


Energy Savings from Building Energy Management Systems

Building Energy Management Systems (BEMS) have the ability to save energy and improve productivity by creating a comfortable working environment.

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Summary

I. Executive Summary	3
II. Energy Savings Opportunities.....	4
Setpoints	4
Occupancy	4
Time schedule	4
Zoning	5
Calendar schedules	5
Holiday/Vacation periods	5
Optimizers	6
Frost protection.....	7
Overrides.....	7
Compensation	7
Outside high limit	7
Disable humidification	7
Control stability	7
Air-handling systems damper economy override.....	8
Enthalpy Control	8
Demand programming.....	9
Night purge/summer pre-cooling	9
Electricity Savings.....	9
Load cycling	9
Variable speed drives.....	9
Maximum demand.....	10
III. The Intelligent Building Approach	11
Energy monitoring, profiling and modeling	11
Energy aggregation.....	12
IV. Conclusion.....	13

I. Executive Summary

Our world is currently facing two particularly important trends: rising fossil fuel prices and concerns about climate change. Both create strong incentives for energy conservation.

The World Business Council for Sustainable Development identified buildings as one of the five main energy users, where “mega-trends” are needed to transform energy efficiency. Buildings account for 40 percent of primary energy in most countries and consumption is rising. The International Energy Agency (IEA) estimates that for buildings, current trends in energy demand will stimulate approximately half the energy supply investments through 2030.

Building Energy Management Systems (BEMS) have the ability to save energy and improve productivity by creating a comfortable working environment. BEMS optimization create improves energy management; however, regular building audits and fine tuning are necessary to ensure the energy management is maintained.

This document summarizes the technical strategies for achieving energy savings while optimizing occupant comfort. BEMS optimization is dependent on the physical plant, operator, level of controls, and zoning, as well as the type of environment to which the system is being applied. This information is targeted to internal energy savings implementation professionals, looking for a resource to guide them in changing parameters, tuning building management systems and recommissioning existing systems.

II. Energy Savings Opportunities

Setpoints

The easiest way to create savings is to reappraise and/or relax set points. Caution must be applied as the changes need to be made in accordance with the overall building scheme, as the settings may be a crucial part of an overall control strategy.

A shift can be applied in accordance with external conditions; for example, with an air conditioned building, the summer set-point for cooling can be increased relative to an increase in outside temperature (within a pre defined band).

A regular review of set points and modification is an essential part of the ongoing energy cycle and must be continually reviewed, looking for opportunities for further savings. When an opportunity for set-point savings has been identified, minor set point changes over a period of time ensures a smooth transition. For example, a stepped change of 0.5° C or 1° F at a time for room temperature.

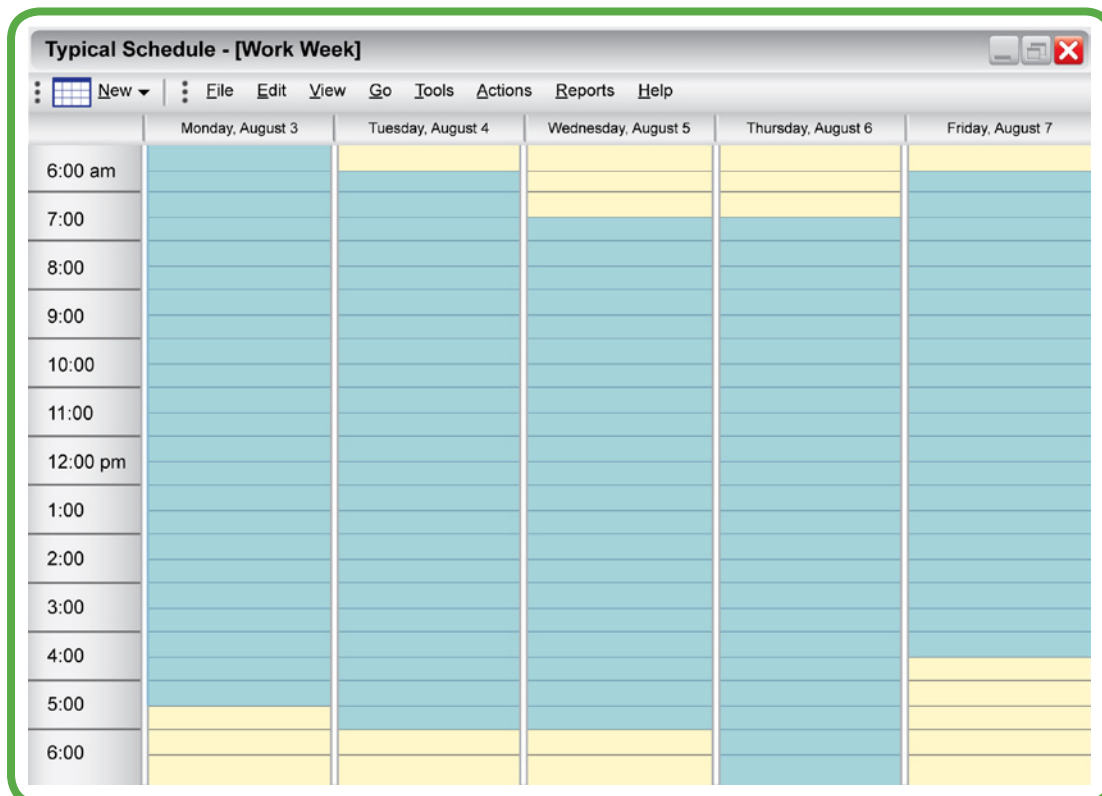
Shifting/relaxing set points in line with a combination of external conditions and time/ calendar rationalization can typically equate to 5–20 percent savings. A set-point reduction can equate to 10 percent savings per degree on your heating bill, with potentially higher savings on cooling/chiller bills.

