEMP 2007). These systems should be considered every time a facility is built or expanded, especially where both heating and cooling will be needed by the facility. There will be some instances where these systems will be the less expensive HVAC option when compared to systems requiring industrial boiler and chiller driven systems. These systems typically have the lowest life-cycle cost of any heating and cooling system. These heat pumps collect heat from the ground and concentrate it for delivery into the building. For 1 unit of energy (1 kWe) taken from the grid, 2 to 3 equal units of thermal energy are taken from the earth (via water in closed loops). The objective in Ground Heat Exchanger drilling is to install a specific total length of heat exchanger in a vertical configuration; it is not important to reach a given depth at a particular site. No temperature gradient is involved; ground ambient temperature works as a heat sink or source. Soil and rock conditions will determine an economical bore depth. Geothermal heat pumps are available and applicable in all 50 U.S. states and D.C.

Similarly but simpler **ground coupled ventilation air systems** use networks of biocide-coated underground fresh air piping to pre-condition incoming air (or recirculated air) offering simpler lower cost options for efficiency improvement as well as the opportunity to provide conditioned air where conventional systems are not practical or cost-effective. This system should be considered when developing a new facility or breaking ground for other reasons especially where heating and latent cooling loads are relatively moderate, for instance not in coastal regions, and not in extreme cold climates.

SOLARWALL® air preheating system (www.solarwall.com) – A solar air heating system heats incoming ventilation and makeup air using a metal cladding system installed on the south-facing wall of a building. This system also reduces a buildings heat loss in the winter and lowers the cooling loads in the summer by preventing solar radiation from striking the south wall of the building. More than 40 systems with over 200,000 square feet of wall are operating in the United States and have cumulatively saved 76 billion Btu. A spinoff technology has been developed that resulted in a combined solar heat and power system (DOE Impacts 2008).

A similar approach may be applied where existing tinted metal is installed over an existing south-facing masonry or concrete wall (Laporta 2008). In this scenario a collection duct is built along the top of the wall and connected to the air space between the metal and masonry wall. Wall perforations are made through the block wall at the back of the duct. A supply fan with differential temperature controls is added to deliver the virtually free solar heat to the space when desired. Energy management system connection is recommended to prevent simultaneous heating and cooling.

Greenfield solar concentrating system (emerging technology) provides both heat and power for buildings applications in a modular system that is assembled without a crane or ladder. (www.GreenfieldSolar.com) The system can be optimized for either heat output or power output. GreenField's StarGen™ concentrator makes maximum use of 'off-the-shelf materials'. 28 identical light-weight mirror modules are easily assembled on-site, providing 900 'suns' of high-intensity concentrated light. Several utilities and municipalities have purchased units for demonstration testing.

Lighting Technologies

Assessment Recommendation Code (ARC)	*Description*	*Times Recommended*	*Average Savings*	*Average Payback (Years)*	*Implementation %*
2.7121	Utilize Daylight Whenever Possible In Lieu Of Artificial Light	434	$3,884	1.0	40.69%
2.7145	Install Skylights	302	$6,129	2.7	18.72%

Some types of daylighting technologies provide simultaneous energy savings, self-reliance and resilience to energy disruptions, improved energy security, and emissions reductions.

Solar tracking daylighting systems – This type of daylighting technology uses very small solar cells to operate a stepping motor to move a set of reflective mirrors to provide much lower life cycle cost than stationary skylights. These tracking daylighting systems provide high light intensity from sunrise to sunset, as contrasted with stationary skylights that typically provide a light intensity profile with a narrow sharp downward parabola with harsh glare at the midday peak. The first systems where developed in part with development resources from DOE's Inventions and Innovation program. Wal-Mart and other corporations have successfully deployed this technology in high bay spaces.

Assessment Recommendation Code (ARC)	*Description*	*Times Recommend-ed*	*Average Savings*	*Average Payback (Years)*	*Implement-ation %*
2.7135	Install Occupancy Sensors	2,813	$1,878	1.3	27.12%
2.7142	Utilize Higher Efficiency Lamps And/Or Ballasts	10,026	$5,170	2.0	53.27%

Occupancy sensors are ubiquitous throughout various lighting applications (ASHRAE 2006). They have been used in many applications; however, they may be used in many additional industrial applications for improved energy savings such as multilevel lighting scenarios or where these sensors are installed locally within light fixtures or groups of fixtures. Future applications might include sensors with various types of lighting in high bays, while using only solid state lighting such as LEDs for safety-based minimum lighting levels near the floor.

Solid state lighting (for example LEDs) is on the cusp of use for general illumination with improved efficiency and lifespan as compared with the best fluorescent technologies. Numerous companies are marketing products for various applications. However, you need to insist on independent LM-79 test reports; compare the product to Energy Star standards; and insist they prove that their LED supplier can generate good LM-80 results (Griffiths 2009). Already, Wal-Mart (GE 2009) and the Federal Energy Management Program are applying LEDs to refrigerated coolers and cases. DOD has begun installation of Cree's LED products in the Pentagon (Cree 2009).

