Money & Energy Saving Resources from the CALIFORNIA ENERGY COMMISSION

ENHANCED AUTOMATION

Technical Options Guidebook

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Discussions on Costs and Benefits $ Costs + Benefits

PREFACE

Acknowledgements

The California Energy Commission commissioned XENERGY Inc. and Nexant, Inc. to develop materials for increasing the awareness of California businesses about enhanced automation (EA) technologies. California Energy Commission staff members Mike Messenger and Claudia Chandler contributed to this guidebook. This guidebook also received input from Energy Solutions and Linda Brandon Design as well as the following trade allies: CMS Viron, Encompass Mechanical Services, Engage Networks, Global Energy Partners, ICF Consulting, Lawrence Berkeley National Laboratories, Northwest Energy Efficiency Council, Sieben Energy Associates, Silicon Energy, and Southern California Edison.

Overview[1]

This guidebook is designed to be an introduction to enhanced building automation controls. EA, as covered in this guidebook, refers to a variety of potential strategies to increase the capability of your existing energy or building management systems to control current and plan for future building energy costs while maintaining the comfort and productivity of all building occupants.

This guidebook introduces EA technologies, discusses associated costs and benefits, and provides guidelines for decision making and implementation. It does not provide specific solutions, but rather seeks to provide readers with the information necessary to pursue the appropriate technologies and strategies for their business.

Target Audience

There are many opportunities for facilities to implement the technologies and systems described in this guidebook. Businesses most likely to benefit from EA will have greater than 200 kW of electric load (roughly equivalent to 20,000 square foot space or greater). Customers with 1 MW or more of load should find EA particularly cost effective due to economies of scale. Facilities under the 200 kW level should check the California Energy Commission's web site at www.energy.ca.gov for programs better suited to smaller businesses.

Types of businesses likely to benefit include:

- Grocery stores
- Hospitals/health care facilities
- Hotels
- Office buildings
- Retail chain stores
- Schools/colleges
- Others, such as multiple building complexes

This guidebook is targeted for:

- Building/business owners
- Building operators
- Building/plant engineers
- Consultants and contractors
- Property managers

Other Resources

The California Energy Commission offers additional resources on EA. Enhanced Automation Project staff will answer questions and set up a free phone consultation with a technical advisor. Additional materials include vendor lists and case studies on successful EA projects. In addition, the ***Business Case Guidebook*** can help financial decision makers evaluate EA opportunities for their business.

To reach the California Energy Commission's Enhanced Automation Project:

- **(866) 732-5591**
- **enhancedautomation@xenergy.com**
- **www.ConsumerEnergyCenter.org/enhancedautomation**

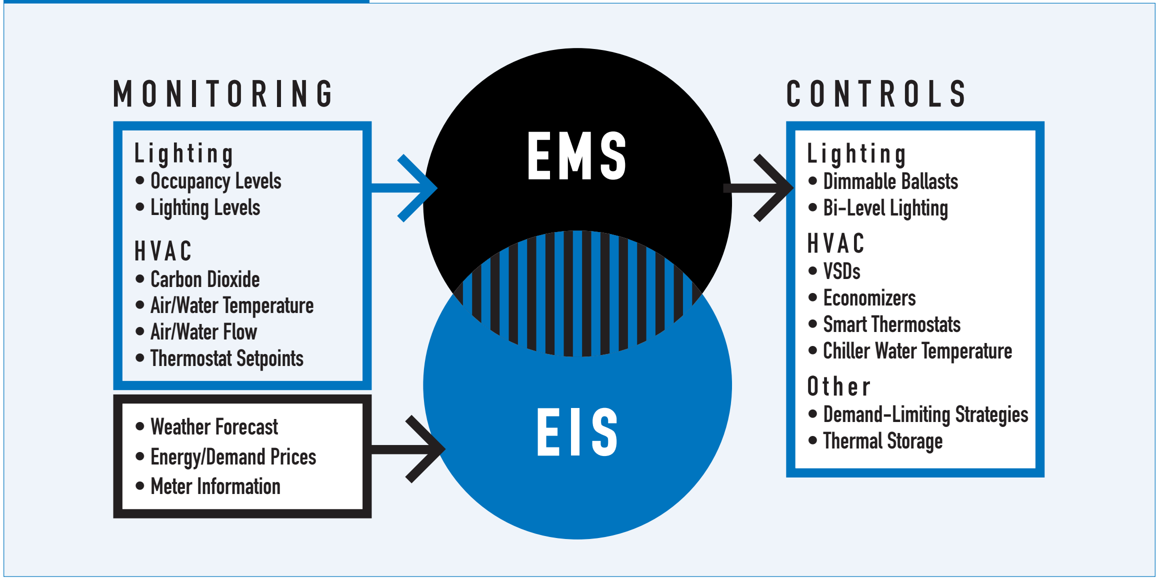
[1] *The information in this guidebook is designed as an overview and is subject to change. The California Energy Commission, XENERGY Inc. and Nexant, Inc. make no warranties, expressed or implied, and assume no legal liability or responsibility for the accuracy, completeness, or usefulness of any information provided within this guidebook. The views and opinions expressed herein do not necessarily state or reflect those of the State of California, any agency thereof, or any of the organizations or individuals that have offered comments as this guidebook was being developed. All of the content, including descriptions, cost and savings estimates, and Internet web site addresses, are as accurate as possible as of May 2002.*

1 OVERVIEW OF ENHANCED AUTOMATION

Enhanced automation (EA) increases the capability of existing energy management or energy information systems to help businesses better manage both energy use and the comfort of the building occupants. Specifically, improved automation systems provide additional equipment use and cost information to building managers. EA systems increase flexibility in maintaining optimal building climate, pinpointing problem areas, increasing worker/tenant productivity, and responding to energy price signals from the utility. In addition, they can be designed for remote access and/or single screen control.

Automation enhancements include adding a new energy information system (EIS) or energy management system (EMS), as well as re-programming or expanding the network of sensors and control devices on an existing EMS. EA systems can manage a variety of building operations, including heating, ventilation and air conditioning (HVAC), lighting, and other systems such as building security and access.

Enhanced Automation



There is a wide range of technological options available. The figure above shows the individual components of a sample EA system integrating HVAC and lighting controls into an EMS/EIS. The EMS and EIS can be configured as a combined and/or overlapping system or as separate systems, communicating with each other and the monitoring and control points in the building. Individual system components can be implemented independently or in a staged, modular approach. Each additional component installed offers increased economic and control benefits.

Enhanced lighting technologies include lighting control and monitoring strategies. These technologies can operate independently or be linked to an EMS/EIS system for maximum control. The technologies discussed in this guidebook are on/off and reduced lighting controls such as inboard/outboard lighting, bi-level lighting, dimming controls, and occupancy sensors, in addition to demand-reduction strategies that can be programmed into the EMS.

Enhanced HVAC technologies incorporate various control and monitoring strategies to improve temperature control and increase operating efficiency. HVAC measures also allow the system to respond to signals received through the EIS. Similar to lighting controls, these technologies can operate independently or be linked to an EMS/EIS. This guidebook discusses the following HVAC technologies:

- Start/stop (on/off) control
- Ventilation control
- Space temperature control
- Thermal storage control
- Central chiller plant control

Demand-Response

Demand-responsive programs are designed to encourage customers to cut energy use during peak electricity demand periods. A power provider usually offers incentives to customers for curtailing load by a specific amount when a peak demand period is imminent or a staged emergency is called.

Demand-response is the action customers take to reduce electrical load and costs in several ways:

- Load shedding/curtailment – reduces a pre-determined load by shutting off equipment or throttling back on consumption, such as raising a cooling setpoint.
- Demand limiting – reduces demand by shutting off equipment or throttling back on consumption to maintain a pre-determined maximum demand limit for a building or system.
- Load/peak shifting – reduces peak demand by shifting load from on-peak hours to off-peak hours.
- Duty cycling – shuts off equipment (typically packaged air conditioning units) to reduce demand.

EMS technologies are found in most buildings greater than 20,000 square feet. EMS are information and control systems that, through a series of sensors and controllers, allow a facility manager to efficiently operate end-use equipment within a facility. These control centers are often run from a centralized operations panel or remotely, such as from an Internet web page.

This guidebook discusses the various communication protocols on the market, which type of system may be best suited for particular applications, and factors to consider when assessing whether to upgrade an existing controls system.

EIS technologies are designed to provide building managers with information on system-wide performance, energy use and utility pricing. EIS provide an additional layer of automation that allows for maximum control over energy usage. They can be directly linked to weather information, building meter data, and utility pricing data. An EIS can be completely independent of an EMS or can provide a gateway to an EMS.

EIS are an integral part of utility-based demand-response programs (i.e., load scheduling, demand shifting or load curtailment) and for real-time pricing rate programs. Businesses can receive and manage real-time price signals from electricity and fuel providers. These systems can be set up to take advantage of periods of low utility rates, curtail energy loads during peak pricing times, or curtail due to an emergency call for a demand-responsive action.

EIS technologies are usually driven by a software package administered either by a single company, a partnership, or a collective group of organizations. Competing EIS technologies have distinct differences and can be categorized as follows:

- *Notification*-based systems gather information on energy use from the utility meter and respond to signals from external sources. External signals include real-time pricing, electric supply alerts, demand-response events, and other information such as weather forecasts. Notification systems also allow limited two-way communication, such as accepting a demand-response request or providing a bid for demand reduction.
- *Analysis*-based systems provide services, such as energy usage and cost data analysis, forecasting, and bill consolidation. As with notification-based systems, these systems can gather and provide either periodic or real-time data, as needed.
- *Response* systems include the functions of analysis-based systems and typically integrate one or more EMS with two-way communication. The response relies on the information received from outside price or emergency signals and the EMS, allowing manual adjustments by the operator or automated reaction and communication by the EIS.

Common Utility Pricing Plans for Large Customers

Energy and Demand: Pay rates for both energy use and the facility's peak demand.

Time-of-Use (TOU): Pay preset rates for energy and demand that are lower during off-peak and higher during seasonal/daily peak demand periods. TOU structures are often mandatory for very large commercial/industrial customers, and voluntary for other customers.

Real-Time Pricing (RTP): Hourly pricing of electricity where the cost per kWh varies by hour and by day, and is therefore less predictable than TOU rates. For example, the utility gives customers a 24-hour price forecast each day for the following day, allowing them to adjust usage daily to minimize costs. Typically, RTP is tied to the wholesale market price.

There are other pricing alternatives available from utilities, such as interruptible rates and other dynamic pricing programs. Customers can sometimes choose from a list of alternatives.

The following are ways to enhance automation in a building:

1) Install a new EMS and/or EIS system:

Install a new EMS, EIS, a combined EMS/EIS, or replace the existing system. Incorporate EA capabilities in planning for the construction of new facilities.

2) Enhanced programming and integration of the existing system:

Optimize the current EMS and/or EIS to take advantage of its capabilities and unused components. Reevaluate current control systems and EMS to ensure they are working optimally and as designed. The existing system(s) may allow for upgrades to EA technologies and strategies. Integration opportunities outside of typical EMS/EIS control systems may include: security/access systems, elevator and escalator operation, water usage, and plug loads (such as computers).

3) Increase the amount of monitoring and control points for the existing system:

Additional sensors and controlling devices can be installed on lighting and HVAC systems.

Will a business benefit from EA?

To help assess whether a building or facility will benefit from installing EA technologies, answering the following questions will help the reader determine if benefits exist for their building(s).

In your building:

1. Are lights turned off when not in use?
2. Does your system automatically vary lighting levels in perimeter offices according to the amount of available daylight?

See the Lighting section 3 if your answer is NO to question 1 or 2.

3. Is your HVAC system optimizing the mix of inside and outside air?
4. Can you adjust lighting and HVAC levels from a central location?

See our Lighting and HVAC sections 3 and 4 if your answer is NO to question 3 or 4.

5. Are you taking full advantage of the functionality of your EMS?
6. Are you able to provide management reports on energy usage and costs quickly?
7. Can you respond to occupant comfort complaints quickly and efficiently?

See the EMS section 5 if your answer is NO to question 5, 6, or 7.

8. Does your electric utility communicate with you via your EMS by providing price signals and other essential demand-response information?
9. Are your current systems simple to operate and maintain?

See the EMS and EIS sections 5 and 6 if your answer is NO to question 8 or 9.

If you answered **NO** to any of the above questions, this guidebook can help you identify ways in which your facility can benefit from EA technologies.

2 WHAT CAN EA TECHNOLOGIES DO FOR A BUSINESS?

Implementing EA technologies can reduce energy costs, increase employee comfort, and allow facility managers to monitor and control conditions at multiple locations. However, businesses often neither know nor receive the full range of EA benefits. In part, this is because first costs preclude implementing EA technologies. Furthermore, benefits not directly related to energy savings, such as productivity, are often overlooked, yet are ultimately more important to most businesses' bottom line; even a one percent improvement in productivity can generate much more profit than calculated energy savings.

How much a business benefits from EA upgrades depends on the current level of automation and which EA upgrades are appropriate for a particular building. EA benefits can be tailored to address the business' goals and priorities—EA can be used for minimizing total energy and demand usage, minimizing total energy costs, or simply increasing the level of control available in a building.

Reduce Energy Costs

- Maximize building energy efficiency
- Match schedule/load to system operations
- Reduce load when rates are high or incentives are offered
- Shift loads to benefit from utility rate structures
- Adjust energy use in response to real-time price signals
- Earn incentives through energy-efficiency and demand-response programs

Reduce Operation and Maintenance Costs

- Pinpoint problem areas quickly
- Receive automated alerts to maintain or replace equipment
- Cycle/schedule/rotate equipment efficiently
- Eliminate unnecessary maintenance

Monitor and Analyze Energy Use

- Track and trend energy use
- Verify energy savings
- Produce system and energy cost profiles
- Improve information management, data extraction, and reporting
- Improve meter reading and operating controls interface
- Access meters and controls remotely
- Automate alarms and signals
- Assess EMS/EIS reaction to curtailment
- Control/monitor on-site generation
- Aggregate and disaggregate building load profiles into end-use components
- Limit losses from power disruptions

Improve Occupant/Customer Comfort

- Increase productivity/increase sales/retain existing tenants
- Improvel comfort by controlling lighting and temperature levels in building zones
- Respond quickly to occupancy/customer comfort complaints

Provide Long-term Benefits to Company

- Identify new energy-saving opportunities
- Forecast energy needs more accurately
- Schedule energy-intensive equipment upgrades more easily
- Negotiate with power marketers
- Win approvals for future energy management projects more quickly
- Take advantage of real-time pricing options
- Enhance corporate culture and image
- Increase building asset value

Provide Societal Benefits

- Improve reliability for all on the electricity grid[2]
- Stabilize and reduce energy prices
- Reduce power plant pollution

[2] *"Retail Load Participation in Competitive Wholesale Electricity Markets," Edison Electric Institute, et al, January 2001.*

3 ENHANCED LIGHTING TECHNOLOGIES AND STRATEGIES

Enhanced lighting technologies consist of control systems that minimize energy consumption of building lighting systems. While upgraded lighting equipment forms the basis for an efficient building lighting system, facility managers should also consider enhanced control technologies as part of any overall lighting upgrade project. This will lower the incremental costs for the EA lighting projects and will maximize the project savings potential.

In general, lighting efficiency strategies focus on providing adequate levels of high-quality light when needed, while either lowering the input wattage or reducing the hours of operation. Some examples of common lighting upgrades include converting fluorescent T-12 lamps and magnetic ballasts to T-8 lamps and electronic ballasts and installing LED exit signs. As listed in the table below, there are three major categories for lighting controls that building managers should also consider during an upgrade.

Lighting Control Categories

TYPICAL		ENHANCED AUTOMATION
Basic Controls	**Advanced Controls**	**Centralized Controls**
On/Off Controls Clock/timer controls Manual dimming controls	Light-level sensors Occupancy sensors Daylighting/hi-lo/dimming	Lighting sweep strategies Override strategies Demand limiting strategies Occupancy sensors Dimming capabilities

While basic and advanced controls provide opportunities to reduce energy usage, enhanced automation centralized control strategies provide building managers with the most effective tools to manage energy usage while maintaining occupant comfort.