Occupancy

Time schedule

Ensuring your building operates accordingly to occupancy levels is a key energy saving action and requires continuous reviewing to ensure the settings are representative.

For example, occupancy patterns of schools and universities continually change due to activities such as after-school school clubs, evening classes, etc. It would be easy to apply a “carte blanche” approach, setting a broad range time pattern, but this would equate to unnecessary periods of heating and cooling. Regular review of occupancy



levels would highlight the possibility to change set points for multiple periods of occupancy on different days.

In addition to a permanent change, the ability to extend a time operation on a one shot basis or on a 0–30 minute timer ensures that a one-off change in occupancy, such as would occur with an unexpected late meeting, are changed for that one period then revert to the normal occupancy pattern.

Zoning

A cost-effective way to save additional energy is to apply further zoning to areas where there are different occupancy patterns. These zoned areas are only heated or cooled when required. Each zone can have occupancy times, compensation, and optimization applied to maximize the savings potential.

Calendar schedules

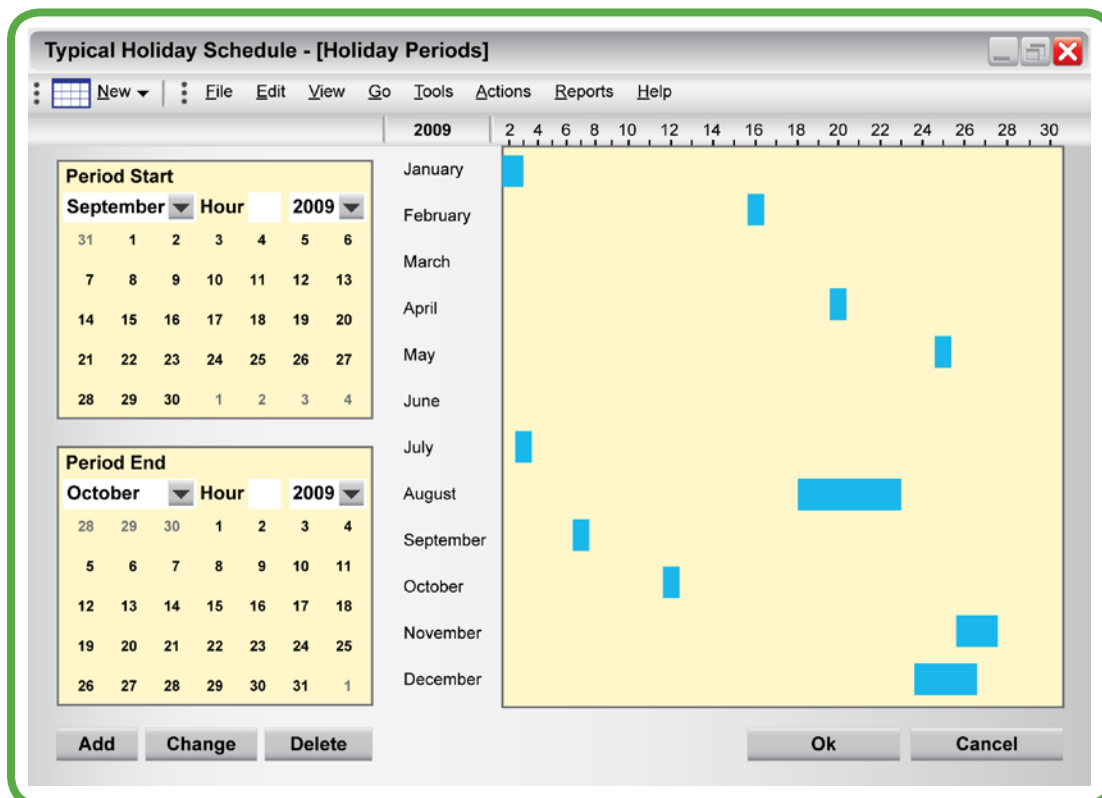
BEMS offer advanced time scheduling capabilities, and within this is the ability to apply schedule patterns for different calendar dates. This enables varied time scheduling to match varying work patterns to be programmed well in advance. This option can be applied to areas where occupancy

levels are constantly changing week to week, such as exhibition halls or meeting rooms. Operator time is thus reduced, because configurations are made once as opposed to making changes on a weekly basis.