PowerRim™ high wattage energy saving compact fluorescent lamp (CFL) adaptor for recessed down lights allows cfls to replace higher-wattage incandescent down lights. This technology will probably only be applicable in the few industrial buildings applications with low-medium height ceilings. (www.powerlux.com). PowerRim was commercialized in 1998 with more than 47,000 installations through 2007. 77 Billion BTUs energy saved in 2007, 1.52 thousand tons of Carbon (DOE Impacts 2008).

Energy saving controls for HID lamps (www.eesolutions.org) (emerging technology) – This new technology is a simple, cost effective approach designed to work with conventional (magnetically ballasted) HID lamps of 70 to 1000 Watts, conserving up to 40% of typical energy consumption by managing illumination to customer needs or applicable standards. These intelligent controls save up to 50% of the maintenance costs associated with HID lighting. Many solutions offer improved HID lighting efficiency, but require replacement of existing lamps. This technology can be retrofit onto existing lamps thus saving capital costs. The fact remains that

HID lighting is the most cost- and energy-efficient technology available today for high power (>100Watts) lighting applications and this technology significantly improves energy efficiency and reduces maintenance costs in this lighting category.

Envelope Technologies

Cool Roof (CoolRoofs 2009) technology is applicable to a broad array of roofing types and can be applied at design or renovation to maintain long-term energy efficient (LBNL 2009) roofing.

Electrochromic windows: 'Smart Glass' technology (www.sage-ec.com) – The technology was commercialized by SAGE Electrochromics, Inc. in 2003. Windows are often the most inefficient part of a building envelope and are responsible for heat loss in cold months and solar heat gain in warm months. If an industrial building contains a large number of windows and wishes to reduce cooling load this technology may be appropriate. In some instances, glare from the sun can make it difficult to see a computer or other LCD screen, requiring the blinds to be pulled, negating the benefits of natural light. Sunlight can also fade furniture, carpets, and drapes, increasing building owners' maintenance costs. Reduces annual cooling loads in commercial buildings by 20% and peak electricity demand (DOE Impacts 2008).

Sunlight Responsive Thermochromic (SRT™) window system (www.pleotint.com) (emerging technology) – A new high-performance window capable of variable tint is being developed that combines dynamic sunlight control, high insulation values, and low solar gain. The Sunlight Responsive Thermochromic windows can reversibly change light transmission based on thermochromic materials activated solely by the heating effect of the sun. The window design allows for good daylighting, a low solar heat gain coefficient, a low U-value, and a high insulation value. Energy savings up to 30% are estimated compared with traditional window systems (DOE Impacts 2008).

Water Related Technologies

High-efficiency direct-contact water heater (www.kemcosystems.com) – This industrial water heating system uses a water-cooled burner sleeve and combustion gas-water contact zone to extract all possible energy from natural gas combustion by bringing water into direct contact with a submerged-flame jet-type burner. More than 3,000 units are in use throughout the United States (DOE Impacts 2008).

D'MAND® hot water recirculating and waste prevention system (www.gothotwater.com) – A system was developed for water heaters to conserve water and energy while providing hot water on demand. The system moves the tepid water back to the water heater rather then discarding it prior to hot water delivery. The primary energy savings are from the reduced amount of energy needed to heat the water returned to the water heater tank. More than 33,000 units have been installed in residential and commercial applications and have cumulatively saved 604 billion Btu (DOE Impacts 2008).

Conclusion

These various technologies provide opportunities for manufacturers with the potential to save money by implementing lower–cost energy savings options in the midst of a difficult economy.

DOE is also developing several tools and resources that can help industrial companies identify opportunities to reduce energy use in general as well as in industrial buildings.

DOE is collaborating with various industrial companies as well as EPA and NIST to developing a business model for plant energy certification called Superior Energy Performance (Superior Energy Performance 2009). A central element of Superior Energy Performance is implementation of the ISO 50001 energy management standard, with additional requirements to achieve and document energy intensity improvements over each 3 year period. This effort may eventually incorporate a module for industrial buildings systems efficiency.

Building upon the success of DOE's Save Energy Now program, DOE resources can help companies accomplish the following:

- Assess buildings and other energy systems as part of an industrial assessment.
- Reduce facility energy consumption 25% by adopting cleaner energy sources, energy-efficient facilities-related best practices, and improved technologies.
- Use tools to analyze energy use, and find savings opportunities:
- Train staff to identify additional opportunities.
- Employ design guidelines; identify and install applicable technologies.
- Receive recognition for protecting our nation's resources.

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