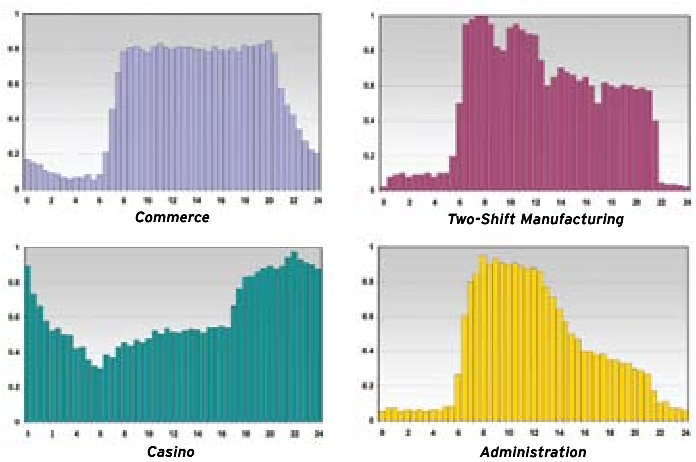
Control for Energy-Efficient Buildings

The building sector is responsible for about 40% of energy consumption and more than 40% of greenhouse gas emissions; hence the interest in increasing energy efficiency in buildings. Heating, ventilation, and air conditioning (HVAC) is the principal building system of interest, but there are others: lighting, active façade systems, renewable generation sources, and storage.

Real-time control and optimization can help building owners and tenants minimize energy consumption and costs based on inputs from occupants, local utilities, and weather conditions. Challenges for implementation of advanced control solutions include the heterogeneity and complexity of typical building environments. New developments in building models and in building automation systems are addressing these and other challenges.

Daily Consumption Profiles: *Every Building Has a Unique Consumption Pattern*



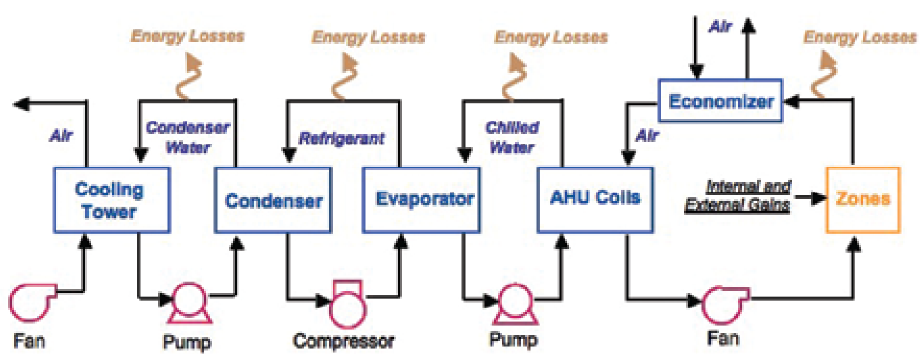
Buildings as Systems of Systems

Buildings are complex systems composed of sub-systems that were traditionally deployed independently of each other. This applies not only to building energy systems, but also to other systems, such as access control, fire protection, and video surveillance.

Heterogeneity. Building components do not necessarily have mathematically similar structures and may involve different scales in time or space. For instance, building control is a complex hybrid problem that includes both continuous and discrete components; major building systems operate in discrete modes (air handlers) or cycle on/off (chiller compressors).

Complex relationships. Building components can be connected in a variety of ways, which may cause complicated dependencies between local and systemwide phenomena. HVAC systems are potentially very large networked systems with complex relationships between the comfort in rooms or zones and operation of individual HVAC components.

Disturbances. Building operation follows a regular daily cycle. For most office buildings, the two major disturbances are weather and occupancy, and efficient control strategies should take both into consideration. The main challenge is with occupancy that cannot be measured. Other categories of buildings may have additional disturbances caused by their specific principles of operation.