3.1 Basic Controls

Most buildings have basic lighting controls, such as on/off switches, simple timers, or manual dimmers. These basic lighting controls should be considered a first step for any buildings that do not yet have them installed.

3.1.1 On/Off Lighting Controls

The most basic type of lighting control is on/off control. Fixtures can be wired to be controlled in rows or some other pattern, with a hi-lo capability, or in an inboard/outboard configuration, which allows some or all of the lamps in a multi-lamp fluorescent fixture to be turned off. For instance, the outer two lamps in a four-lamp fixture may be turned off to cut energy use and light levels in a space by 50 percent. Light levels in an area can be lowered uniformly at certain times or locations. Common applications include reducing light levels after hours for security and cleaning crews or where there is a significant contribution of daylight, such as near windows.

3.1.2 Clock/Timer Controls

Clocks and timers provide automatic control of lighting systems, based on a user-determined schedule. They do not rely on someone to set switches manually. Such controls can also override central control and require resetting at specified intervals.

3.1.3 Manual Dimming Lighting Controls

Manual dimming is a more flexible form of lighting control than simple on/off controls. It allows occupants to reduce light levels variably and reduces input wattage accordingly. Lights can be dimmed either by fixture or in groups, which provides occupants much greater control over light levels. Special dimming ballasts and controllers are required for fluorescent and HID applications, and the technology is becoming much more affordable and widely available.

Dimming fluorescent lights yield virtually a one-to-one relationship between power consumption and light level when high-quality controllers and ballasts are used. For example, when light levels are reduced by 25 percent, the power levels are reduced slightly less than 25 percent. When light levels are dimmed, comfort levels are not necessarily affected and many occupants may not notice the difference. In addition, dimmers can be centrally controlled and gradually dimmed to minimize disruption to occupants.

CASE STUDY

Macanan Investments installed an EIS for near real-time access to utility meter data and installed a dimmable lighting system with three levels of light output. The 62 percent level was intended for use during emergency curtailment situations only, but owners found they could operate lights at this level during peak afternoon hours without disrupting occupancy comfort.

Refer to Enhanced Automation Case Study #3 for more details.

3.2 Advanced Lighting Controls

Lighting control strategies generally focus on identifying situations where variable amounts of light are required, based on occupancy, usage, or availability of supplemental daylight. These strategies are implemented by a system of sensors and controls, which optimizes light levels and reduces energy consumption. The controls may be either local to the lighting zone or may be part of an overall facility EMS.

3.2.1 Light Level Sensors

Light-level sensors, or photocells, can initiate on/off, multi-level, or dimming strategies according to actual light levels in the space, based on user-defined requirements. This allows the use of artificial lighting only as a supplement to available daylight in perimeter areas, when possible, which minimizes overall power consumption. Light-level sensors are sometimes also used to maintain lumen levels over the life of a lamp by providing more energy to the fixture as its light output levels decline. Building spaces with significant contributions of daylight, such as offices and work areas with windows, may often be grossly overlit when undimmed lighting is turned on. Using the signal from light-level sensors to adjust artificial lighting to supplement natural lighting in these areas can result in significant electricity savings—20 to 70 percent of an undimmed system.

3.2.2. Occupancy Sensors

Occupancy sensors also automatically control lighting systems based on space occupancy. These sensors can also enact on/off, multi-level, or dimming strategies, according to user-defined inputs. Occupancy sensor controls are often most appropriate for after-hours situations where light levels are normally reduced or off but must be turned on for the occasional occupant. In addition, areas that are occupied sporadically, such as warehouse space, laboratories, conference rooms, private offices, or portions of large open work areas, are also good applications for occupancy sensor controls.

3.2.3 Daylighting/Hi-Lo/Dimming

The use of natural daylighting offers significant peak demand savings because it can reduce a facility's electric consumption during peak daytime periods. Natural daylight is also the highest quality light. Businesses that require a high degree of color accuracy like print shops have long used natural daylight in their work. In addition to reducing costs and offering high-CRI (color-redering index), natural daylight may provide occupants significant health benefits and feeling of well-being.

The availability of daylight in facilities is dependent upon local conditions, as well as the location and design of specific spaces and lighting zones within a facility. Orientation and window area will determine the feasibility of incorporating daylight into the overall lighting system, and electric light sources will always be needed as a supplement. Daylight can be admitted through vertical sources, such as windows or glass block, or through top sources, such as skylights. Toplight sources typically provide about three times the light as side sources, and they can even employ some advanced technologies, such as reflective light pipes or louver systems to collect and distribute the light. In addition to passive daylight systems, active systems, such as those that use tracking reflectors or mirror systems, are becoming increasingly available.

A daylighting control strategy employs photosensors to control fixtures in specific zones. The control of the fixtures is calibrated with the available daylight to provide occupants with optimal light levels. The reduction in energy use by the system is accomplished by using either a hi-lo step-dimming ballast technology, or a continuously variable dimming ballast technology. For fluorescent fixtures, light levels can be reduced to as low as zero to 10 percent, while for HID metal halide systems and high-pressure sodium systems, reductions to 50 and 35 percent light output can be achieved, respectively. Continuous dimming for HID systems are also available. Savings can vary greatly, but a 20 to 30 percent range is typical.

Sample Lighting Project

A business retrofits an overhead T-8 fluorescent lighting system with dimmable ballasts in a 20,000-square-foot building. Prior to the retrofit, the lighting system averages 1.2 Watts per square foot. If the lights are on for 5,000 hours per year, total energy consumption is 120,000 kWh per year. The cost of the dimming system is approximately $10,000 (including commissioning costs). The dimming system resulted in an average 30 percent reduction in lighting energy use with an annual savings of 36,000 kWh and 7.2 kW. At $0.10/kWh and $12/kW/month (for a four month period), the reduction in energy use results in $3945.60 cost savings for installing dimmable ballasts. The payback is two and half years.

3.3 Centralized Controls

The lighting control systems discussed above address the control of lighting fixtures locally throughout a facility. Centralizing these control systems to an EMS provides opportunities for single-point control, energy use trending, demand-reduction strategies, and greater comfort for building occupants. While common lighting strategies may be justifiable based on energy savings and energy efficiency alone, the installation of enhanced systems and protocols can increase energy savings, especially when centrally managed. Centralized controls may be dedicated to lighting only, or they can be integrated as part of an overall facility EMS (see the EMS section 5 for more information).

3.3.1 Lighting Sweep Strategies

In most facilities, a maintenance person, custodian, or staff person manually turns the lights on in the morning and off in the evening. This strategy often wastes energy because it keeps all lights operating from the time the first person arrives until the last person leaves, regardless of whether all lights are needed. Modern lighting control systems used in major retail stores, large office complexes, or multi-building facilities utilize "sweep" controls that turn off certain lamps or fixtures at preset times. These periodic, programmed, sequential sweeps are meant to ensure that fixtures are turned off as soon as the activity in an area diminishes. Sweep programs often employ low-voltage relay systems and generally provide some level of local warning as well as override control so occupants will not be "caught in the dark." Local override (on a zone-by-zone basis) can be initiated by manually operating a wall switch, calling a central operations center, or dialing a code via a telephone that activates the circuit until the next sweep.

Some large retail stores use a functional sweep strategy for their lighting systems. General background ceiling lighting is energized at a partial level for staff entry and stocking. General valence-type display lighting is energized shortly before customers enter. Display lighting, the most inefficient (and heat producing) lighting in the store, is turned on only a few minutes before customers enter. Display and architectural lighting at many other types of facilities can be controlled similarly.

3.3.2 Override Capabilities

An EMS or other central lighting control system is also able to record the override requests for accounting purposes, if necessary.

3.3.3 Demand Limiting/Load Shedding

If the lighting control system (or EMS) is interfaced with an EIS, sweep controls can also be used as a peak-limiting, demand-responsive, or price-responsive control strategy. The system can be programmed to automatically reduce lighting power (and lighting levels) in non-critical areas if a peak emergency signal is received or if real-time energy prices exceed a certain value. This requires a dual-level lighting system that could tolerate lighting reduction without compromising safety or productivity.

3.3.4 Occupancy Sensors

Occupancy sensors that only turn lights on when occupants are present can be connected to the EMS to provide information on building occupancy or can be tied in to the HVAC system.

3.3.5 Dimming Capabilities

Similarly, dimming controls can be interfaced with a central EMS/EIS to implement a demand-reduction strategy using the dimming system as the means to lower demand for the building.

3.4 Costs

The cost of enhanced lighting technologies varies depending on the quantity purchased, programming strategies, and labor involved. The costs (per unit, unless specified otherwise) listed in the table below come from a study commissioned by the California Energy Commission to determine costs of various measures.[3]

Cost of Enhanced Lighting Technologies

Enhanced Technology Upgrade	Materials	Labor	Total
Lighting Ballasts			
HID hi-lo	$50-$100	$100-$150	$150-$250
Fluorescent dimming ballasts	$50-$75	$10-$200	$85-$275
Lighting Sensors			
Wallmount occupancy sensor	$50	$10	$60
Ceilingmount occupancy sensor	$100	$50	$150
Daylight photo sensor (per system)	$50	$60	$110
Lighting Controls			
Dimmer, two fixtures per circuit (per fixture)	$440	$270	$710
Dimmer, ten fixtures per circuit (per fixture)	$175	$110	$285
Timeclock, 24 hour electromechanical	$40	$90	$130
Timeclock, 7 day digital	$30	$70	$100
Timeclock, 7 day electromechanical	$110	$90	$200
Timeclock, 7 day electromechanical, 3 phase*	$300	$90	$390
Central (EMS) control (per point)**	n/a	n/a	$1,100

**Unit for use with HVAC equipment as well as lighting. **See EMS section for more information. n/a = not available*

3.5 Benefits

Potential energy savings from enhanced and/or centralized lighting controls will vary depending on many factors such as existing conditions (hours of use, type of lighting, and more). In pre-Title-24 buildings, adding modern controls can save up to 50 percent of the electric lighting energy consumption with little or no user impact. In most buildings built during the first generation of Title-24 (1978 to 1987), the installation of modern controls can save up to 25 percent of the electric lighting energy consumption with little or no user impact. In many second-generation Title-24 office buildings (1987 to 1992) and retail establishments (1988 to 1992), as well as buildings constructed under the most current generation, there are still opportunities to save energy with lighting controls. The table below summarizes savings for five different lighting measures plus the costs of enhancement. See appendix for description on calculating savings per building square foot.

[3] *"2001 DEER Update Study", prepared for The California Energy Commission contract number 300-99-008, prepared by XENERGY Inc., August 22, 2001.*

Example of Savings on Lighting Retrofits

If your current system is	And you upgrade to	Costs of enhancements	kWh savings*	Peak kW savings*
Manual On/Off whole circuits	Bi-level lighting, sweeping off one or two lamps of a fixture or checkerboard fixtures	$1,000 per circuit	5%-15%	5%-15%
Manual On/Off (shut off by staff in evening)	Sweep control via EMS (lights are "swept" off periodically unless local override is requested)	$500 to $1,000 per circuit	5%-10%	0%-5%
No light level control (fluorescent)	Dimming controls (via EMS)	$50 to $100 per ballast plus $500 to $1,100 per lighting circuit for EMS dimming control	2%-10%	5%-20%
No light level control (HID fixtures)	Multi-level on/off control (multi-level ballast)	$250-$750 per fixture plus $500 to $1,100 per fixture control via EMS	2%-10%	5%-20%
Constant, variable or multiple light level control (via EMS)	Demand or price-responsive control (via EIS)	$1,100 per lighting control point	2%-10%	2%-10%

** Savings on the total building energy/demand usage during peak period.*

3.6 Further Considerations

In new building construction, it is important for designers, engineers, and architects to consider all enhanced technologies for lighting systems. Clearly, the installation of these technologies is less expensive and more cost-effective when built into the original building design, which can allow for the integration of design specialties, i.e., connecting lighting controls with HVAC systems. Ease of accessibility and integration into the general energy and systems infrastructure make new construction the ideal time to consider enhanced technologies.

Retrofitting existing lighting systems with control technologies requires a careful analysis of conditions and economics to determine the practicality and cost-effectiveness of the project. Buildings with fixtures that are turned on unnecessarily in certain areas or at certain times of the day are good candidates for EA strategies. Buildings with areas that are only occasionally occupied or that receive significant contributions of daylight from windows and skylights are also good candidates.

Existing wiring methods and layout, as well as other building conditions, often dictate the lighting control technologies, if any, that are most appropriate for the facility. For example, if an existing lighting system is wired according to an inboard/outboard scheme or switched by rows, retrofitting light-level sensors to control the fixtures can be more easily and economically accomplished than in a facility requiring extensive rewiring. In addition, the building's ceiling construction can have a significant affect on the overall practicality and labor required to install the equipment. For instance, a suspended ceiling allows faster and easier installation than a plaster ceiling, which would require patching and painting. A poured concrete ceiling could make the project prohibitively expensive.

4 ENHANCED HVAC TECHNOLOGIES AND STRATEGIES

Enhanced HVAC technologies refer to integrated systems with improved EMS ability to manage the operation of single or multiple-buildings from remote locations. Enhanced HVAC systems receive signals via an EMS from a large number of sensor points that record pressure, flow, temperature, or power, and issue control commands to equipment according to pre-programmed control algorithms. However, EA HVAC system operation can be based not only on internal thermal and load factors such as outside and inside air temperatures, but also on external signals received through an EIS, such as energy prices, distribution system conditions, or participation in load reduction programs. EA allows integration of the EMS control management functions with information obtained through a separate EIS (both systems, EMS and EIS, are discussed in sections 5 and 6, respectively).

This section describes the control strategies that apply to typical HVAC systems, including system types, costs, savings, and associated benefits of integrating building automation with EIS for advanced HVAC system control. The table below lists the technologies discussed in this section, which focus on operation and control strategies designed to minimize energy costs. Using them, building managers can also take advantage of demand-reduction opportunities, such as demand-response programs or real-time pricing. There are a number of strategies available to efficiently control HVAC equipment. Several technologies described in this section can stand-alone but are most efficient when connected to centralized controls, while others require centralized controls for operation.

HVAC Control Technologies and Strategies

Time and temperature control	On/off control Space temperature control Combined time and temperature control Other operating temperature and time control
Advanced time and temperature control	Shut-off with high limit Night ventilation Optimal start
Variable capacity control	Variable-air-volume (VAV) designs Variable-speed exhaust systems Variable-speed control of cooling towers Variable-speed drives for centrifugal refrigeration machines (including chillers) Variable-speed pumps for condenser water or chilled/hot water pumps
Demand-response ventilation	Carbon dioxide sensing systems Occupancy sensing systems Carbon monoxide sensing systems for garages
Peak load shifting strategy	Thermal energy storage
Chilled-water system control	Chilled-water temperature control Condensing temperature control Cooling tower/evaporative condenser fan control

Many EA control strategies for HVAC systems can be implemented to some degree with existing electric, pneumatic or digital control systems. However, upgrading control hardware and/or software to accommodate advanced control capabilities can provide additional benefits. Linking the various sensors and controllers through a digital system is necessary to achieve the higher level of operating control needed to effectively manage and optimize energy use and minimize energy costs.

4.1 Time and Temperature Control

These time and temperature controls are simple and should be considered at a minimum for buildings. These controls are not considered EA but provide the opportunity to move in the direction towards EA or position a business to control its HVAC system demand quickly.

4.1.1 On/Off Control

On/off control is a basic operating function. Nearly all HVAC systems have automatic start/stop controls through individual unit-time switches, a central time switch, run-down timers, and sometimes occupancy sensors. Mechanical time switches or programmable time controls should control the daily startup and shutdown of all major non-24-hour HVAC equipment. Only systems required for comfort or process control should have continuous operation. Simple time switches can be applied on a one-for-one basis or applied to a larger system through a central electric or pneumatic control system. With central systems, separate time controls may be implemented for the cooling equipment, heating equipment, or ventilation fans.