Holiday/Vacation periods

To ensure energy savings during public holidays when businesses are closed, holiday schedules are used in conjunction with time schedules. For example, In the UK, typically there are 8 public holidays. To determine the energy savings for a commercial property, multiply the facility availability of 52 weeks by 5 working days = 260; therefore 8 public holidays equates to over 3% possible energy savings.

With an integrated systems approach, a single change to a core time schedule or holiday schedule can propagate to all integrated systems, including lighting, security, and access control. This ensures HVAC systems work in empathy with the actual required occupancy, therefore maximizing energy savings throughout the building by reducing operating costs.



Optimizers

Prior to the introduction of optimizers in the mid-1970s, many buildings were controlled entirely by a mechanical time clock. These were often set to switch on the building at a specific time and often assumed the worst weather conditions, such as heavy snowfall, thus running the building's central heating system from the early hours of the morning till the late evening, without change.

Synonymous with energy savings is the "Optimizer." Prior to the introduction of the BEMS, an optimizer was a stand-alone controller with an outside temperature sensor located on a north wall and internal space temperature sensor(s). A temperature rise rate was calculated in accordance with how cold it was outside and this became a time factor which was tuned based on the heat loss of the building and the difference between the internal temperature and the desired occupancy temperature.

Based on this the plant was switched on at a time prior to the required occupancy time, which equated to putting in the "optimal" amount of energy. The start time depended on the external temperature, the indoor temperature, and how much energy was required to meet the desired occupancy space temperature at start time.

The optimum "off" function that worked the opposite way was the next innovation to follow. It predicted the "off time" based on the external temperature, the room temperature, and the earliest possible time the building could have its heating plant switched off, whilst still retaining comfort conditions at the end of the occupancy period.

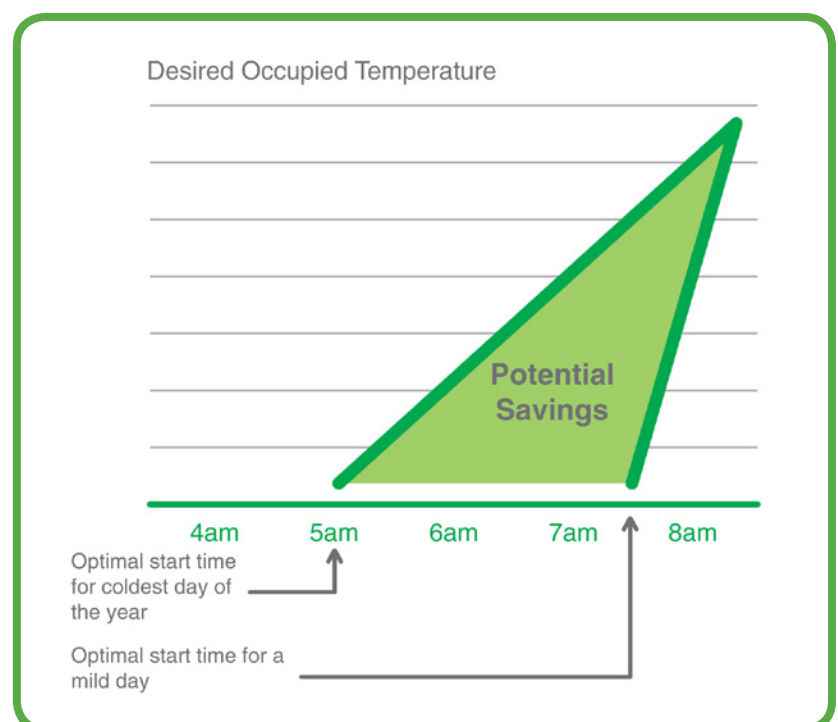
A low-temperature protection setting is applied to protect the internal fabric of the building which can be damaged through condensation should the temperature/humidity condition reach dew point.

Optimizers provided typical energy savings of 5–25% (potentially higher with cooling/chiller plant) compared with standard controllers where a limit of 2 hours is applied to the startup time.