System view of HVAC

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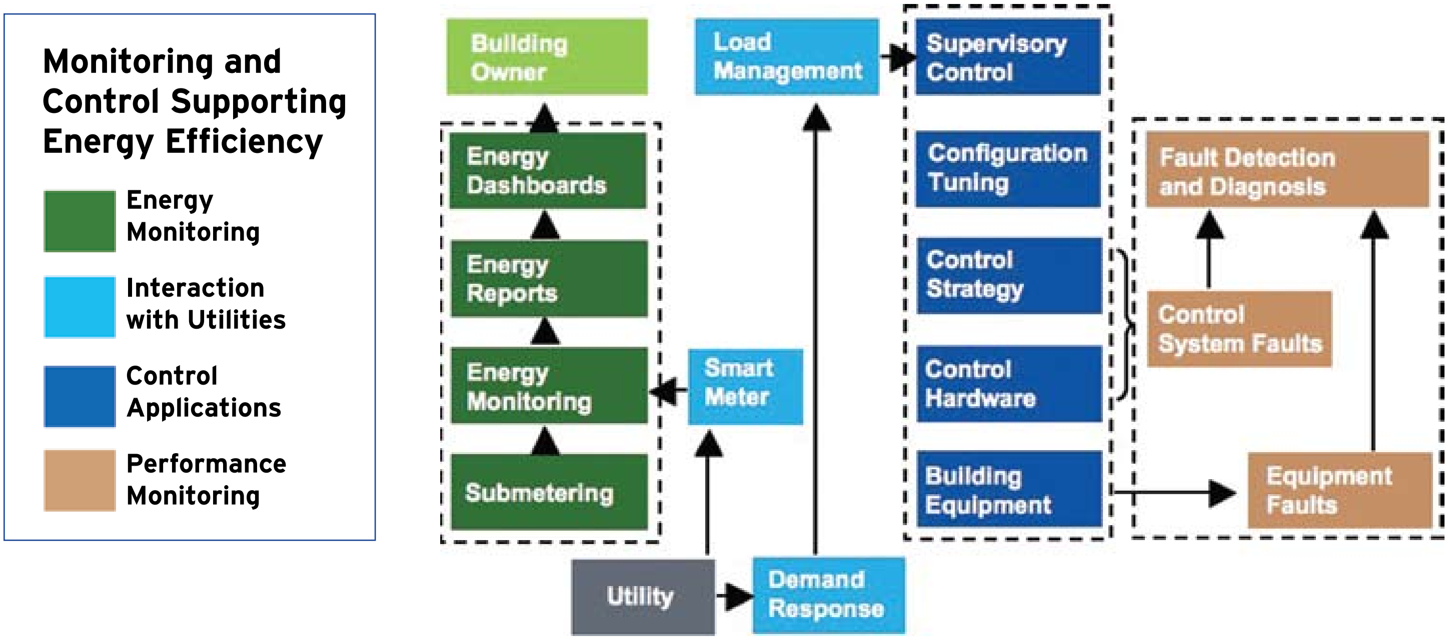

Challenges and Opportunities in Energy-Efficient Buildings

Entropy is the perpetual enemy of building operations. Building systems degrade over time, and today little can be done about it. Historical operational data is difficult to gather from building management systems, accurate models are generally not available and are hard to develop, and the availability of skilled staff is limited. Recent developments are helping overcome this difficulty: with building information models (BIMs), a standardized way to describe aspects of buildings has become available; most medium-to-large buildings now routinely capture large quantities of operational data; and energy efficiency and load management have become high-priority imperatives. These developments are opening up new opportunities for advanced control in building energy management.

Multivariable supervisory control. The primary goal of building control is to run the HVAC systems to maintain occupants' thermal comfort and system energy efficiency. HVAC control requires adjustments of multiple setpoints, including chilled water temperatures, supply air temperatures, and room air temperatures. Robust multivariable supervisory control strategies need to be developed to enable optimal HVAC operation as well as other building control and optimization applications, such as dynamic load management and dispatching of energy generation, consumption, and storage devices.

Whole-building optimization. Optimization of building energy consumption can be formulated at the whole-building level to cover subsystems such as HVAC, lighting, on-site generation, and storage. The optimization is complicated by disturbances, including weather conditions, occupant behaviors, and prices of electricity and other primary sources of energy. Solving the problem means having to make dynamic decisions on optimal operation of all building energy subsystems. Today this problem is handled by human operators or simplified rule-based logic, but a holistic whole-building optimization approach is needed to address this problem appropriately and achieve maximal cost savings.

Performance monitoring and health management. Physical and control system faults in HVAC systems cause inefficient operation, increased energy use, and reduced equipment life. Many of these problems could be prevented with widespread adoption of automated performance monitoring and equipment health management. The uniqueness of most HVAC implementations, lack of design information, and limited sensors for monitoring have been obstacles that are in the process of being overcome.