4.1.2 Space Temperature Control

The principal functions of HVAC systems are to provide and maintain environmental conditions for occupant comfort or an industrial process. For example, to provide room temperature control, an adjustable space temperature sensor (thermostat) sends a signal to a chilled-water valve, hot water valve, hot water zone pump, zone damper, AC compressor, fan/compressor combination, VAV box, furnace, electric coil, or other device. The device then delivers thermal energy to warm or cool the space. In packaged systems, the thermostat usually connects directly to the AC unit. In central chiller plant systems, space temperature control is usually centralized through a pneumatic or electric EMS.

4.1.3 Combined Time and Temperature Control

Most modern buildings have combined time and temperature controls that allow programmed on/off control schedules.

- Self-contained time/temperature controls for packaged units control occupied and unoccupied heating and cooling temperatures according to a programmed schedule. They may also control fan operation (separately from cooling or heating).
- Central time/temperature controls allow different occupied and unoccupied temperatures for fan, chiller, and boiler operation.

4.1.4 Other Operating Temperature and Time Control

Components of all HVAC equipment and systems, from the simplest to the largest and most complex, have sensors and control devices that maintain operating parameters within desired operating limits.

Supply air temperature control requires a temperature sensor in the supply duct to open and close a valve or adjust a damper position to provide the set supply air temperature. A simple DX (direct expansion) air conditioner has a throttling tube or valve to control the flow of refrigerant to the cooling coil.

Mixed-air temperature control is a sensor that controls return air and outside air dampers to maintain a fixed mixed-air temperature

Outside air sensors are sometimes installed even in fairly basic control systems. Outside air temperature input is used as a basis for many control strategies including:

- Lockout controls – Cooling ceases below a set outside temperature.
- Reset controls – Chilled water, hot water, condenser loop water, or mixed-air supply temperature is adjusted by operating mixing valves or dampers depending on the outdoor temperature.

- Economizer control – Economizer control is a more complex type of temperature control. The economizer strategy, also called "free cooling," uses outside air for cooling rather than mechanically cooled air. This control works only when the outside air conditions are in the appropriate temperature (and sometimes also humidity) range. Sensors determine outside air and return air temperature (or enthalpy). When the system is in cooling mode and outside air temperature is lower than the return air temperature, up to 100 percent outside air is brought into the system for cooling. If the outside air temperature is higher than the return air temperature or if the building is in heating mode, the outside air damper is returned to its minimum position. Economizer systems may be designed with dedicated exhaust and outside air fans with damper or variable-speed drive control.

Condensing temperature control maintains a set condenser-water temperature in a water-cooled system, by controlling the tower fans. In an air-cooled system, the condenser fans cycle to maintain a set refrigerant pressure. In an evaporative condenser, both fans and water flow operate to maintain a set refrigerant pressure.

4.2 Advanced Time and Temperature Control

In addition to basic time controls, there are opportunities for efficient and effective control and energy management. Costs for multi-level temperature and time controls will vary widely with building size and the sophistication of the HVAC system. The California Energy Code (Title-24) requires time and temperature controls for new buildings.

The most significant cost in enhancing time and temperature control capability is the time and effort to understand how the system operates and to determine the setpoints that minimize energy use while maintaining adequate comfort. Equipment costs are minimal since most buildings have these types of controls in place, but they are not used to the utmost capability or are not centrally controlled. Several strategies for advanced time and temperature control are discussed below.

4.2.1 Shut-off with High Limit

Shut-off with a high limit is a strategy that shuts off the entire HVAC system during unoccupied hours, but a high-limit temperature sensor/control starts up the fans, boiler, or AC equipment if the indoor temperature gets too hot or too cold. This reduces the heating or cooling load on the system and the time to return to occupied temperatures when the building is occupied again.

4.2.2 Night Ventilation

Night ventilation reduces the cooling load at night when outdoor temperatures are cooler than the specified indoor air temperature. In spaces that are not air conditioned at night, flushing with cool outside air can also reduce the cooling load on the system when it starts up in the morning. This strategy applies to any building type or size. With simpler control systems, some or all fans may operate for a fixed period of time each night rather than to achieve a particular temperature setpoint. With an EMS, the system can sense outside and inside temperatures and decide whether or not to operate the fans and determine the optimal time to run them. The night purge cycle is activated only on warmer days (i.e., when daytime temperatures exceed a certain value or when the outside air temperature is a preset amount below the inside space temperature).

4.2.3 Optimal Start

Optimal start is a control strategy that calculates the necessary warm-up or cool-down time for the building by taking into consideration both the indoor and outdoor temperatures. Controls automatically start the HVAC equipment at the latest time necessary to achieve the setpoint temperature when occupants arrive. Optimal start can be performed by a simple analog system and is commonly implemented as a standard control option with even the simplest central digital control systems. This control strategy can reduce system operation from 15 minutes to two hours per day.

This strategy is typically only implemented with a larger packaged unit system or a central chiller system because it requires outdoor and indoor air temperature sensors. For a system controlling distributed buildings or a campus of several buildings, individual start-up schedules can be implemented for each building. Most EMS software includes an optimal start programming option. Some offer artificial intelligence routines that can adjust the start-up time based on historical system response.

4.3 Variable-Capacity Control

HVAC systems respond to varying loads in several ways. Common design techniques include:

- Bypass (recirculation) of chilled water or hot water (around the heating or cooling coil)
- Throttling valves or dampers
- Variable-pitch sheaves for belt-drive pumps or fans
- Variable-inlet vanes (fans or centrifugal cooling compressors only)
- Electronic variable-speed drives (fans or pumps)

All of these control technologies are commonly activated by stand alone controls or by an EMS (pneumatic or electric) to improve part-load system efficiency. However, bypass and throttling strategies waste energy and should be avoided if possible. Variable-pitch sheaves and inlet vanes save energy but do not improve efficiency as effectively as more modern electronic motor speed controls. Depending on the specific technology used by the control devices, these are referred to as VSDs (variable-speed drives), ASDs (adjustable-speed drives), or VFDs (variable-frequency drives).

VSDs are power supply equipment that change the rotation speed of the HVAC equipment in response to a control signal that indicates demand for flow. In general, VSD control strategies save energy by closely matching the power input of a motor to the output requirements, maximizing the efficiency of the system. Significant energy and peak demand savings can result from speed control, compared to the older constant-volume/variable-temperature control systems. Variable-flow air-handling and pumping systems can save motor and heating/cooling energy in several components of commercial HVAC systems.

4.3.1 Variable Air Volume Designs

Air distribution fan energy is a significant fraction of energy use (about 10 percent) in any conditioned building. Many modern HVAC systems use an air distribution and temperature control design called variable air volume (VAV) to reduce fan energy required for temperature control. VAV systems use either inlet vane throttling or fan speed modulation as a volume control technique. Fan speed control by a VSD is preferable to inlet vane throttling because the fan power requirement with electronic speed control is much lower (20 to 50 percent of the fan power), compared to inlet vane capacity control.

4.3.2 Variable-Speed Exhaust Systems

Controlling exhaust fan volume (particularly in large exhaust systems in hospitals) saves fan energy as well as the energy required to heat or cool make-up air when exhausting excess conditioned air.

4.3.3 Variable-Speed Control of Cooling Towers

Many cooling towers employ either two-speed fans or variable-speed controls to control cooling tower energy use. The volume and temperature of air (also known as heat rejection load) moved through a cooling tower to maintain a given output water temperature is lower when outside temperature or humidity is lower (or both). A cooling tower has a certain capacity for cooling even when the fans are not operating. The heat rejection capacity of a tower is approximately proportional to airflow when the fan is operating. Thus, it is usually preferable to implement a tower fan control strategy that begins with the fan(s) off, step in the fan(s) at a low speed, and increase the fan(s) speed to high as the load increases or ambient conditions become more severe. When there are multiple fans in multiple tower cells, a strategy in which all fans operate at low speed together and increase to higher speed in response to increasing output water temperature will save substantial fan energy for the reasons described in the section on VAV control.

4.3.4 Variable-Speed Drives for Centrifugal Refrigeration Machines (including chillers)

Many HVAC or commercial refrigeration systems operate at less than their full-load capacity during a substantial part of their operating day. Inlet guide vanes that throttle the compressor suction are a common means of reducing refrigeration output capacity. However, throttling results in inefficiencies as varying motor speed via a VSD to modulate output results in lower demand (kW) per ton of output at part loads.

4.3.5 Variable-Speed Pumps for Condenser Water or Chilled Water

Motor-driven pumps circulate condenser water, chilled water, or both in larger central cooling systems. Before variable-speed drive equipment was available, capacity modulation and temperature control in these systems was achieved by throttling a valve (imposing a pressure drop) or by recirculating a portion of the water. Both of these methods are inefficient. Decoupled primary/secondary systems are now common both in new construction and as an efficiency retrofit for chilled-water systems with variable cooling loads. Variable pumping systems can be quite complex and often involve changes to fan coil valves and distribution piping. Moreover, centralized computerized control (i.e., an EMS) is necessary to assure optimal operation of these systems.

4.4 Demand-Response Ventilation

All nonresidential buildings are required to have fresh air ventilation. Typically, ventilation fans operate continuously during occupancy to replace oxygen that is consumed and to dilute and replace carbon dioxide and other impurities that are generated indoors. Because ventilated air must be tempered from ambient conditions to match the indoor conditions, fresh air ventilation requires both fan energy (to distribute it throughout a building) and heating or cooling energy (to bring it to the interior space temperature and humidity). Because ventilation control affects indoor air quality and health, it is imperative to implement reliable, failsafe control, careful monitoring, and alarms as part of the control strategy. Thus, demand-responsive ventilation should only be applied in conjunction with advanced controls, such as a direct digital control EMS.

4.4.1 Carbon Dioxide Sensing Systems

In a typical building, the only source of carbon dioxide (CO_2) is from human respiration. Relatively accurate and inexpensive CO_2 sensors are currently available. For intermittently occupied spaces of low CO_2 concentrations, the ventilation rate can decrease to a minimum of 0.15 cubic feet per minute (cfm) per square foot as long as the CO_2 concentration does not exceed a maximum level (California Title-24 specifies an 800 parts per million). This can be an effective energy-saving strategy and is particularly applicable to spaces with highly variable occupancy like auditoriums, gymnasiums, classrooms, meeting rooms, public and even some private offices, restaurants, cafeterias, and retail stores.

CO_2 sensors can be installed in any system that has independently controlled fresh air dampers capable of a wide range of flow rates (such as an economizer system). However, the CO_2 control system must be able to take control of the outside air damper whenever the building is not in economizer mode. Most unitary or packaged systems with an economizer, which is required by Title-24 for new construction, have a preset temperature control system for the economizer, and adding an interface for independent CO_2 control system can be difficult. As a result, CO_2-based ventilation strategies are implemented principally in buildings with built-up central HVAC systems rather than buildings using packaged equipment, unless the packaged equipment is specifically designed to accommodate customized outside air damper control.

CASE STUDY

As part of a plan to expand the existing EMS, Hewlett Packard Company added automated demand control ventilation. The EMS was re-programmed to send digital signals to reduce VAV box maximum air volumes. These reductions translate into a decrease in the power requirements of air handlers, pumps, and water chillers. CO_2 sensors were installed to ensure that air quality levels remain above standard as outside air intake is reduced.

Refer to Enhanced Automation Case Study #2 for more details.

4.4.2 Occupancy Sensing Systems

Occupancy sensors similar to those used for lighting systems can be installed in rooms to minimize or shut off supply air and/or exhaust to the rooms entirely when unoccupied. This strategy may be beneficial in buildings with large areas, e.g., training rooms, conference rooms, and chapels. However, for spaces where significant warm up or cool down periods are needed, this strategy is not recommended.

Occupancy-sensor or key-activated equipment is common in some countries and is now becoming more prevalent in hotel rooms in the United States. These systems can also be wired to shut off the lights, TV, exhaust fan, and to set back the heating/cooling temperature.

4.4.3 Carbon Monoxide Sensing Systems for Garages

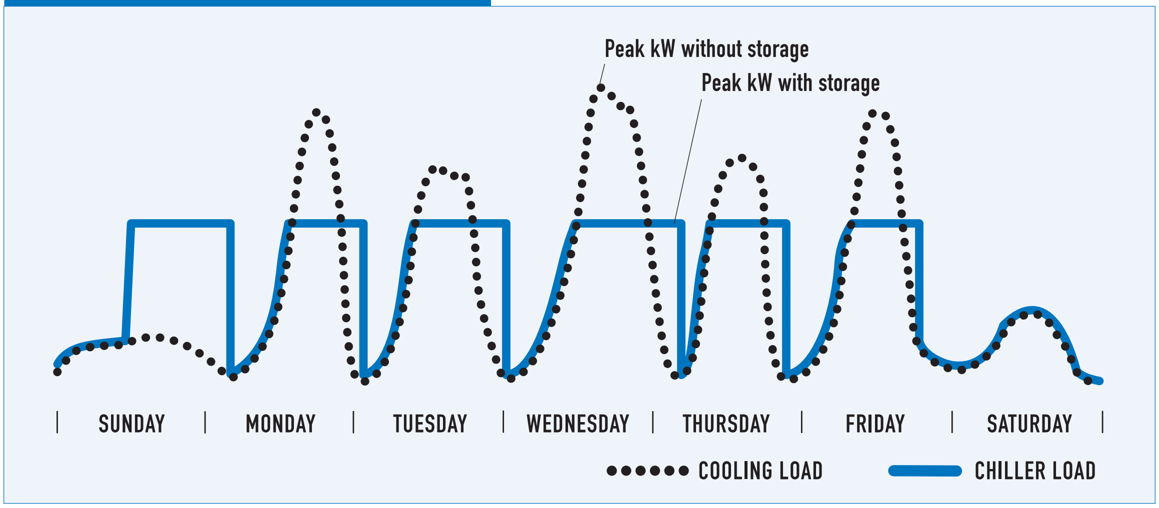
Carbon monoxide (CO) is an indicator of other gases of automotive exhaust. Indoor or partially indoor parking garages and shops have high volumes of exhaust and require supply ventilation to remove exhaust-contaminated air. Some of these systems operate continuously during the day and others are on time control to operate only when incoming or outgoing traffic is highest. Where permitted by code, a system of CO sensors tied to the supply and exhaust fans via the EMS will usually allow significantly reduced fan operation. In most applications, a CO control system will limit fan operation to morning and late afternoon rush hours when entrance and exit traffic is heaviest.

4.5 Peak Load Shifting Strategy

Thermal storage for HVAC is a peak-load shifting strategy in which refrigeration equipment makes cold water or ice during non-peak hours. The water or ice can be used to cool the building during peak hours, minimizing or shutting off chiller(s) during peak hours. The energy use (kWh) of a system designed for thermal storage is often slightly greater than a system without storage. The chiller operates at a lower efficiency to make lower temperature chilled water. A thermal storage system can reduce the on-peak chiller energy by up to 100 percent of the chiller load. Refer to the utility and government web sites listed in the Resources section 9 for more information.

Thermal storage systems are used in facilities that experience a significant cooling load during the peak period of the day. These systems are especially appropriate for facilities in which the night cooling and electric loads are very small because they can be operated in a "valley-filling" mode and produce the required cooling at night without increasing peak demand, as indicated in the figure below. In buildings operated 24 hours per day, the total building demand might increase because the storage chillers may need to operate at the same time as the building cooling chillers.

Thermal Storage Load Profile



The existing (or projected) cooling load profile should be reviewed by an engineer to determine the technical and financial viability of thermal storage as an energy cost-saving option. In addition to the cooling system characteristics, the electricity rate structure, the duration of the time-of-use periods, prices of energy, and demand during each time-of-use period are important elements for an operator or operation support contractor to understand in order to achieve the maximum benefits.

Thermal storage requires a hydronic (water-based) cooling distribution system. Its application is therefore limited to buildings in which a chilled-water cooling system exists or is proposed for new construction. Thermal storage systems are often difficult to retrofit because they require significant changes to piping and space for installation of storage tanks, and existing chillers may not operate efficiently at the lower temperatures needed for thermal storage. Thermal storage can often defer the entire load of the chiller, as well as the cooling tower and condenser pumps, to the off-peak period, significantly decreasing peak demand.

Depending on the peak period window and the building type, the required thermal storage capacity ranges from two to five tons per hour per square foot. Thermal storage systems require closer control than non-storage systems. Central computer-based controls are usually necessary for thermal storage systems, which in turn require a more knowledgeable operator or operating/support contractor.