The principle of optimization remains the same in today's BEMS, with the advantages of algorithm choice, such as a linear relationship between rate of rise and internal temperature and logarithmic. Defined by the Building Research Establishment in the UK, use of logarithmic algorithms can potentially offer an additional 8% savings in energy used during the preheat period due to more accurate start time calculations.

With BEMS systems, it is also possible to apply optimization to the cooling system. The modern optimizer can determine whether to initiate either a heating optimized start or a cooling optimized start, ensuring the building operates for the minimum time and results in energy savings.

The optimizer stores the parameters and learns to suit the building/zone through self adaption to obtain the best settings. The occupancy pattern is determined by time schedules for heating/cooling within the building. If the time schedule is overridden by an external switch, it is important that self adaption is inhibited during these manual overrides and failures.



The BEMS provides extensive reports on the optimizers' operations and they must be regularly reviewed to ensure the maximum savings are achieved. This can be done after different external temperature conditions and on different days of the week. The BEMS optimizer has additional "boost" functions that may be applied if the internal temperature did not reach occupancy levels in the previous 24 hours, such as would be the case on a Monday morning. This is enabled automatically to ensure comfort levels are achieved.

Frost protection

It is fundamental that when a building is switched off either in normal operation or in Holiday/Vacation mode that a frost protection strategy is in place. Frost protection strategies will allow pumps and the heating system to remain off when the building is not occupied to save energy. The pumps and heating system will energize when the temperature outside, in the main pipework or in the space fall outside of acceptable ranges.

Overrides

In instances where systems are occasionally manually over-ridden, a regular review identifies is essential to ensure energy is not used unnecessarily.

Compensation

With a water-based system, such as radiators, compensation is normally applied whereby the temperature in the circuit varies in accordance with the external temperature. The colder it is outside, the higher the water temperature in the circuit. There are minimum and maximum settings applied. This must be reviewed regularly or after any overhaul to ensure the compensation parameters are still representative and prevent overheating, which typically saves 5–10% on energy use.

Standard compensation can be enhanced by the addition of room influence, solar influence and wind influence, whereby a number of sensors are fed back into the control loop and influence the setpoint. This, in turn, provides improved comfort conditions and prevents overheating.

It is important to ensure that the maximum Delta T (temperature difference) for your system is achieved/maintained for any boost period to ensure the quickest consistent run-up and boiler efficiency.

Outside high limit

A water-based heating system, even with compensation applied, can be switched off if the outdoor temperature exceeds a pre-set value where difference between internal and external temperature is minimal or even negative. Heating is not normally required in a building when the outdoor temperature exceeds 16° C or 61° F, dependant on building type. It is important that hysteresis is applied to prevent plant turning on and off rapidly with a minor temperature change outside. Hysteresis is a method of control that will keep the plant turned off until the temperature rises a few degrees above the setpoint—similar to a household thermostat. Each building is different and the setpoint should be calculated accordingly.

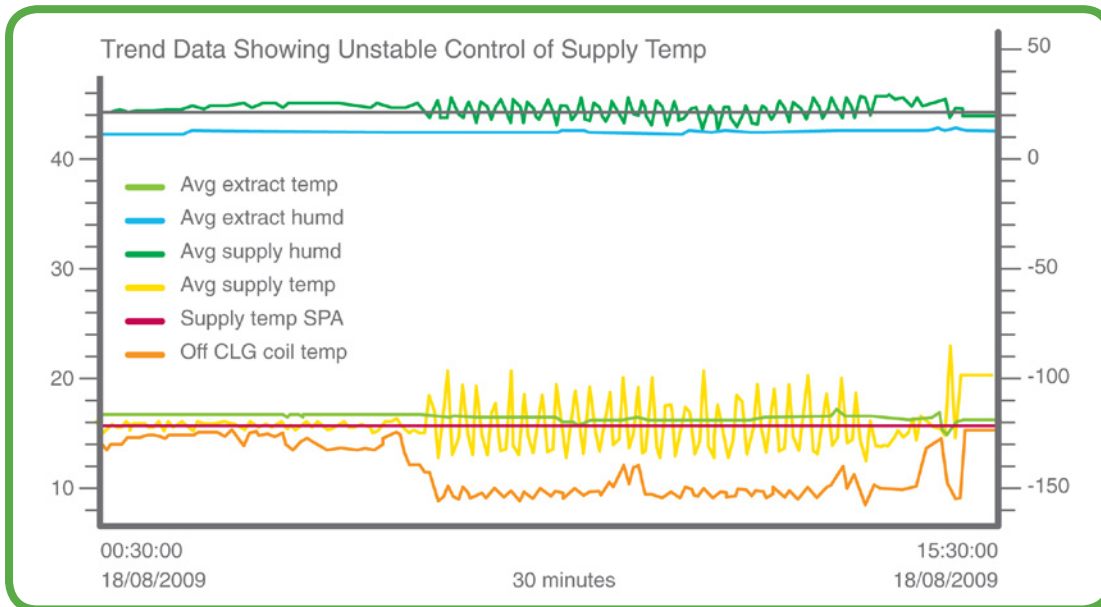
A low limit can be applied with cooling to ensure free cooling is used when the external temperature is below a pre-set by closing a cooling valve, zone, or disabling the primary chilled water plant (See Enthalpy Control). For example, a chilled water plant is disabled when the external temperature falls beneath 12–14° C or 54–57° F. Providing cooling is not required for process or there are no significant heat sources within the building.

Disable humidification

If the humidity (outdoor moisture content) is above the required level and satisfactory humidity levels are achieved in the return duct, then humidification systems can often be disabled. This application must be reviewed on an individual air-handling unit basis to ensure the control scheme allows this. Some air handlers rely on 100% humidified air to reheat the supply to the desired level. Location of people and equipment is a consideration.

Control stability

A lack of stable control increases energy usage by typically 3–5%, and decreases the life of valves and actuators.



Primary heating, chilled water, and central air-handling units must provide a stable supply temperature to their served areas, such as distributed air-handling units, VAV boxes, or fan coil units.

Unstable primary plant and/or the local plant control having incorrect PID settings causes hunting. Hunting occurs when a system first overcorrects itself in one direction and then overcorrects itself in the opposite direction and does not settle to a stable position.

The image above shows a graph of unstable control where the supply temperature increases and then decreases continually. This can cause over-heating followed by over-cooling which may only equate to a slight +/- variation around the temperature setpoint, but causes mechanical wear and tear, as well as inefficient energy usage.

By physically watching the control items for movement, the BEMS' trend analysis capability monitors valve positions and assists in the fine tuning of the control loop to maximize savings. Unstable control can occur due to changing plant performances and efficiencies. For example, a blocked filter reduces air flow. Regular reviewing of control loop performance is important to highlight failing loops or those that are hunting.

Air-handling systems—damper economy override

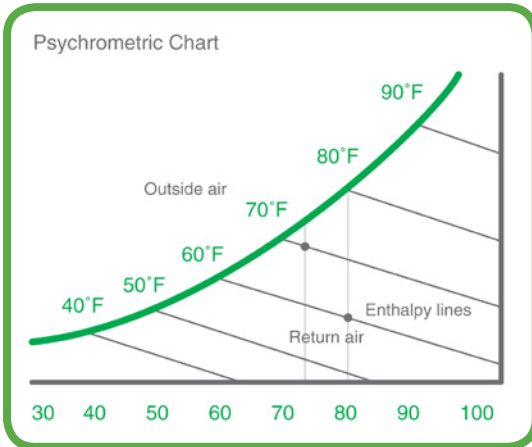
Most air-handling unit systems consist of a supply and extract with a recirculation duct with dampers on each to recirculate the already heated or air-conditioned return air or to utilize fresh air as a free cooling source.

Fresh air brought into the building is usually set to a fixed percentage (typically 10%). By using an air quality sensor in the return duct, the percentage of fresh air can be reduced when air quality is good, which is normally at the beginning of a working day, equating to energy savings and increased occupant productivity. Variable air volume systems need to maintain air by volume that can be used in conjunction with air quality.

Enthalpy Control

Enthalpy is the total heat content of air. This can be applied to air-handling unit systems with heating and cooling and humidity control. The principle is that even though the outside air may be warmer than the return air, there can be less total heat in Kj/Kg of energy.

A software algorithm is used to set this switch and dampers are positioned to utilize the “warmer” outside air which has a lower total heat content.



Demand programming

This program will constantly look at the heating and cooling control valve positions to determine if there is a load on its associated system. If any (or a low percentage) of the valves are open more than 5 percent, then the systems operate normally to satisfy the demands. If all the valves (or a high percentage) are less than 5 percent open, then the secondary pumps are disabled. After a time delay, the primary pumps and main heating or cooling systems are disabled, providing there are no other demands from any other systems. This improves efficiency of the primary system, as it only operates during a predefined time schedule if there is a genuine demand and not just because the time schedule is on.

Night purge/summer pre-cooling

If the cooling load at start of building occupancy is required and if the night time external air is cooler than the required occupancy temperature then Night Purge can be applied.

This sequence enables central heating and chilled water plants to be disabled and air-handling unit systems to run in full fresh air mode for a period of time, typically 30 minutes, in the early morning hours, before the sun has risen. This fills the building with fresh, cool air and reduces the initial load on the primary system at occupancy start. Flushing the building with fresh air also clears out residual carbon dioxide/vitiated air and provides building occupants with cleaner air.