4.6 Chilled-Water System Control

A number of advanced control strategies apply to central (chilled-water) systems that usually improve the overall efficiency of the cooling system. Several of these are described below.

4.6.1 Chilled-Water Temperature Control

Chilled-water temperature is typically set in the chiller control panel. Modern central control systems interact with the chiller control panel to allow chilled-water temperature to be set remotely and changed based on a variety of other factors that indicate chiller loading. Generally, the chiller efficiency increases by about 1.5 percent for each degree increase in chilled-water temperature.

Chilled-water temperature control can save energy and reduce peak kW demand. With constant-flow systems, short-term peak demand reduction might be achieved by raising the chilled-water temperature setpoint temporarily in response to a reset control strategy. However, the system must be carefully thought through by the engineer to define the optimal temperature and flow conditions to minimize overall power at a given cooling load. Increasing chilled-water temperature increases air and water flow requirements, which may increase fan and pump power requirements to meet the space-cooling load. Because fan power increases as the cube of the air-flow rate, relatively small increases in air rate can result in large increases in fan power. For this reason, advanced control strategies can only be implemented with an EMS.

4.6.2 Condensing Temperature Control

Similar to the evaporator temperature, the condensing temperature is also an important factor in determining the efficiency of cooling equipment. In general, the lower the condensing temperature is, the higher the efficiency of the refrigeration equipment. For any given cooling load and ambient condition, there is an optimal condenser temperature that will minimize the combined fan and compressor power. An engineering analysis by an experienced engineer or review of operating trend log data (via the EMS, if installed) will reveal a control strategy using a number of sensor inputs that can be programmed to minimize the chiller/cooling tower power. As a start, allowing the condenser water temperature setpoint to float four to 10 degrees above the ambient wet-bulb temperature (with a lower limit defined by the chiller specifications) should minimize the total input power for a given cooling load.

4.6.3 Cooling Tower/Evaporative Condenser Fan Control

Cooling towers and evaporative condensers are where the heat removed from the building by the cooling system is rejected to the atmosphere. For most cooling towers, about 10 percent of the heat-rejection capacity can be achieved by the evaporative effect of water flow without any forced air flow (i.e., with the fans off). From that point, for a given ambient condition, the heat-rejection capacity of a cooling tower increases linearly with the air flow through the tower. For this reason, the optimal control strategy for a multiple cell tower or condenser with VSD fan speed control is to operate all of the fans at low speed and allow the speed of all fans to increase together until the condenser water temperature setpoint is reached. With two-speed fan motors, the strategy would be to "stage in" all of the fans at low speed first, then sequentially increase the speed of one fan at a time to high (if necessary) until the temperature setpoint is reached.

Older analog control systems usually use a fixed temperature setpoint. Tower operation is linked to an associated chiller, and the leaving water temperature determines the fan speed only. Optimized cooling tower control can be difficult due to the number of inputs required with stand alone controls. However, if the sensor and control points are integrated in an EMS, the EMS can determine the fan speed from a complex algorithm involving ambient wet-bulb temperature, chiller status, cooling load, supply and return condenser water temperature, or other appropriate inputs.

4.7 Costs and Benefits

This section discusses the costs and savings as well as other benefits of several HVAC technologies and strategies discussed above. Below the tables, there is further explanation on the caveats and considerations surrounding the costs and benefits of some of these measures.

Costs for Adding to an Existing EMS

Measure	Costs	Notes
Shut-off with high limit	Programming time	
Night ventilation	Programming time	Activate HVAC fans in economizer mode
Optimal start	$100-$1,100 per zone	If additional hardware (e.g., temperature points) is needed, cost will be on the high end of the range – otherwise only programming time
Variable capacity control	$300-$500 per horsepower plus programming time	Adding a VSD can change the design of the HVAC system
Demand-responsive ventilation	$1,000-$4,000 per system, CO_2 or CO sensor costs $100-$300 each	Several additional sensor points, wiring, and programming
Thermal storage	$200-$400 per ton-hour or $500-$800 per ton-hour if new chiller is needed	Costs are for storage tanks, pumps, heat exchangers, and piping – new chiller might be required for efficient operation at low temperatures*

** For a new building, costs versus a non-storage system may increase up to 20%-30% more.*

Benefits for HVAC EA Measures

Measure	Energy Savings	Notes
Shut-off with high limit	20%-40%	Compared to full time operation at occupied temperature setpoints and for typical 9-to-5 building
Night ventilation	0.1%-2% of cooling energy use	May reduce morning demand on the HVAC system
Optimal start	5%-10% of fan and heating/cooling costs	Saves hundreds of hours of fan and cooling system operation compared to fixed start-time strategy
Variable capacity control	10%-30% of fan or pump energy use, 5%-15% of total building energy use	Benefits are highly site and application specific, peak demand savings tend to be lower because variable-capacity systems have more impact on efficiency during part-load operation
Demand-responsive ventilation	20%-70% of ventilation HVAC use, 2%-7% of total building energy use	Compared to outside air flow rates in normal operation
Thermal storage	10%-50% of cooling use, 2%-10% of total building energy use	Compared to conventional, non-storage operation

4.7.1 Variable-Capacity Control

VSDs can add significant complexity to the control of HVAC systems and therefore must be carefully designed and implemented. Potential modifications that add cost include distribution boxes and diffusers (for air systems) and control valve selection and temperature control strategy (for hydronic systems). Although variable capacity control strategies can be implemented through self-contained pneumatic or electric control systems, their effective application to optimize energy savings usually calls for an EMS to provide the response, precision, flexibility, and real-time tracking necessary to optimize system operation.

4.7.2 Demand-Response Ventilation

The energy savings impact of demand-responsive ventilation control can be significant when compared to a typical design of full-time, constant-volume ventilation. The type and use of the building and the existing ventilation strategy affect the potential energy savings. CO_2-based controls can reduce overall energy use for buildings where actual occupancy is much lower than the design occupancy for a large part of the operating day. In many applications, impacts occur during the peak hours as well as early and late in the day, so peak demand savings will also result.

Occupancy-sensing HVAC controls can be very effective in reducing energy use and peak demand in hotels and training facilities with many small meeting rooms. Control of garage ventilation based on CO levels should be cost-effective when compared with constant or timed fan operation and should be considered if permitted by local building codes. Demand-responsive ventilation is also worth considering for a garage system with an existing time control, although the return on investment period will be longer as the time control achieves most of the potential savings.

4.7.3 Thermal Storage

The financial benefits of thermal storage depend entirely on the energy (kWh) and demand (kW) load that can be moved from the peak period to the off-peak period and the difference between the on-peak and off-peak price of kWh and kW. A time-of-use rate structure is necessary for thermal energy storage to be cost effective. Nearly all utilities have a time-of-use rate and/or a special rate to encourage thermal energy storage. The savings depend on the load profile of the facility, the cooling load, and the electricity price structure. If real-time or hourly pricing electric rates apply, the thermal storage system control can interface with the price signal and other variables from an EIS to manage system operation for least overall cost.

4.8 Further Considerations

The primary reason for installing EA is to achieve greater control of building systems while lowering overall operating costs. Some of the benefits that EA provides to HVAC control include:

- Demand-based control that minimizes cooling loads
- Optimized control that reduces HVAC loads with systems such as external shading, economizers, etc.
- Coordinated operation of interactive subsystems
- Coordinated and optimized control of subsystems to meet thermal loads at minimum energy input (i.e., optimize overall system efficiency)
- Coordinated and optimized operation of multiple complex systems (i.e., multiple buildings on a campus or multiple remote buildings)
- Informed or automatic decision making on system operation related to external factors

Similar to lighting, opportunities exist to improve the efficiency and savings levels of the HVAC systems for most buildings. In new construction, designers and engineers should consider all EA technologies for the HVAC system as cost-effective technologies can most easily be installed at the time of construction.

When retrofitting existing HVAC systems with controls, a more detailed, complicated analysis is necessary to determine the practicality and cost-effectiveness of the project. Buildings with no central controls are good candidates for HVAC EA, especially buildings that have varying occupancy levels and varying requirements in the individual cooling/heating zones.

5 ENERGY MANAGEMENT SYSTEMS

This section discusses upgrading/reprogramming an existing energy management system (EMS) or installing a new system. EMS are found in most commercial settings and have become widely-accepted by facility management. As prices have dropped and equipment control technologies have become more sophisticated and available, EMS have become important tools for energy managers to define and implement the most effective energy strategies. EMS vendors report that existing systems are found in approximately 75 percent of commercial facilities that are over 50,000 square feet. In short, an optimized EMS should be considered in almost every type of commercial building with peak demand charges greater than 200 kW.

All control systems provide a number of basic control functions that, taken together, form the system control strategy. Many of these basic control functions are required by the California Energy Code (Title-24) for new buildings and are used to some degree in most large commercial buildings. All buildings, regardless of their size and sophistication, should include basic control functions as a part of their operating strategy. These systems may be implemented through stand-alone or central systems, such as an EMS. The specific EA operating control strategies to consider in a building depend on the overall design of the HVAC and lighting system and the degree of control for which the owner is willing to pay.

Enhanced control abilities achievable with an EMS include:

- **Real-time monitoring** of all sensor, control, and status points from a central location
- **Convenient troubleshooting** of comfort or other complaints from a remote or central location
- **Alarms and notification** delivered through automatic paging or telephone messages to the system operator if equipment is not operating correctly
- **Daily, hourly, or minute-by-minute trend records** of any sensor or control point
- **Energy use or operating records** for tenant billing, cost accounting, security, building access, maintenance, or safety documentation
- **Sophisticated control strategies** to maximize operational efficiency

EMS strategies specific to lighting and HVAC systems are discussed in the previous two sections. This section addresses the following topics:

- What is an EMS and what distinguishes it from a building automation system (BAS)?
- What are the various building control technologies?
- Costs and benefits of EMS
- Choosing a vendor
- When to install and/or keep an existing system
- Communication protocols
- Connectivity to the EIS

5.1 What is an EMS?

An EMS provides customers with the ability to centrally monitor, analyze, and control their facilities' building systems and equipment to achieve energy-efficient operation. Fundamentally, an EMS is an information and control system used to optimize operations of end-use equipment using a computer with application software, a custom-programmed database, a communications network, and a series of control devices and data sensors.

An EMS operates building system equipment through a control loop, which is comprised of controllers, sensors, switches, relays, and end devices. These parameters could include air temperature, water temperature, lighting levels, and many other points that monitor or allow for action.

5.1.1 BAS vs. EMS

An EMS can be either an independent system or be based on the monitoring and control characteristics of a building automation system (BAS) or a system control and data acquisition system (SCADA). Vendors often package their direct digital control-type (DDC systems are defined below) BAS[4] so the system can be upgraded to an EMS through the addition of controllers and/or software. SCADA installations are not nearly as prevalent as BAS installations. Energy information system (EIS) technology (described in section 6) can be used even when limited EA functionality (in BAS and SCADA) is available. SCADA systems, for example, can have a gateway with an EIS to offer real-time energy monitoring, billing validation, rate negotiating, and load aggregation. The capabilities of a BAS, which are specific to building systems control by design, offer advantages in application development cost and easier integration with EMS software and equipment.

An EMS optimizes equipment operation through supervisory control programming that implements more advanced system control strategies than typically found in a BAS. The supervisory control programming requires additional monitoring and control system parameters than traditional BAS control systems for execution.

Both EMS and BAS can use direct digital controls (DDC) or pneumatic control systems, which are described later in this section. EMS typically can handle the functions of a BAS. Traditional BAS functions (for DDC or pneumatic controls) include:

- Facility environmental conditioning
- Environmental system monitoring and control
- Facility security/access control (DDC only)
- Facility fire system annunciation/control (DDC only)

[4] *Unless otherwise noted, the guidebook refers to the DDC type EMS.*

In addition, EMS functions (for DDC type controls only) can also include:

- Supervisory monitoring and control
- Supervisory control strategies
- Optimum start/stop
- Duty cycling
- Load shedding
- Load shifting
- Data analysis tools for energy accounting

Employing EMS analysis tools also permits the evaluation of system performance, historic data trends, and current building operation to make effective decisions on methods that further optimize the system. For example, businesses can use an EMS to display energy usage trends over time and to facilitate assessment of different lighting, HVAC, or equipment control load-reduction strategies. However, actual trending and data storage capabilities depend on the system installed.

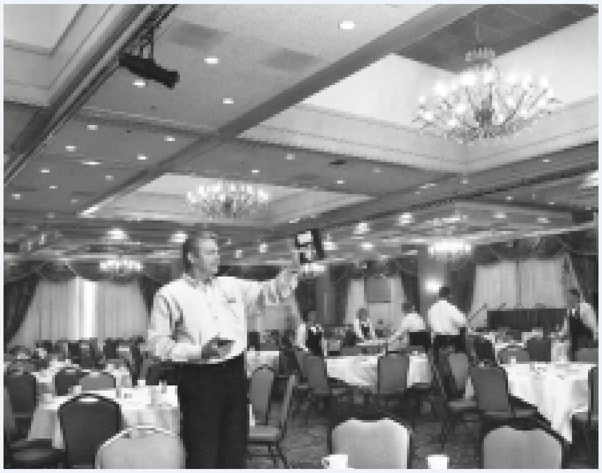
5.1.2 System Communication

Historically, customers have accessed the EMS or BAS through a local hardwired communications network linked with remote telephone connections. However, several vendors now offer EMS and BAS access via the Internet, which permits remote access. Also, currently available are local wireless EMS and BAS, which function similarly to hardwired systems. Wireless systems offer improved ease and speed of installation, which is particularly beneficial in difficult retrofit and variable system applications.

CASE STUDY

The Doubletree ®Hotel Sacramento installed DDC modules to monitor and control chilled water loop temperatures, outside air intake, and fan speeds. A software interface to the utility meter allows for real-time access to energy use data. Facility operators can now see which systems are drawing the most load and use the EMS to shed chiller and fan loads accordingly.

Refer to Enhanced Automation Case Study #6 for more details.



There are several different types of EMS/BAS technologies that are intended to control building systems. The following discussion distinguishes between three of the main types of EMS/BAS technologies: pneumatic controls, electric controls, and DDC systems.

5.1.3 Pneumatic and Electric Controls

Generally, pneumatic and electric control systems are installed either in facilities with a significant amount of similar controls already in place or in smaller, low-complexity buildings. Pneumatic systems employ an air compressor that supplies pressurized air through a system of distribution lines to sensors and devices like thermostats, valves, dampers, and actuators to control operations. Pneumatic systems are reliable, economical, and typically less expensive than their electric counterparts. In many instances, the existing pneumatic actuation can be reused or reinstalled during the upgrade from a pneumatic to a DDC control system.

Widely available electric control systems are comprised of electric system controllers, sensors, thermostats, switches, relays, and actuators connected by electrical wiring. Frequently, mechanical equipment manufacturers offer stand-alone electric controls as an integral component of the mechanical system it serves, but these controls are limited in their functionality and the capability of viewing or knowing the overall building system performance.

While pneumatic and electric systems require relatively little maintenance, they do require an ongoing preventive maintenance program to ensure proper operation. Pneumatic and electric systems do not accommodate remote monitoring of equipment operations or space conditions and are typically not as easy to modify or expand as DDC systems. In addition, most changes to equipment operating sequences require additional components and connections, resulting in higher labor and material costs than would be the case with DDC systems.

5.1.4 Direct Digital Controls

DDC is a system in which networked microprocessor-based controllers are connected to devices that either sense information or control operations of facility systems and equipment. DDC is the most common EMS technology currently being installed.

DDC systems are more powerful, flexible, and have more features than their pneumatic and electric counterparts. They are also easily scalable from small to large and from simple to complex systems. DDC systems provide facility managers with sophisticated information such as data trends and historical data, which can be invaluable for efficient operation and troubleshooting. DDC systems offer a high degree of sensor accuracy and control precision, as well as a higher level of system analysis and control strategies than other systems. Typically, these systems have a user-friendly interface, which can be accessed locally or remotely to adjust the system or modify its capabilities. DDC systems also can serve to reduce maintenance and calibration costs and are generally easily expandable. DDC is relatively easy to integrate with (or might include) other computer-based building systems like fire, security, and maintenance management systems and can generally carry out more sophisticated and complex control strategies.

Pneumatic actuation of end-use devices is frequently used with both new DDC installations and pneumatic system upgrades to DDC systems. This hybrid control system provides a faster control response of the load, providing better control at less cost than electric actuation. However, this type of system requires an air compressor to provide clean, dry air for control.

For some building and HVAC types, DDC is not the most appropriate or cost-effective option. For example, basic unitary or multi-unit control systems (electric or pneumatic) provide basic control and simple energy management functions, usually based on simple thermal, flow, or pressure sensors. These systems are designed for and used on a single building only. Most any other facility should consider installing DDC systems.

5.2 Costs

The installation costs associated with an EMS vary widely due to varying levels of complexity between one facility and another, as well as the economies of scale inherent in larger systems. However, the installation cost for a typical EMS installation can be roughly approximated, using the building square footage and the commercial cost factors of $1.75 to $4.00 per square foot. These numbers were derived from interviewing various EMS installation companies. Note that these cost estimates do not reflect the complexity or size of the installation directly but nonetheless provide a rule of thumb.

Complexity levels refer to the ability of EMS to perform. These functions range from static to dynamic control. Static refers to simple control capabilities that do not necessarily rely on any monitoring information and perform operations from programmed algorithms that are based on fixed, set parameters. Dynamic refers to the automation and optimization of strategies with multiple inputs and outputs. The table below shows the control components of the various functions in static and dynamic EMS (including mid-level) along with the associated costs.

EMS System Complexity Levels and Costs

System Complexity Level	Control Components	Average Cost per Building Square Footage
Static	Packaged units and chiller start/stop control based on time and temperature; fan and possible lighting on/off control based on time; and/or water temperature control based on time and temperature	$ 1.75
	Static plus: Economizer controls; Chiller plant controls; variable-speed drive control; night temperature control; CO_2 ventilation strategies; and/or lighting control strategies	$ 3.00
Dynamic	Plus: optimal start/stop; demand limiting strategies; daylighting controls; thermal storage controls; and/or optimizing HVAC operations	$ 4.00

Alternatively, an average cost per-point approach can be used to determine an approximate EMS installation cost. Commonly, an average cost per point of $1,100 is used.[5] A point refers to any controller or sensor signal connected to the EMS. Caution needs to be exercised when using average point costs to develop installation cost estimates because point costs can vary widely, depending on the cost of the end device, distance from control panel, point concentration, need for plenum-rated cable vs. conduit and wiring, level of installation difficulty, end device cost, and control strategy complexity.

[5] *"2001 DEER Update Study," prepared for the California Energy Commission contract number 300-99-008, prepared by XENERGY, Inc., August 22, 2001.*

$ The table below provides typical costs per unit for common end devices found in EMS.[6]

Typical Costs* for Common End Devices for EMS

Monitoring Points	End Device	Material	Labor	Total
Outside Air Temperature	RTD with Outside Air Enclosure (C)	$ 40	$ 600	$ 640
Space Temperature	Wall mount RTD (P)	$ 30	$ 600	$ 630
Exhaust Air Temperature	Duct Mount RTD Temperature Sensor (C)	$ 65	$ 325	$ 390
Chilled Water Temperature	RTD Temperature Sensor and Brass Well–new construction (C)**	$ 90	$ 850	$ 940
Duct Static Pressure	Differential Pressure Sensor (C)	$ 275	$ 325	$ 600
Fan Status	Current Sensor (C)	$ 100	$ 480	$ 580
Electric Consumption	Electric Meter (C)	$ 1,150	$ 500	$ 1,650
Water Consumption	4 inch Water Meter – new construction (C)	$ 1,650	$ 650	$ 2,300
CO_2 Level	Duct mount CO_2 sensor (C)	$ 800	$ 425	$1,225
Control Points				
Chilled Water Valve Control**	3 inch 2-Way Valve with Electric Actuator–new construction (C)	$ 530	$ 550	$ 1,080
Mixed Air Damper Control**	(2) Electric Damper Actuators, Proportionalw/Spring Return (C)	$ 960	$ 500	$ 1,460
Fan Speed	VFD input (C)	$ 125	$ 325	$ 450
Pump Start/Stop	Low Voltage Relay (C)	$ 35	$ 595	$ 630

**Costs are for a 50-foot cable run.*
*** Includes mechanical installation*

C=conduit electric metallic tubing and wire installation
P=plenum cable installation cost

The total point costs in the table above are for the material and installation costs of the point (raw cost). Additional EMS cost elements incurred during system implementation are presented in the table below and are calculated based upon a 250-point system.[7] An average raw point cost of $600 is assumed, plus additional costs for the implementation items.

Total point cost $600 per point X 250 points	$ 150,000
Additional material and implementation costs	$ 151,670
Total system installation cost	$ 301,670

As a quick check, the average-per-point cost of about $1,200 for the calculated system cost is consistent with the average point cost value of $1,100 per point given in the text above.

[6] *Raw point costs, which do not include commissioning, programming, and control panel costs. Reference: "2002 Mechanical Cost Estimating", RS Means Company Inc., Kingston, MA and Kele, Memphis, TN June 2001.*
[7] *Number of points varies widely and depends on square footage, HVAC system, and complexity of EMS.*

Typical Additional Material and Implementation Costs for a 250-point System[8]

Hardware and Software System Components	Description	Unit Material	Unit Labor	Extended Total
Outside Air Temperature	Includes processor, system software, CD drive, monitor, mouse, printer, and modem	$6,000	$ 250	$ 6,250
Central Computer BAS Software	Provides remote monitoring and control and advance control strategies	$6,000	—	$6,000
BAS Communications Network	Plenum cable, 2000 ft	$ 1.50/ft	$ 2.00/ft	$ 7,000
(13) 16-Point Control Panel	Materials and installation	$2,000	$300	$29,900
(4) 32-Point Control Panel	Materials and installation	$3,500	$550	$16,200
System Design/ Installation				
Calibration	Analog Point Calibration	—	$80/point	$ 20,000
System Commissioning	Includes end-to-end wiring check, end devices operation, program installation and verification	—	$120/point	$30,000
System Engineering	Includes system design and point programming	—	$80/point	$ 20,000
Project Management	136 Hours	—	$ 120/hr	$ 16,320
TOTAL Additional Material and Implementation Cost				**$151,670**

5.3 Benefits

In general, the benefits of installing an EMS, in addition to energy savings associated with the strategies programmed, include improved system operation, energy management and control, and management of system maintenance.

- **Improved system operation via:**
  - Higher sensor accuracy
  - Superior temperature control and occupant comfort
  - Centralized scheduling
  - Higher control scheme complexity capability
- **Improved energy management and control via:**
  - Efficient equipment operation
  - Energy use tracking (used to monitor performance of energy saving operation strategies or sub-metering tenant spaces)
  - Central building system monitoring
  - Ability to implement control strategies

[8] *"2002 Mechanical Cost Estimating," RS Means Company Inc., Kingston, MA and Kele, Memphis, TN June 2001.*

- **Improved management of system maintenance via:**
  - Central and remote building system monitoring
  - Recording of equipment runtime and automatic generation of scheduled maintenance work orders
  - Trending and monitoring of system parameters used for troubleshooting building systems and equipment
  - Alarm monitoring to detect abnormal conditions and equipment malfunctions and notification
  - Improved response time to abnormal system operation
  - Automation of daylight savings time adjustments
- **Additional benefits of installing EMS features are:**
  - Connection to multiple facilities and software tools provides easy aggregation of energy real-time use, allowing enterprise level analysis and decision making
  - Integration of multiple building systems (building access/security, fire), resulting in intelligent buildings
  - Sub-metering of utilities for tenant billing or tracking of energy project performance

In general, energy savings resulting from the installation of a DDC EMS range from 10 to 15 percent of building energy use, especially when a poorly operating/maintained pneumatic or an older DDC has been upgraded. Reprogramming or installing additional monitoring and control points in an existing system can provide energy savings as well.

5.4 Further Considerations

There are a number of important decisions to make when considering an EMS as an EA strategy. These considerations are discussed below.

5.4.1 Choosing a Vendor

Most EMS manufacturers provide systems with the features and capabilities described in this section. However, different equipment manufacturers employ different distribution and support strategies that should be considered when making an equipment selection. Some equipment is sold and supported through a network of factory outlets or local distributors, while other equipment is offered through local maintenance and installation contractors. Depending on how vendor support contracts are structured and how facility management activities are conducted, one or more of these business models may be more desirable. For example, if a company is at a single site and has been contracting out building maintenance, then a system supported by a local building maintenance contractor might make sense. If, on the other hand, the company operates at several sites in multiple regions of the country, there may be an advantage to selecting a vendor with a national presence. The decision making process is described in more detail in the Decision Making section 7 of this guidebook. Also, available from the California Energy Commission is a list of EMS vendors.

5.4.2 When to Install a New or Retrofitted EMS

Both new or retrofit installations of EMS are often beneficial. However, retrofit installations to existing mechanical systems cannot compensate for poorly functioning mechanical systems and/or equipment. Customers must evaluate the existing building system design and equipment for inherent operational problems and weigh the benefits of an EMS installation accordingly. However, if an EMS is over 12 years old, a business should seriously consider replacement.

5.4.3 Reprogram an Existing System or a Install New System

For facilities with an installed DDC system, EMS functions may be gained by adding equipment and/or applications programs, depending on the age of the DDC equipment. The average life cycle of a DDC system ranges from 10 to 15 years, based on system maintenance habits, field conditions, and technology advances. Typically, DDC manufactures' current product offerings are backward-compatible to older system products, which allows the two systems to be connected, upgraded, and expanded. However, a detailed analysis should be done analyzing the functionality, features, and the limitations of a system made up of new and old elements. Each application must be evaluated independently. The network communications speed, memory capacity, and upgrade of the older system may compromise performance. Improvements in system user interface methods, speed, and equipment should be considered when making upgrade or new system decisions. Additionally, EA expansion options may be limited to products and services offered by the original vendor, due to proprietary issues.

5.4.4 Communication Protocols

Communication protocols, a critical part of an EMS, are standardized rules governing the transmission and reception of information between devices (computers and controllers) connected through an EMS communications network. EMS vendors and/or components with differing communications protocols may not be compatible or may require additional hardware/software components. The additional hardware or software components required for system integration are known as gateway or interface panels. Costs can range from $5,000 for off-the-shelf models to over $15,000 for custom models.

The IEEE Standard 802 defines three distinct classes of communication protocols as follows:

- **Standard protocols** are detailed in published documentation and are administered and controlled by a standards governing body,
- **Public protocols** (or shared protocols) are detailed in published documents but are administered and controlled by a private organization, and
- **Private protocols** (or proprietary protocols) are not released in published documents and are for use by and administered and controlled by private organizations.

Previously, EMS components were manufactured to operate only with private protocols. More recently, however, these manufactures and building system equipment manufacturers have added the capability of their systems to operate with standard protocols and/or interface with systems manufactured by other manufacturers. Many vendors have hierarchical layers of communication networks within an EMS, where specific types of control panels and/or devices are capable of being connected to other similar types of panels on the same layer.

Customers should be aware of specific system communications protocol requirements or of any communications compatibility issues of systems and equipment regarding system implementation and future system expansion connectivity.

The following four categories of communication protocols are commonly installed with DDC systems:

Proprietary systems. Many DDC equipment manufacturers use a proprietary communications protocol developed and owned by the manufacturer. This limits the connection of future system devices to those of the same manufacturer and/or the manufacturers' partners. As a result, this protocol type is called a closed protocol.

BACnet™. The BACnet™[9] communications protocol was developed by and is administered and controlled by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) as a standard communications protocol (ANSI/ASHRAE Standard 135-1995) for DDC. The standardization of an open protocol allows control panels/devices of differing manufacturers to be connected and operated on a common DDC communications network.

Although the BACnet™ protocol permits the interconnection of equipment from different manufacturers, some of the capabilities present with the native system may be lost. Manufacturers' DDC equipment must be tested and certified to be considered "BACnet™ compatible." Installing BACnet™-compatible systems and components allows more flexibility in selecting subsequent products for future systems.

LonTalk. LonTalk is a standard network communications protocol developed by the Echelon Corporation and is administered and controlled by Electronic Industries Alliance. This protocol is considered to be a standard protocol due to its listing as an ANSI/EIA standard (709.1 Control Networking Standard) and allows a DDC network to connect to multi-vendor DDC components, termed interoperability. The standard protocol status allows any DDC component manufacturer to incorporate the LonTalk protocol into its product. The product is then tested by the LonWorks® Interoperability Association and listed as LonMark-certified.

TCP/IP Protocol. Transmission Control Protocol/Internet Protocol (TCP/IP) was developed by the Advance Research Projects Agency (ARPA) and may be used over Ethernet networks and the Internet. Use of this communications industry standard allows DDC network configurations consisting of off-the-shelf communication devices such as bridges, routers, and hubs. Various DDC system manufacturers have incorporated access via the Internet through an IP address specific to the DDC system.

5.4.5 Connectivity to EIS

In addition to other functions, an EIS can provide program or price signal alerts from an energy supplier to enact a load reduction. It can be connected to a facility EMS via a gateway, which provides the link to end-use equipment and controls. The end user, either manually or through an automated response, can then reduce load. In most cases, the EIS collects data at the overall facility level, often at the revenue meter, and can include information about billing, usage, and trending. It can also deliver the demand-response signal as well as monitor a load-shedding event. The EMS, on the other hand, can provide some of the same information, but the EMS primarily functions as the data and controls link to the actual end-use equipment and circuits. The next section discusses EIS in more detail.

[9] *BACnet™ stands for Building Automation Control network.*

6 ENERGY INFORMATION SYSTEMS

While most EMS allow end users to view and track the energy use of equipment or applications within a facility, some customers want to access that information on a more system-wide basis—particularly if their operation has multiple buildings or sites. EIS can operate independently of, or can serve as a gateway to, the EMS and are generally designed to address these fundamental monitoring and tracking needs.

The energy information collected at the meter allows for a facility-wide overview of energy costs and usage, giving the end user more information from which to make critical energy-saving and purchasing decisions. Additionally, EIS platforms collect building data to be analyzed later for measurement and verification or to trend usage over time. Most EMS do not collect and store a large amount of information for a long time, but rather the information can be kept in an EIS.

EIS is a relatively new technology compared to EMS, but can provide energy and demand savings in ways not previously available. This section addresses the following fundamental issues surrounding EIS:

- What is an EIS and what distinguishes the information and services associated with an EIS from the information and capabilities of an EMS?
- How much does an EIS cost? What cost considerations cause system pricing to vary across vendors and systems?
- How can a business use an EIS to participate in load-curtailment opportunities to reduce energy bills and reduce the likelihood of rotating blackouts? What advantages does an EIS offer end users?

6.1 What is an EIS?

An EIS is a software and/or a communication protocol administered either by a single company, a partnership, or a collective that provides information to end users, utilities, and suppliers on system-wide performance. Information commonly received includes energy use, real-time prices, and weather forecasts, all on a computer screen.