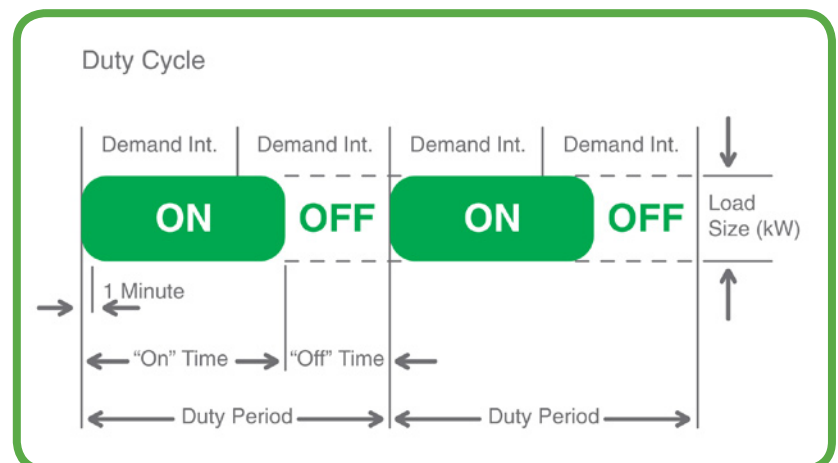
Electricity Savings

Load cycling

Load cycling refers to switching off an electrical load for a period of time on a regular basis. Load cycling can be applied to background systems, such as a fan or pump so that it will not result in consequential inconvenience. You should override load cycling if conditions exceed a pre-set, such as a low space temperature.

If for example, the system is switched off for 5 minutes within a 20-minute period, then the savings per hour equals 20 minutes or 25%. When applied, load cycling typically results in 5–25% savings on the electricity bill, depending on the size of the plant.

Disadvantages of load cycling are that regularly starting and stopping plant may cause an increase in electrical load during start up and could decrease the overall life of the plant. In these cases the use of a variable speed drive should be considered.



Variable speed drives

The use of variable speed drives in various aspects of a building is now prevalent. Many are used mainly as soft start-up and then operate at a fixed speed. The information held within the BEMS can relate to environmental conditions and occupancy levels from access control, with these data algorithms relating to demand. For example, varying the air volume through the working day,

based on occupancy levels from the access control or air quality sensors ensures that the minimum amount of energy is used on any partially occupied area of the building. Reducing a 50Hz-motor by 20% to 40Hz equates to 50% energy reduction.

Maximum demand

Maximum demand sets a limit for the maximum consumption allowed (normally over a 30 minute-period) and is a cost reduction measure by preventing this limit from being exceeded.

If any one limit is exceeded then a “penalty” is applied to the electricity bill that could equate to paying a higher tariff per KW/H consumed. The aim is therefore to ensure that the maximum demand limit is not exceeded. Cost reduction associated with maximum demand implementation can be substantial if demands were regularly exceeded and penalties applied.

A controller is synchronized with the maximum demand meter and forecasts whether the limit will be exceeded by monitoring the rate of electricity consumption, versus the amount of remaining energy and time.

The algorithm associated with maximum demand is complicated, but the net result is that site-wide

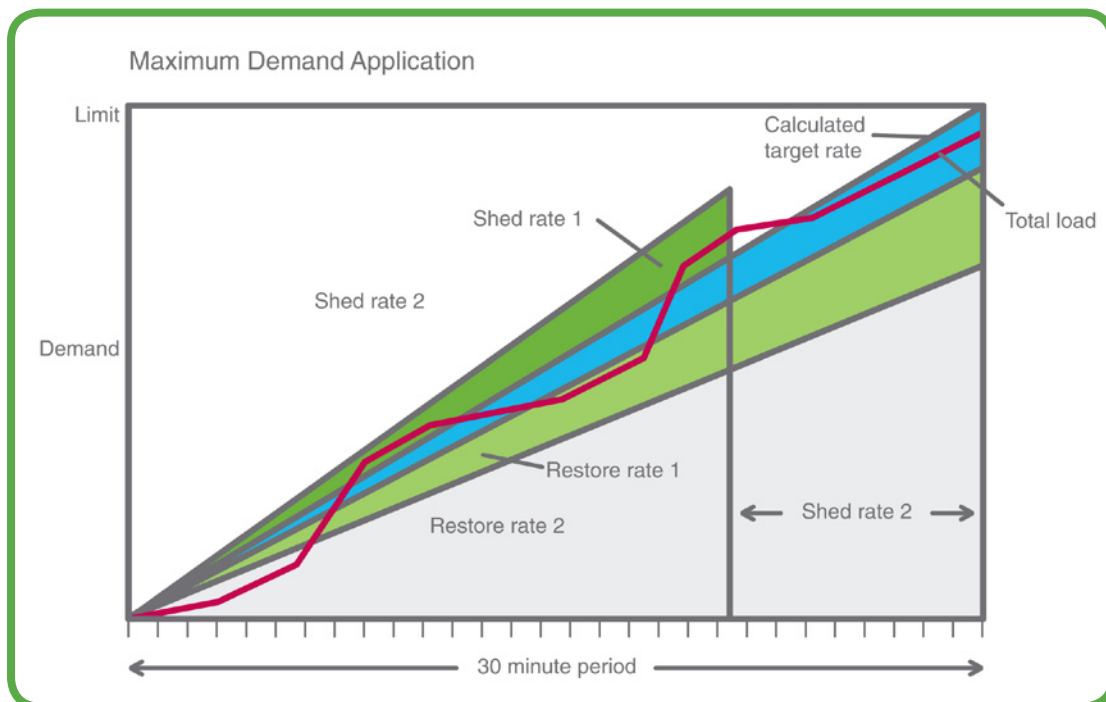
electrical loads are shed if the algorithm predicts the limit will be exceeded. Electrical loads are reinstated after the danger period has passed.