The following list illustrates the product offerings and descriptions of various features and benefits used to market EIS:

- Monitor the real time of energy use of a facility for analysis of building data
- Monitor wholesale energy prices which allows end users to selectively adjust energy consumption when prices are highest
- Provide reports analyzing billing for any errors, inaccuracies, and decision making
- Identify building equipment inefficiencies with real-time information on energy usage patterns
- Aggregate and analyze operational information creating benchmarks that correlate to operation inputs
- Prepare, evaluate, and respond to load-curtailment requests and analysis of effects of the response from operational changes
- Able to adapt to changing energy demand, availability, pricing and weather conditions
- Compare and analyze alternative electric rate structures

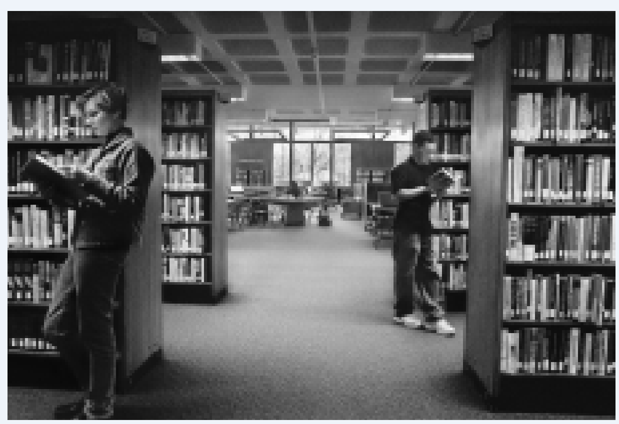
Generally, EIS can be divided into three types:

- **Notification – based systems** alert the operator or EIS (for a potential responsive action) of peaking demand conditions or abnormal events. While any building type or load size can potentially benefit from notification-only systems, they are often most appropriate for buildings where there is a desire to curtail load when a supply shortage occurs or to alleviate costs when rates are high. For the same reasons, these EIS types are also valuable for demand-response programs and for gathering periodic or real-time utility meter data. This platform allows companies to bid for demand reduction.
- **Analysis – based systems**, in addition to notification-based services, provide the ability for data analysis of energy usage and cost, forecasting, and bill consolidation. They are recommended in many situations, but are most beneficial for buildings with a high level of automation, which allows for more accurate and comprehensive data collection. EIS with analysis capabilities can provide a wide range of benefits from savings on administration costs in billing tenants to planning budgets for upcoming years.
- **Response – based systems** are a step above analysis-based systems because they react automatically to peaking demand conditions or external signals to reduce load, or they provide the necessary information for the operator to react. These systems provide the gateway for two-way communication between the EIS and EMS. Automated response systems are usually necessary for high-demand facilities. Reacting manually can be time consuming, prone to errors, or possibly an incomplete implementation of the desired demand-reduction activities. It is important to consider occupant comfort when planning the auto-response signal. Building types where comfort is critical, such as hospitals, hotels, and retail, should be conservative when programming the automated response system for load-reduction.

CASE STUDY

Foothill-DeAnza Community College District installed a system with Web-enabled EIS and EMS components as a result of the energy crisis in 2001. From a password-protected website, the District is now able to curtail up to 1.7MW of peak load within minutes and can monitor the immediate effects of curtailment on campus-wide demand levels

Refer to Enhanced Automation Case Study #4 for more details.



There can be conceptual overlap among the functional aspects of energy information and management systems due to the wide variety of options available to meet specific end-user energy needs. One-on-one customized implementation of services by vendors, flexibility, add-on platforms and specialized services make it difficult to guide customers as to which system, platform options, and communication protocol may be the best suited for their needs. Technology vendors offer recommendations to end uses regarding which communication protocols are needed to participate in a demand-reduction program as well as to discuss the functions, costs, and benefits of one protocol over another.

6.2 Costs

EIS costs are primarily in the areas of software, communications, and transaction management. Costs are more subject to variation due to alternative technology and design approaches among vendor products. Regardless of the specific application, however, there are three basic fee structures when contracting with a vendor for EIS platforms:

- Overall set-up or licensing fees
- Monthly fees
- Transaction fees

6.2.1 Overall Set-up or Licensing Fees

This general category of fees varies based on who is being charged: the utility or the customer. It is heavily dependent on what type of metering technology a site has or needs to interface with the vendor's network platform. For example, some vendors charge installation fees to end users that vary depending on the needs of a particular site, and if the company intends to implement an automated response. Utility charges can include licensing fees, platform system maintenance, or information service access.

6.2.2 Monthly Fees

Monthly fees vary significantly among vendors, among customers, and from site to site. In most cases, monthly fees assessed to customers include 24-hour, 7-day-a-week access to vendor assistance and data center resources. Some vendors, particularly if an automated EMS is in place for an end user, charge monthly fees based on load monitoring and metering. In those cases, the structure and amount of those monthly fees is site and equipment capability specific and is negotiated on a case-by-case basis. Businesses that have chosen internal EIS may not be subject to monthly fees.

6.2.3 Transaction Fees

Transaction fees are assessed only if the company participates in a demand-response program. These fees are charged per event. This transaction fee generally covers two-way notification. In some cases, verification and settlement of load with the entity providing the demand-responsive program is included in the transaction fee. Other vendors may charge an additional per customer/site per event verification and settlement fee.

These costs are summarized in the table below.

Energy Information System Costs

Cost Component	Cost Range	Factors Affecting Cost
Installation Fees	$1,500–$15,000	Existing metering and equipment interface capability Facility size/equipment type, number of points
Monthly Fees	$0-$1,500[10]	Often negotiated or offset by utility payments to vendor
Transaction Fees	$50–$200	Specific fee/payment arrangement with vendor or utility in contract

Costs can be explained via the three levels of EIS: notification, analysis, and response. The costs can be divided into hardware hook-up, such as devices at the meter and wiring; software licensing and initial system installation; system usage or licensing via an application service provider; and other fees, which include service and maintenance.

[10] *These ranges of costs were obtained through a number of discussions with EIS technology vendors. In many cases, an EIS vendor contracts directly with a utility to offer their platform of services. In these cases, costs for EIS software and monthly fees are paid to the vendor by the utility. The utility has the discretion to pass through all, some, or none of the fees in any number of ways across its customer base.*

End-User Costs of Varying Levels of EIS (per site)

EIS Levels	Hardware Hook-up (per site)	Costs to Acquire or Use Energy Information Software and Systems		Service, Maintenance & Other Costs or Fees (monthly/site)[2]
		Software Licensing & Initial System Installation (&/or annual fee)	System Usage (ASP[1]) or Licensing (monthly/site)	
Notification	$0-$3,000	$3,000 (&/or > $500/yr)	$25-$100	$0-$50
Notification & Analysis	$3,000 or more	$5,000-$10,000 (&/or > $1,000/yr)	$100-$250	$100-$150
Notification, Analysis & Response	$5,000-$15,000	$25,000-$50,000 (&/or > $1,200/yr)	$400-$1,000	$400-$1,200

[1] *ASP = Application Service Provider*
[2] *Other fees depend on the services included in an EIS such as data storage capabilities and weather forecasting.*

6.3 Benefits

Customers find good value in using an EIS for several key reasons:

- **Quick and Reliable Information.** Many EIS offer a platform consisting of multiple suites (or analytical tools), that calculates and graphs costs and savings, which would otherwise be costly and time-consuming to develop independently. Examples include energy bill summaries across facilities and/or checking for billing errors.

- **Analytical Tools.** In addition to aiding in equipment and energy related decisions, this information can also be used in company reports and updates to communicate trends or illustrate usage over time. EIS allow end users to view energy usage historically or in real time, offering a quick way to manage old or persistent usage problems. To take advantage of the analytical platforms, an end user need not have metered the building's energy usage for real-time data collection links to the vendor's software server (but would need interval meter data). However, many vendors offer enhanced analysis and decision making tools in response-based systems capable of providing real-time feedback to end users.

- **Energy Usage Adjustment.** EIS can allow energy or facility managers to adjust electrical demand in real time (particularly at peak hours when demand charges from utilities can be high) based on the information that is collected directly from meters and analyzed using their EIS software. Some EIS also include an automation component for load shedding in which an end user may choose to automate its load response based on any number of predetermined parameters, rather than by manually adjusting equipment and controls. The energy savings associated with an EIS platform or suite of services varies depending on the goals of the end user, the efficiency of existing equipment, and the decisions facility or energy managers make in response to the information obtained from an EIS application.

- **Software Upgrades and Support Centers.** As part of the EIS contract, nearly every vendor offers customer access to technical assistance and a call center with 24-hour, 7-day-a-week access.

- **Load-Curtailment Incentive Program Participation.** A number of EIS allow end users to participate in utility demand-response programs (for bidding) by including utility pricing information in the calculation of a customer's real-time energy use for real-time monitoring. This allows customers to view savings at different levels of load curtailment.

6.3.1 Use of an EIS to Participate in Load-Curtailment

The previous section described how end users may choose to make load adjustments based on consumption and pricing information received through an EIS to save money both in operating costs and on energy bills. However, more formal demand-response program participation, which involves program enrollment, pays the end user incentives for curtailing energy usage if the end user cuts back to an agreed-to minimum amount when the program administrator calls an “event.” A demand-response event could be based on an economic threshold in the market or may be based on an emergency geared to avoid shortages. In such cases, program guidelines spell out when and how to participate. Under specified circumstances, program participants are paid in exchange for load reductions on demand.

Properly configured, an EIS can monitor a building’s load and usage and allow end users to participate in a demand-response program. To respond to demand-response program events, at a minimum, an EIS would need to provide real-time pricing information so that the customer could decide whether the benefits of participation exceed the cost of participation. If a customer has interval meters already installed through an EMS, then an EIS protocol can, using a gateway box or other similar linking device, access that real-time load information and combine it with real-time pricing information. Then, a customer can make load optimizing decisions based on reliable and timely energy and pricing presented through the EIS protocol(s).

CASE STUDY

Alameda County enhanced their existing EMS and added EIS capabilities in anticipation of electricity shortages during the summer of 2001. The county is now able to shed up to 1.4 MW of load within minutes of notification by powering down the chillers as needed.

Refer to Enhanced Automation Case Study #1 for more details.

6.4 Further Considerations

There are a number of challenges in assessing the key differences between one EIS platform and another. The issues include the use of open protocols, limited partnerships and subcontracting, and co-branding with utilities among EIS vendors and among other vendors. Just because an EIS is configured with services to meet information needs for one project, facility, utility territory, or program does not mean that other capabilities or information needs cannot be negotiated as extra services. Similarly, vendors that sell services bundled together may be willing to customize the package.

Some EIS platforms offer tiered services. For example, lower cost systems may offer simple notification of demand-response program-initiated events and can be scaled to meet the needs of smaller commercial as well as larger multi-site customers. Higher end EIS platforms offer "end-to-end" services and are more flexible and can be customized to specific site needs. These platforms include the analysis of system-wide data and implications (cost and energy usage) based on a number of alternate load-reduction, load-shifting, scheduling, or generation strategies, and in some cases include automating the client-specified load strategy.

7 DECISION MAKING

The decision making process for an EA project is similar to the steps taken for any energy efficiency retrofit or upgrade. Before deciding on which alterations or enhancement will be made to an existing building control system, goals and other criteria must be set and all constraints and other issues and tradeoffs that will affect the decision must be identified.

7.1 Evaluate Current Conditions/Situation

An audit of the facility and its existing building technologies and equipment is often a necessary first step. The audit will:

- Determine the current condition of the building systems
- Assess current control strategies and monitoring capabilities of the building systems
- Identify comfort and equipment maintenance problems
- Discover efficiency and control opportunities

Each system should then be evaluated for potential EA enhancements that will improve monitoring and control while increasing comfort levels, eliminating maintenance problems, and reducing energy use.

7.2 Goals

Project goals should be set early in the decision making process. These goals generally fall into five main areas, all of which can be achieved by enhancements to building automation systems.

- Improved tenant comfort levels
- Improved building system control and monitoring
- Lower energy costs
- Improved system reliability
- Reduced operation and maintenance costs

Project goals should be spelled out clearly with as much detail as possible. For instance, a goal might be set to reduce energy costs by a certain percentage. With specific written goals, equipment vendors and installation contractors will know what is expected from the beginning to avoid unpleasant surprises at the end.

7.3 Budget

The available capital project budget should always be considered when setting goals. It serves no purpose to set a goal with a cost that cannot be funded. If an organization's budget cycle requires that projects be specified in advance, then this as an opportunity to do so. If capital budget monies can be moved to the most attractive projects, then the full benefits of the EA project should be compared to those of competing capital projects. The budget is usually the biggest constraint for most projects. An organization will set a budget for the project based on its criteria for rate of return, tenant needs, regulatory compliance, and/or available capital. Whether or not a project is on or under budget is usually the most important criteria used when assessing its relative success. Programs may exist to help with initial funding and keeping the project within budget.

Before defining a preliminary budget, the project scope and schedule constraints should be considered. If the budget is not carefully constructed, the project scope may have to be reconsidered and redefined to fit within the available budget. Consequently, deciding on a final project scope may require several iterations before the project is submitted for approval.

7.4 Other Budgetary Considerations

During the decision making process, it is important to be aware that there are constraints that cannot be controlled. This understanding will produce a more realistic project scope and budget than just using a contractor's estimate. Only facility management staff will realize the constraints of the site, tenants' needs, and the organization's business situation. Typical non-budgetary constraints include:

- **Timing.** The second largest constraint for most projects usually involves timing. Project deadlines are often determined by the operation and profitability of the organization's business. The project may have to be scheduled around tenant occupancy issues, planned maintenance periods, move-in or move-out dates, equipment availability, budget cycles, or some other external constraint.
- **Staff resources.** Changes to the building automation system will put great time demands on the staff for training, inspection, commissioning, and coordination. Who is available for these tasks and how they can be made available while still providing the normal level of facility maintenance and operation service must be carefully considered.
- **Physical space and accessibility.** Many projects are constrained by physical space or access issues. Mechanical equipment, ductwork, and controls often have to be made to fit into spaces that are not ideal. Consequently, equipment is selected that fits the space but is not the most efficient or lowest cost.
- **Ability to hardwire.** Multi-story buildings often have congested cable troughs, duct chases, and ceiling spaces that make installing new wiring very expensive. These constraints are typically found in retrofit projects.
- **Business uncertainties.** The business cycle may result in reduced capital budgets; the organization may be expanding or contracting; the cost or consequences of equipment disruptions may preclude controls projects; or controls may not be a priority for the organization.
- **Scheduling windows.** Most projects require that existing systems be shut down for tie-ins and testing. For sites that operate continuously and where system down time is not an option, the project scope may have to include the installation of a parallel system that can be installed and tested before switching over. This work presents less of a problem for sites that are normally unoccupied on weekends and nights.

7.5 Other Criteria

Other factors to consider when evaluating EA projects and their design alternatives include:

- **Functionality/flexibility.** The project must function as intended under all foreseeable circumstances of weather, occupancy, and space utilization.
- **Reliability.** One of the most important criteria is the reliability of building automation systems and building equipment systems. Tenant satisfaction can justify double- and even triple-redundant systems to preclude failures.
- **Maintainability.** When installing new equipment or revamping existing systems, maintainability is critical. Claims that equipment is "maintenance-free" should not be accepted at face value. The quantity of spare parts to stock on site and the supplier's ability to support the system or equipment are significant issues. In addition, consider access for operation, inspection, and maintenance. The computer programming and control settings must be designed so that the staff can operate, adjust, and maintain them and keep the system operating at peak performance.

- **Expandability.** Expansion capability is a very important criterion when deciding which system to purchase. It is not possible to know what additional points or functions may be necessary in the future for the EMS/EIS, but having a system that is not expandable or only expandable with proprietary components may preclude future expansion without a significant cost.
- **Energy consumption.** For most building equipment choices and control strategies, the cost of operation over the life of the equipment exceeds its first cost by several times. Therefore, control strategies that minimize run time or improve part-load efficiencies often have very attractive rates of return and provide the cost justification for the control enhancement project.

7.6 Tradeoffs/Issues

In the decision making process, competing criteria and constraints must be prioritized. The classic tradeoff is between cost and schedule. Obviously, it is less expensive to install equipment during business hours than during overtime periods. If a system can only be made available for out-of-service work on a holiday, then the cost of overtime should be made less important than the consequences of business disruption.

- **Sequencing of Work.** Some project steps must be done sequentially, while others can be done simultaneously. Determining the sequence of a project depends on the technical aspects of each step, its relationship to other steps, the overall project schedule and the overall project cost.
- **One vs. Multiple Contractors.** Specialized contractors can provide a high level of expertise in their specialty, while general contractors provide less technical expertise but considerable management and coordination ability. If a project is sequenced so there are fewer contractors and subcontractors involved at any one time, project management can be simplified and the work can be done at less cost. Managing, inspecting, and coordinating several small contracts is often very difficult and can result in higher overall costs than when these same tasks are contracted to a general contractor. The advantages of each contracting strategy should be considered when sequencing the work.
- **Customized vs. Off-the-shelf Software Systems.** While customized systems may appear easier to implement and operate initially, off-the-shelf systems are generally easier to maintain in the long run, and the initial and ongoing costs of customization are avoided. Once a system is customized, it is necessary to maintain a programming capability to keep the system running when hardware or software is upgraded. For facilities with a relatively large staff that includes building automation programming capabilities, customization may be desirable. For smaller facilities without a programming staff, customization work can be contracted to consultants and equipment vendors. Expenses for system maintenance and customization must be considered in the rate of return calculation for the project and balanced against the increased costs that may be incurred with use of off-the-shelf systems.
- **Replacing vs. Re-programming.** Customers with existing EMS/EIS that are considering replacing their system should consider the tradeoffs involved in enhancing or reprogramming their existing system. It is often less expensive and less disruptive to enhance an existing system than replace it. Full replacement is recommended when the existing system is inadequate to meet the current and future needs of the facility or is obsolete to the point that it is no longer operational.
- **Staged vs. Complete Implementation.** Many building automation systems are modular in nature and can be built up over multiple years. Thus, a system with basic automation functionality can be installed in the first year and enhanced in succeeding budget years with other modules, such as work order processing, spare parts inventory control, and preventive maintenance tracking.

- **Total Costs.** The total project costs including first cost and operating costs, should be evaluated for each of the proposed project alternatives. Included in these costs are licensing fees, monthly fees, transaction fees, software support costs, energy costs, chemical costs, spare parts costs, and repair costs. These operating costs, taken together with the first costs for procurement and installation, are used to project the lifetime project cost. The combined reductions in energy and maintenance costs and savings due to improved functionality and reliability can then be used to determine the project rate of return. These cost/benefit calculations will be very important in the decision to go forward with the project.

7.7 Evaluating Options

Once the decision making process reaches the evaluation stage, the project options are tested against the goals, constraints, criteria, and tradeoffs a final time. The following questions should be asked:

- Can the project be completed within the available budget?
- Will the project achieve the goals for operability, functionality, reliability, and maintainability?
- Can the project be installed on time?
- Can the project be installed in a manner that does not disrupt our business?
- Does the project meet the internal rate of return?
- Will management approve?

Once all of these factors are satisfied and all tradeoffs have been identified, a final project scope and budget can be determined for the recommended project. Often one or more project alternatives are identified and preliminary costs and benefits for each are prepared for presentation to management. In those cases, management considers the tradeoffs and establishes priorities to make the final decision.

7.8 Gaining Management Approval

Most facility or building managers will need management approval to implement any of the systems described in this guidebook, so a compelling business justification is necessary. Management is frequently most interested in improvements that are cost effective. However, most of the EA technologies and strategies discussed in this guidebook do not merit implementation solely on their energy and demand savings—many of the strategies incorporated in EA deserve consideration for their non-energy saving benefits. When presenting the EA project to management, the benefits discussed in Section 2 can be used to facilitate consideration of the full range of benefits, such as increased productivity, in order to build a persuasive case for EA. In addition, before any final decisions are made, a detailed building audit is usually performed. The audit, besides reporting on the existing system, can pinpoint any areas of concern and in need of an upgrade.

A companion publication for the financial decision maker, the **Business Case Guidebook**, discusses evaluating the economic feasibility of implementation and presents the economic costs and benefits of investing in building automation. Additionally, six case studies are available that showcase customers who have implemented successful EA projects at their facilities, using EMS and EIS technology.

Sample Project Decision Making Process

Assess current conditions/situation:

An audit was conducted to determine what would be a viable upgrade to the building energy system. The building lacked monitoring or control capabilities, resulting in lights left on in the evenings. However, the building had an existing EMS for HVAC monitoring and controls.

Set goals:

The building owners were concerned about rising energy costs and reliability issues resulting from rolling blackouts.

Define budget:

The facility manager decided that the lighting fixtures could be upgraded to T-8s and electronic ballasts from T-12s and magnetic ballasts. During this retrofit, management decided to also install dimming ballasts. The budget was large enough to allow the retrofit and connect these fixtures to the EMS for centralized dimming capabilities.

Identify non-budgetary constraints:

Timing – The building operators decided to do the retrofit when a large tenant was remodeling.

Staff resources – This project did not require much time from building personnel. An outside contractor did the work.

Physical space and accessibility/Ability to hardwire – These were not issues in this building.

Business uncertainties – Tenants had been in the building for over eight years and business was stable. There was no concern about having unoccupied spaces.

Scheduling windows – Work was done by contractors after hours. In spaces where the tenant remodeling was occurring, the contractors worked during business hours to save on overtime costs.

Consider other criteria:

Functionality/flexibility – Centralizing dimming controls were expected to be reliable for the use of space in this project.

Reliability – This retrofit was not expected to affect tenant satisfaction. One EA case study[11] has shown that varying light output does not result in complaints from occupants.

Maintainability – Dimming ballasts are similar to electronic ballasts and resulted in no additional maintenance requirements or costs for the company.

Expandability – Further upgrades to centralizing controls of the lighting system were possible, such as demand-limiting capabilities via the EMS.

Energy consumption – Savings on retrofitting T-12s to T-8s were a known efficiency upgrade with well-documented savings. Savings from the dimming controls resulted from the ability to understand and control the light output centrally. Demand savings were realized when the dimming controls are used during peak times.

[11] *Case studies on various EA projects can be found at www.energy.ca.gov/enhancedautomation or by calling 866-732-5591.*

Tradeoffs/Issues:

Sequencing of work – If any issues arise, centralizing dimming controls could be eliminated from the project scope. Therefore, the lighting retrofit was planned to occur first.

One vs. multiple contractors – Two contractors were required for this project. It was expected that the lighting contractor would do the lighting retrofit and wiring of the dimming controls. However, an EMS vendor was needed to program the dimming strategies into the software.

Customized vs. off the shelf software systems – Dimming controls were off-the-shelf software. The company decided not to have a customized system.

Replacing vs. reprogramming – It was possible to connect controls to the existing EMS instead of installing a new one.

Staged vs. complete implementation – If any issues arise, centralizing dimming controls could be eliminated from the project scope.

Total costs – After addressing all these issues, the total project costs (including non-contractor and material fees) were within budget. Final contractor bids were required prior to implementation.

Evaluating options:

The company compared the economics of the options before deciding to do this retrofit. Also, all the questions in the guidebook regarding evaluating the options were answered favorably.

Gaining management approval:

Management approved the decisions made for all the above ideas because they were well documented, justifiable, and reasonable. In addition, the managers were convinced that the prospect of reducing lighting loads on demand from their energy service provider would a great advantage in controlling energy costs with additional non-energy cost savings benefits. Showing a case study similar to this EA upgrade was an added bonus for the management group.

8 IMPLEMENTATION

The implementation of a project like an EA improvement is not much different from any capital improvement project. The basic steps are:

- Preparing the plans and design
- Involving operating staff
- Determining construction sequencing and responsibilities
- Selecting vendors and contractors
- Informing building occupants
- Permitting, construction, and installation
- Testing and commissioning
- Training operating staff
- Performing ongoing system maintenance

These steps are generally accomplished in the order listed. All steps are necessary to complete a project on time, on budget and that works as intended.

8.1 Plans and Design

First, and most importantly, there must be full and complete equipment and performance specifications. Only knowledgeable and competent personnel who understand the proposed equipment, the existing building and building systems, and construction and installation issues should prepare these plans. This ensures that control settings achieve the desired results, and the finished system works in a smooth, logical fashion. This will require a significant amount of time with the designer to ensure that the result accomplishes the desired objectives and meets the criteria. Potential contractors and vendors must know and understand what the expectations are for the resulting enhanced system.

Often an equipment vendor or contractor can prepare a design-build proposal that will meet these requirements, but such proposals should always be compared with separate design and construction proposals to assure completeness and cost effectiveness.

8.2 Involving Staff

The building maintenance and operating staff are essential to the success of the project and should be part of the planning process from the very beginning. Staff should contribute to the criteria list described in the previous chapter and should be involved in the planning and design process.

Maximizing the potential benefits of the system will only be possible if well-trained facility staff use the system. The best opportunity for that training is often during the programming development phase. Coordination between the programmer and facility staff during this time is likely to produce a system that makes more intuitive sense to facility staff than having the programmer work without their input. Moreover, facility staff will be able to develop a much better understanding of the system and its capabilities than from a typical training course demonstration.

8.3 Construction Sequencing and Responsibilities

Since the installation of an EA project is usually a retrofit of one or more building systems, it may require the building control system to be out of service for a period of time, disrupting normal operations. Disruptions can be minimized and their impacts reduced by careful attention to construction sequencing. Disruptive portions of the work may be scheduled to coincide with normal, periodic shutdowns.

Construction responsibilities can be shared between the contractor and facility staff so as to provide both a cost and a training advantage. Any equipment, such as remote sensors and controls, that will subsequently require periodic inspection and maintenance is a prime candidate for staff installation under vendor supervision.

8.4 Selecting Vendors and Contractors

Vendor/contractor selection should be based on more than the lowest bid. The equipment specification and performance specification prepared in the first step described above should be a part of each bid or proposal. Any exceptions must be noted and explained. The successful bidder/proposer should also provide a warranty guaranteeing that the installation will perform as expected.

Obtaining and contacting references from potential vendors/contractors is strongly recommended. Any negative comments should be fully explored and taken into consideration when deciding which firm to use. Also, it is important for the future reliability and maintainability of the system to consider the following when selecting equipment vendors and the programming team:

- **Hardware support.** The pace of technological development of electronic systems may make a new state-of-the-art system obsolete in a relatively short time. This makes it important that the hardware suppliers selected have a large installed base of similar equipment in the area and a reputation for supporting their equipment in the long term. Spare parts should also be readily available from a local source.
- **Software support.** Long-term software support and training capability is an important consideration when selecting a system. Future building renovations, software upgrades and staff turnover will lead to the need for periodic training and system maintenance. Therefore, it is important to select a vendor that has a strong software support and training capability.

Taking the time to interview the contractor and key support personnel who will be designing and installing the system's software is a valuable exercise. This can help ensure that the system installed will be easy to use and identify which contractor will be most appropriate for follow-up consultation and troubleshooting.

8.5 Informing Occupants

Once the vendor/contractor is selected and the construction timing and sequencing is established, an occupant communication plan should be prepared and executed to minimize lost productivity. This plan should ensure that occupants know and are prepared for the construction noise, system operation disruptions, and other distractions that will occur during the project construction phase. They should also be prepared for the resulting changes in the operation of systems that will affect them.

8.6 Permitting, Construction, and Installation

Normal construction management techniques apply, as well as activities that are unique to EA projects. Permitting, construction, and installation activities should follow traditional protocols and should be customized to the business's procedures.

Additional activities include taking advantage of any opportunity to inspect and measure the "before" condition and the performance of the systems being affected. These data will help to measure the actual improvement resulting from the project.

8.7 Testing and Commissioning

Testing and commissioning allows the manager to determine the project's compliance with the full and complete performance specification prepared in the design phase. In these projects, the final stages of construction are often done under tremendous time pressure to meet completion date requirements, which can result in poorly installed or missing elements necessary for the correct operation of the equipment. Every sensor and every control must be properly installed, correctly calibrated, and operating for the EMS and EIS system to work as designed and as programmed.

A systematic testing and calibration process should be an integral part of the system start-up process. This can be a requirement that the installing contractor must meet, or it can be contracted to an independent commissioning contractor. At the completion of each test, responsibility for remedial action should be clearly assigned according to the requirements of the contract and included in a "punch list" of items to be corrected before acceptance and payment. Avoid potential disagreements over who is responsible for operating problems between the equipment manufacturer, the controls vendor, the installation contractor, or the specifying engineer. By making one of these parties contractually responsible for the proper operation of the equipment it will be necessary to deal with only one contractor to resolve equipment problems. This entity or a commissioning contractor should be made responsible for resolving problems and adjudicating disputes.

The controls should be tuned to operate interactively in a manner that maintains occupant comfort and optimizes the uses of energy. The actual calibration records, balancing reports, and control settings developed in the commissioning process are valuable documents for future troubleshooting, recalibration and rebalancing activities. The contract should require that these documents be delivered at the end of the commissioning phase, and these documents should be kept for future reference.

Commissioning does not end with the completion of the EA implementation project. Periodic system tune-ups to recommission the system will ensure that the system continues to operate optimally. This is required because the building changes over time as tenants move in or out, equipment is replaced, equipment surfaces foul, and new control points are added.

8.8 Training

Training facility staff to operate and maintain the EA equipment properly is very important. They must not only know how to properly maintain and operate it, they must be motivated to do so through an understanding of the system's benefits.

The most frequent complaint regarding this type of equipment is that it requires more technical attention than anticipated by the building operations and maintenance staff. Without that attention, sensors are improperly calibrated, controls are overridden, and computer software gets "out of tune." Unless the equipment is regularly checked and maintained, many of the expected benefits can be lost.

Funding should be allocated in the construction budget to train facility staff on the design and operation of the EA system. The equipment vendor and the programming team should conduct the training. Training should include a review of building control points and the location of the controlled devices, the equipment start-up and shut-down calendars, the temperature setpoints, setbacks, and lockouts, and the control sequencing logic for interactive systems. Additionally, facility staff should be thoroughly trained on navigating and operating the new software package. At the end of the software training, facility staff should be comfortable logging on and off and finding and changing equipment calendars, control setpoints, and control sequences. Without a well-trained staff, many valuable features of the enhanced building control system can go unused.

8.9 Ongoing System Maintenance

The last step to be completed is determining the terms for ongoing system maintenance. At some point following the commissioning and startup of the new system, the contract for installation and startup will be fulfilled and the team of equipment vendors and contractors that supplied and installed the system will no longer be available for troubleshooting and system configuration. Either a new contract will have to be issued to the equipment and service suppliers that installed and worked on the new system, or a new system support provider will have to be selected.

It is important to select a vendor with a good reputation for prompt service and an ongoing commitment to the installed hardware and software. This is often the original equipment manufacturer or its local representative. Sometimes, however, an independent consultant that specializes in the systems installed is the best choice.

IMPLEMENTATION CHECKLIST

This checklist may be helpful when implementing EA projects.

Plans and Design

- ☐ Review plans for full and complete equipment and performance specifications
- ☐ Compare design-build proposals and separate design and construction proposals
- ☐ Involve operating staff in process

Construction Sequencing and Responsibilities

- ☐ Sequence construction for minimal disruption
- ☐ Share contractor construction responsibilities with operating staff
- ☐ Provide vendor supervision for staff installation

Selecting Vendors and Contractors

- ☐ Interview contractor
- ☐ Ensure that vendors warrant that the installation performs as expected
- ☐ Obtain and contact vendor/contractor references
- ☐ Check if vendor/contractor has hardware and software support

Informing Occupants

- ☐ Execute occupant communication plan

Permitting, Construction, and Installation

- ☐ Inspect and measure “before” construction/installation performance

Testing and Commissioning

- ☐ Check compliance with full and complete performance specification
- ☐ Calibrate sensors and controls
- ☐ Test equipment (with installation or commissioning contractor)
- ☐ Ensure that remedial action is taken prior to payment
- ☐ Make one party contractually responsible for proper operation of equipment
- ☐ Require delivery of actual calibration records, balancing reports, and control settings
- ☐ Conduct periodic system tune-ups for recommissioning

Training

- ☐ Allocate budget for training
- ☐ Train building O&M staff on equipment and software

Ongoing System Maintenance

- ☐ Check and maintain equipment
- ☐ Issue new contract or find new system support provider
- ☐ Make sure the contractor/vendor has a good reputation and ongoing commitment to their hardware and software

9 RESOURCES

Most of the resources listed below provide a range of information, from databases of contractors and vendors to explanations of an energy management system (EMS) and enhanced automation (EA) strategies. The first section includes utility and state web sites that can link the reader to programs and educational and/or informational items, ranging from technology descriptions to databases of vendors in the area. Next, there is a list of U.S. Government sources that provide similar material. The third section contains various industry sources that provide information on vendors, contractors, EA systems, list serves, and more. There are also two books that are recommended. Finally, to contact the California Energy Commission for more assistance, please use the information provided at the end of this section.