Electrical loads are shed in rotation per priority level and a matrix enables the choice of load criticality. The rate at which they are shed and restored is continually reviewed by the calculations.

The demand target can be calculated by the BEMS if further reductions to electricity consumption are required. Determining which electrical loads can be shed can be complicated. The lowest level may be electrical water heaters, the highest level may be one of a number of chillers, whereby it may be out of sequence for a period of time as it goes through a shutdown sequence before it is reintroduced to the control scheme.

Indirect reduction of maximum demand could be applied by overriding the amount that a chilled water control valve can open to.

This would indirectly reduce load to the chilled water plant and therefore reduce electricity consumption; however, the time in which the valve takes to do so may not be practical, but may be possible on parallel routines.



III. The Intelligent Building Approach

Intelligent integrated building solutions are becoming standard. Building integration can include access control, intruder detection, security, chillers, lighting, digital video, power measurement, variable speed drives, etc. The integrated approach provides access to all building systems through one coherent and customizable user interface. Additionally, building integration reduces training costs and standardizes alarms and logged data.

Integrated building systems also lower capital expenditures because data networks are shared, there are less computers and servers, and devices have numerous uses. For example, a passive infrared detector, normally only used by the intruder systems, can also trigger CCTV recording, relax setpoints for HVAC control, and turn off lighting when no occupancy is detected. Another example, when access control is used to gain entry to a building, this signal is used by the lighting control and HVAC systems to change from economy levels to occupied mode.

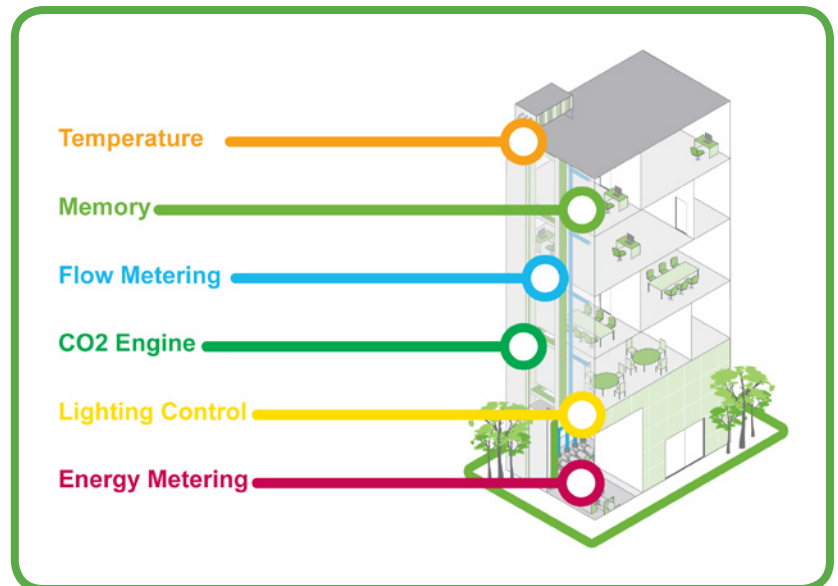
On-going operating expenses are also reduced because there are fewer computers and networks to maintain and fewer user interfaces, ensuring those who operate them are more efficient and productive. Integrated control strategies offer extended energy savings by allowing the building systems to work in empathy with each other. Using information from all the systems, strategies can be deployed to reduce the use of energy-consuming devices and create a comfortable and productive workspace.

Energy monitoring, profiling and modeling

Energy monitoring, profiling and modeling applications provide the information needed to make informed decisions based on energy usage patterns. Understanding and reducing the building base load is a primary step in reducing utility costs.

Data can be gathered in intervals (15, 30, 60 minutes) by the electricity utilities data provider (mandatory where consumption exceeds 100KW/h

in some markets). Gas and water meters are often connected to spare inputs. With the customer's approval, utility grade data is accessed along with the hardwired or soft-calculated BEMS meters and is further processed to enable presentation and data analysis through a secure internet site. This information can be graphed throughout the day allowing you to see energy use rise when building systems start and energy use decrease when occupancy and building use decreases.



This information is used to validate energy consumption; for example, you can ensure energy consumption matches the actual occupancy of a building, taking into account any preheat/cool cycles.

The load profile is the focus for energy optimization to a) understand and optimize the building base load consumption, b) reduce peaks, and c) reduce daytime use. The ability to compare and benchmark information by overlaying equivalent days such as a Monday's profile or a specific week's profile provides an accurate picture and highlights anomalies for investigation.

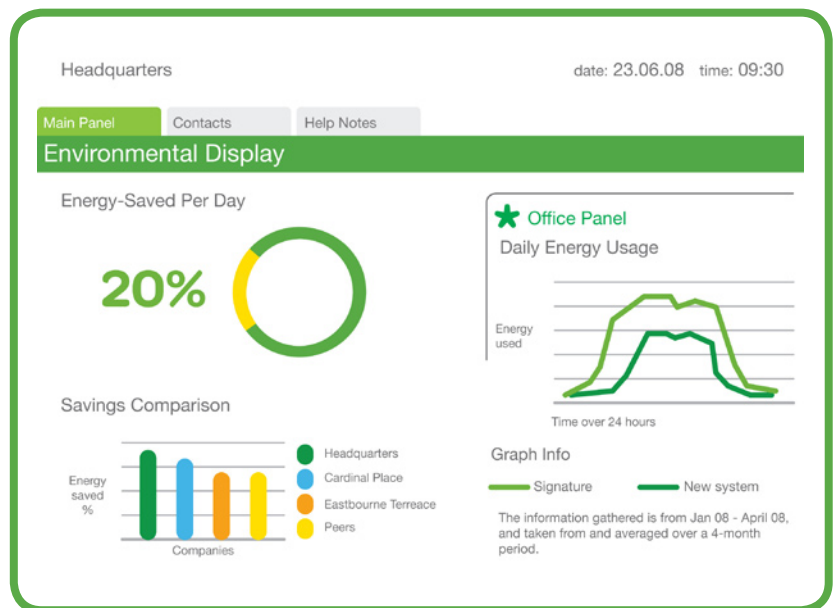
Modeling enables “What if” scenarios to run on existing data factors. For example, “What if I reduce my energy by 10% between 09:00 and 11:30, or by 16KW between 17.30 and 19.59?” with visual feedback in terms of energy reduction, CO2, Carbon, etc.

The utility modeling cost reduction techniques can deliver savings for various industries. The modeling tool is easy to use and is provided as a web service on a day +1 basis.

Utility performance visibility complements the real-time alarm and controls facilities of the BEMS software. Importantly, it extends the benefits of a single utility meter, as meters can be soft calculated for smaller areas of the building, giving additional perspectives of the site’s performance, such as a consumption profile for a given department or tenant, as well as trends and savings achieved through investments, etc.

Energy aggregation

Energy aggregation is used when there is more than one site involved. The use of technology can collect, aggregate and analyze total energy usage and more importantly the overall consumption profile, spanning all buildings. The data can be used to negotiate improved tariffs, based on the aggregated profile, significant savings can be negotiated.



IV. Conclusion

A flexible, easy-to-use, networked BEMS is an important tool for the implementation and monitoring of energy conservation measures. Through its direct digital control capabilities, the BEMS provides occupants of a facility with a comfortable, precisely-controlled environment.

The energy-saving opportunities available through a BEMS help address the needs for energy and environmental improvements—improvements that are clearly demanded by government organizations and the public alike. The features of TAC's BEMS demonstrate our commitment to remain at the forefront of technical innovation and to provide the "best of breed" BEMS systems and tools to maximize the energy savings capabilities of our customers systems.

For more information, please contact Brandi McManus, Solution VP, Energy: brandi.mcmanus@buildings.schneider-electric.com.

Note: All figures quoted for energy savings are for guidance based on practical experience or where figures have previously been published and vary according to the type of plant being controlled and the building construction.

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On October 1st, 2009, TAC became the Buildings Business of its parent company Schneider Electric. This document reflects the visual identity of Schneider Electric, however there remains references to TAC as a corporate brand in the body copy. As each document is updated, the body copy will be changed to reflect appropriate corporate brand changes.