9.1 Utility and State Programs and Information

California Energy Commission (www.energy.ca.gov)

The California Energy Commission web page lists many sources of funding available throughout the state for energy-efficiency and demand-reduction projects. A specific web site dedicated to rebates, loans, and grants, is found at:
http://www.consumerenergycenter.org/index.html

An energy business directory is available on line at:
http://www.energy.ca.gov/export/

The peak load reduction programs (SB5x) are listed at:
http://www.energy.ca.gov/export/

A list of the California electric utility companies, which include investor owned utilities, municipal utility companies, rural electric cooperatives, and irrigation districts is at:
http://www.energy.ca.gov/electricity/utilities.html

Pacific Gas & Electric Company (www.pge.com)

PG&E has a web page with all their resources for businesses, including incentives, descriptions of various energy-efficiency programs, and tools for measuring energy savings:

http://www.pge.com/003_save_energy/003b_bus/index.shtml

There is also a supplier and services directory found at:
http://www.pge.com/003_save_energy/003b_bus/003b1d9_supplier_directory.shtml

Equipment guides may be found at:
http://www.pge.com/003_save_energy/003b_bus/003b1d8a_equip_guides.shtml

In addition, a database for lighting and HVAC controllers is also available on their website. The database includes CO_2 and VOC demand ventilation control devices, automatic daylighting controls, interior photocell sensors, lumen maintenance, occupant sensing, and automatic time switch lighting control devices:
http://www.pge.com/003_save_energy/003b_bus/003b1d8b_equip_db.shtml

Southern California Edison (www.sce.com)

SCE provides information on incentive programs, services provided by the utility to its customers, and information on energy-saving products (such as lighting controls):
http://www.sce.com/sc3/010_bus_sols/010a_small_business/010a3_elec_equip_info/default.htm

San Diego Gas & Electric (www.sdge.com)

SDG&E provides a list of their energy-efficiency programs at:
http://www.sdge.com/efficiency/bus_rebates.html

Services and information for businesses are included at:
http://www.sdge.com/efficiency/ee_guide.html#eeguide

9.2 Government Sources

The California Independent System Operator (www.caiso.com)

California ISO has a web page with links to sources of information for energy efficiency and other informative sites specific to California. Additionally, this web site provides information on energy prices, including daily predicted supply and demand:

http://www.caiso.com/PowerCentral/conservation.html

The US Department of Energy (www.energy.gov)

The Department of Energy provides links to many different resources, ranging from energy-efficiency equipment information to cutting operation and maintenance costs:

http://www.energy.gov/efficiency/index.html

Energy Efficiency and Renewable Energy Network (www.eren.doe.gov)

The Energy Efficiency and Renewable Energy Network has information for businesses (mostly directed to small businesses) on saving energy. There is a list of references and sources. Additionally, EREN provides tips on financing, planning, and where to find more help:

http://www.eren.doe.gov/energytips/

Environmental Protection Agency – ENERGY STAR® (www.energystar.gov)

ENERGY STAR® has a web page that includes interactive tools and calculators for estimating potential energy and cost savings associated with energy efficiency measures:

http://yosemite1.epa.gov/estar/business.nsf/webmenus/Business

The web site also includes a database of contractors and products:

http://estar4.energystar.gov/estar/CPDCaseStudy.nsf/ASAPSearch?OpenForm&Seq=6#_RefreshKW_P42

9.3 Industry Sources

Air Conditioning, Heating, Refrigeration NEWS

This web site is an on-line news magazine that discusses industry news and energy-related information. It provides a way to keep up to date on the latest regulations and products. It is an extensive resource that allows users to locate products, get technical support, and discover new business opportunities:

http://www.achrnews.com/

There is also an on-line forum where participants can post their comments or ask questions:

http://www.i-boards.com/bnp/news/

AutomatedBuildings.com

This web site is an on-line magazine that provides information and resources on automating buildings. The following web page provides links on environmental control, energy metering/ accounting systems, lighting control, fire, security, communications, high- tech tools, web resources, and interactive information systems. Monthly updates are available for free. Training and education information are also found here:

http://www.automatedbuildings.com/frame_resources.htm

Contracting Business Interactive

The web site covers HVAC mechanical system and design/build/maintenance contracting, provides news, and an HVAC web directory:

http://www.contractingbusiness.com/

Energy Ideas Clearinghouse

The Energy Ideas Clearinghouse site provides comprehensive and objective energy information, education, resources, and technical assistance for increasing energy efficiency in the commercial sector. There is also a list of various energy list servs:

http://www.energyideas.org/

Facilities Net

This web site is an on-line resource for building operators and managers and provides numerous useful sources, such as a buyer's guide:

http://www.facilitiesnet.com/fn

There are also bulletin boards on education, energy management, software, and technologies:

http://www.facilitiesnet.com/fn/PF/PFmenu.shtmllticket=12345678901234567891114753723

HVACMALL

HVACMALL is a useful place to look up technologies, products, events, news, companies, and resource links of associations, and more. The web page also provides chat rooms and forums on various subjects:

http://www.hvacmall.com

Illuminating Engineering Society of America

This web site is for lighting professionals but includes a manufacturer database:

http://www.iesna.org/

Iowa Energy Center's Direct Digital Controls Project

The Iowa Energy Center developed this web site in conjunction with the U.S. Department of Energy Office of Building Technology, State and Community Programs (DOE-OBT), Pacific Northwest National Laboratory (PNNL) and Facility Dynamics Engineering. The purpose of this web site is to provide the public with unbiased information on DDC and an easy searchable guide to vendors who sell DDC systems. Both generic and specific information on DDC systems can be found here:

http://www.ddc-online.org

Lighting Research Center

The LRC web page provides information on lighting technologies, usage, and educational opportunities:

http://www.lrc.rpi.edu/

Lighting Resource

This web site contains information on lighting for specific markets, OEM components, ballasts, and a manufacturer database:

http://www.lightingresource.com/

Lightsearch.com

Lightsearch.com provides manufacturer and distributor information, data on various lighting controls and lamps, and case studies:

http://www.lightsearch.com/

Peak Load Management Alliance

This web page brings together all the players in peak load reduction: utilities, government, end users, marketers, manufacturers, and distributors. This organization develops, demonstrates, and evaluates methods for reducing peak electrical demand in times of shortness of supply:

http://www.peaklma.com

Thomas Regional

The Thomas Regional is a guide to industrial products and services that includes over 550,000 distributors, manufacturers, and service companies in all key U.S. industrial markets. It also includes brochures, linecards, and links to suppliers' web sites. Although it is advertised as an industrial site, commercial products and services are available as well, particularly in the automation and controls area. New users may need to sign in to access all the data. The site makes it easy to narrow down searches to geographic areas:

http://www.thomasregional.com

9.4 Books

Controls and Automation for Facilities Managers: Applications Engineering by Viktor Boed, June 1998.

This book discusses HVAC engineering and DDC applications with the discussion of using real time utility data received over the network (EIS systems).

Energy Efficiency Manual by Donald R. Wulfinghoff, Energy Institute Press, 1999.

This book discusses ways to save energy and money through activities such as cleaning evaporator coils, placing placards near thermostats, installing dimming controls, and using optimal start capabilities on a chiller.

9.5 Technical Assistance

You can receive technical assistance by calling 866-732-5591, by emailing enhancedautomation@xenergy.com, or visiting www.energy.ca.gov/enhancedautomation.

10 APPENDIX

Calculating Energy Savings from Percent Savings

The following tables give the typical energy consumption (electrical and gas) per square foot (sf) for various building types and various end uses. The data were collected from the California energy demand forecast.[12] These data can be used to determine energy and gas (and demand) savings, and subsequently cost savings. Keep in mind that these calculations provide a ballpark figure to help jumpstart the process of making an Enhanced Automation (EA) business case.

To calculate the possible savings, conduct the following steps:

1. Determine your building type.
2. Determine what end use is affected by the EA measure you desire to implement.
3. Look up the percent savings (in the Technical Options Guidebook) achievable with the EA measure to be implemented.
4. Determine where your building situation lies within the range of savings quoted in the guidebook.
5. Calculate the kWh/sf saved:

   kWh/sf saved=(% savings of EA measure) x (kWh/sf of enduse)

6. Multiply the kWh/sf saved with the building size to determine the annual kWh saved. For peak demand savings, divide this number by the operating hours or equivalent full load hours (required for equipment that can run on variable loads).
7. For a reality check, determine the building annual energy use and compare to the savings achievable with the EA measure.

Energy Consumption (kWh) per square foot per end use per building type

End Use	Cooking	Cooling	Heating	Indoor Lighting	Misc.	Office Equipment	Outdoor Lighting	Refriger-ation	Ventilation	Water Heating	Total
College	0.18	2.51	4.78	3.15	1.15	0.18	0.20	0.57	1.61	1.76	16.09
Hospital	0.32	9.38	5.42	10.82	13.56	0.68	0.36	0.46	2.89	5.78	49.66
Hotel	0.32	2.74	3.55	3.43	2.42	0.02	0.50	1.28	0.91	1.18	16.35
Large Office	0.15	4.88	3.51	9.38	4.03	0.64	1.12	0.10	3.29	0.26	27.36
Retail	0.11	2.19	0.62	5.61	1.44	0.09	1.05	0.62	1.22	0.09	13.04
School	0.24	1.30	1.94	2.98	0.44	0.08	0.79	0.21	0.88	0.75	9.61
Small Office	0.18	2.73	0.55	4.65	3.33	0.64	1.38	0.20	0.86	0.20	14.72
Average	0.20	3.66	2.37	6.22	3.27	0.35	0.90	0.50	1.87	0.51	19.86
Percent of Total	0.01	0.18	0.12	0.31	0.16	0.02	0.05	0.03	0.09	0.03	1.00

[12] *"California Energy Demand, 2000-2010," California Energy Commission. Publication # 200-00-002. July 14, 2000.*

Therms per square foot per end use per building type

End Use	Misc.	Heating	Water Heating	Cooking	Cooling	Refrigeration	Total
College	0.06	0.37	0.03	0.00	0.03	0.00	0.49
Hospital	0.30	0.23	0.31	0.01	0.03	0.00	0.88
Hotel	0.13	0.24	0.09	0.02	0.01	0.00	0.48
Large Office	0.30	0.71	0.06	0.00	0.10	0.00	1.17
Retail	0.11	0.11	0.02	0.00	0.02	0.00	0.26
School	0.12	0.49	0.03	0.00	0.01	0.00	0.66
Small Office	0.14	0.04	0.00	0.00	0.02	0.00	0.21
Average	0.16	0.31	0.08	0.01	0.03	0.00	0.59
Percent of Total	0.28	0.53	0.13	0.01	0.05	0.00	1.00

Sample calculation using above methodology

The project involves installing VSDs on fans and carbon dioxide sensors for demand ventilation in a 100,000 square feet college type building. The achievable savings with this measure are about 25 percent of the affected end use, (in this case, ventilation). Ventilation in college buildings uses (1.61 kWh/sf)/(16.09 kWh/sf) = 10 percent of total energy use. Therefore, the energy savings per square foot is:

0.25* 0.10* 16.09 kWh/sf = 0.40 kWh/sf.

The measure will save about 0.40 kWh/sf. Multiplying through with the building square footage, total annual energy savings with this enhanced automation strategy is 40,000 annual kilowatt-hours saved. To summarize, the building uses 16.09 kWh/sf. At 100,000 square feet, annually the consumption is 1,609,000 kWh. The EA measure will save about 2.5 percent of the total energy use.

Savings for Multiple Measures

To determine savings for multiple measures for those that are not additive:

1. Determine the percent savings for the measures individually.
2. Take the savings from one and calculate the total kWh and/or kW savings for that measure.
3. For the next measure, apply the percent savings to the “new” building kWh and/or kW.
4. Repeat steps 2 and 3 until all the measures savings are calculated.

11 GLOSSARY

Building automation system (BAS) is a less advanced control system than the energy management system, which includes supervisory control programming with additional monitoring and control points. See definition for EMS.

Business Case Guidebook provides an overview of benefits and costs and helps financial decision makers determine if EA is practical for their business. Call the California Energy Commission's EA Hotline at 1-800-732-5591 to receive a copy.

California Energy Code, also known as **Title 24**, is the State's regulations for minimum energy requirements and performance for buildings. Published by the California Energy Commission, Title 24 defines requirements for building energy use in new construction, as well as additions and alterations to existing buildings.

Centralized controls refers to a system that runs, manages, and links components of a building's energy system to one master location.

Commissioning provides building owners with means for verifying that their functional needs are rigorously addressed during design, construction and acceptance.

Communication protocols are standardized rules governing the transmission of information between computers and controllers connected through an EMS communications network. These include proprietary, BACnet™, LonTalk, and TCP/IP Protocol.

CRI, or Color Rendering Index, is a measurement of the ability of a light source to represent colors in objects indexed with a 0 to 100 scale, where 100 is equivalent to the sun's light rays.

Daylighting is the use of natural daylight in a building to offset or augment artificial lighting.

Demand-response refers to the action that customers take to reduce electrical load. See definition for demand-responsive programs.

Demand-responsive programs are designed to encourage customers to cut energy use during peak demand periods. A power provider often offers incentives to customers for curtailing load by a specific amount when a peak demand period is imminent or a staged emergency is called.

Direct digital controls (DDC) consist of networked microprocessor-based controllers connected to devices that monitor or control facility systems and equipment.

Dynamic pricing is a rate structure that sets prices for a short period of time (or continuously, such as real-time pricing).

Economizer is a component of an HVAC system that provides cooling without the use of mechanical refrigeration or air conditioning. An economizer saves energy by regulating dampers when the outdoor air temperature and ambient conditions are sufficient to provide the heating and cooling needs of the building interior.

Energy information systems (EIS) are a platform that communicates with external and internal signals of a building, such as electricity prices, weather, and power quality. EIS can also provide a gateway to the energy management system as well as analyses of various levels of data.

Energy management systems (EMS) are monitoring and control systems that allow remote monitoring and control of equipment in a building.

Enhanced automation (EA) increases the capability of an energy management or energy information system to manage both the energy use in buildings and the comfort of the building occupants.

HVAC – Heating, ventilation, and air conditioning.

Inboard/outboard lighting refers to dual ballasted/dual switched fluorescent light fixtures (generally 3-lamp) where the center lamp is switched independently from the outer 2 lamps. This system allows for four lighting levels: all lamps off, one light on, two outer lamps on, or all three on.

kW – kiloWatt, equivalent to 1,000 Watts.

kWh – kiloWatt hour. Equivalent to the energy expended when 1000 Watts are used for one hour.

Load shedding/ curtailment/shifting and peak limiting are strategies used to reduce peak demand by moving the operation to less expensive time periods or applying demand reduction strategies.

MW – Megawatt, equivalent to 1,000,000 Watts.

O&M – Operations and Maintenance.

Peak hours are defined in this guidebook by the period of time when overall demand for grid electricity is highest.

Plug load is the energy dedicated to equipment in a building that is not permanently attached, for example, table lamps, office equipment, and computers. Electrical draw from lighting, HVAC equipment, motors, and other hard-wired features of a building are not included in this definition.

Price signals refer to data on the cost of utility electricity and fuels sent electronically or via telephone line. This can occur through an EIS system.

Real-time monitoring refers to the ability of recording, observing, and reacting to data points on a real-time basis.

Real-time pricing is an electricity rate structure that varies with the wholesale electric market prices.

SB5x is a bill the California Legislature passed in April 2001 in response to the high electricity prices and power outages. It provides funding to the California Energy Commission and other state agencies for grants and rebates to reduce electricity peak load demand.

Supervisory Control And Data Acquisition (SCADA), consists of collecting information, transferring it back to a central site, carrying out necessary analysis and control, and then displaying this data.

Setback/Setforward control refers to reducing (setback) or raising (setforward) the temperature setpoint for cooling or heating systems in a building in an effort to reduce heating or cooling requirements.

Title-24, see definition for the California Energy Code.

Variable Air Volume (VAV) includes HVAC components that operate by varying the volume of constant temperature air delivered to the area as the load changes, rather than using constant air volume.

Variable Speed Drives (VSDs) are also known as adjustable speed drives (ASDs) and variable frequency drives (VFDs). VSDs change the rotation speed of equipment motors to better match the actual power needed.

CALIFORNIA ENERGY COMMISSION

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For more information,
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Printed on recycled paper with soy based ink

PUB. NO. 400-02-005f