MILITARY EMCS: IMPLICATIONS FOR UTILITIES, CITIES, AND ENERGY SERVICES

Michael MacDonald and Michael Gettings
Oak Ridge National Laboratory

ABSTRACT

This paper discusses possible extensions of energy monitoring and control systems (EMCS) to a high level control for many buildings over a large area (large scale EMCS). Extensions of current EMCS approaches appear to be emerging technologies. Initial awareness of possibilities for such extensions was generated as a result of a study conducted on the effectiveness of EMCS used by the U.S. Army. Further interest was generated upon learning about other systems that make use of extended control to many buildings over a large area. An overview of certain factors that appear to have an impact for the large scale EMCS concept, limited trend data available on energy and cost savings for the military systems that were evaluated, operational and maintenance considerations that impact use of the large scale EMCS, a discussion of some implications for potential future use of large scale EMCS, and recommendations for possible future work on study and implementation of such systems are presented. The concept of large scale EMCS offers important challenges and opportunities for utilities, cities, and energy services to advance the art and science of building energy and comfort control. We hope the large scale EMCS concept can lead to useful, real applications that provide benefits for many people and organizations. Significant benefits appear possible for extensions of present EMCS technologies, and significant work is needed to understand and promote these potential benefits.

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INTRODUCTION

The acronym, EMCS, has been used to stand for Energy Monitoring and Control System(s) and Energy Management and Control System(s), with the military using the former. EMCS have been used as a tool in building energy management for many years, with significant growth in systems in the late 1970's through the present. Following the microprocessor trends for controls in general, EMCS have increased in power and decreased in costs in the 1980's.

This paper discusses possible extensions of EMCS to a high level control for many buildings over a large area (large scale EMCS). More information concerning installation, specification, configuration, problems, or use of an EMCS can be found in ACEC, 1984; Payne, 1987; Ottaviano, 1985, and the USACE reference entries. Extensions of current EMCS approaches appear to be emerging technologies. Initial awareness of possibilities for such extensions was generated as a result of a study conducted on the effectiveness of EMCS used by the U.S. Army. Further interest was generated upon learning about other systems that make use of extended control to many buildings over a large area (KSA, 1988; TII, 1988).

With a large, central, high-level system approach, the cost of (knowledgeable) system operators and maintenance staff can be spread over a larger number of buildings, and knowledge levels of energy system operators and maintenance staff have been a cause of concern in the past (Kolb, 1988). Also, current trends toward distributed control, with several levels of control "intelligence" (Int-Hout, 1986), augur important potential for high-level systems of the future. Implementing such a system offers technological and institutional challenges, but the potential benefits of improving energy control in more buildings indicates to us that system architectures and approaches should be explored more fully.

Utilities sometimes use load management control approaches to effect reduced power loads during periods of peak demand. An EMCS is a recognized system for demand side management (EPRI, 1987) and is most often used to control both energy consumption and power levels (to reduce costs). An EMCS can also lead to improved overall control of a building or group of buildings by providing operator feedback on the status of systems and comfort conditions.

Monitoring of energy use with a large central system offers an interesting counterpoint to the control and monitoring of energy systems. In the Army EMCS are just beginning to be used to monitor energy use on a day-to-day basis to determine whether excessive use is occurring relative to an expected target for that day. This is the type of information and approach that was used for a prototype expert system for a large, institutional building (Haberl and Claridge, 1987). The implications of this work for large scale EMCS are that, on the scale being used by the military to monitor an entire base, advanced, expert system, diagnostic software could be developed to track and control energy use and power levels for entire cities or utility service areas at a level not previously possible (see Richardson, 1985).

The mix of residential and commercial/industrial types of buildings found on a military base provides an example of the scheduling tradeoffs possible with this mix. Commercial/industrial peak electric use occurs from about 10 a.m. to 5 p.m., while residential peaks are controlled to occur before and after this period. Some scheduling benefits may also be possible for large scale EMCS covering a mix of buildings in a city or utility service area.

A mix of EMCS subsystems was also found on the Army bases to handle two building types: large, complex and small, simple. Small, simple buildings include houses, small barracks, small offices, small shops, etc. Large, complex buildings include hospitals, large barracks, many restaurant facilities, large offices, laboratories, etc. The control hardware for the small, simple buildings is also simple, and control signals are typically transmitted by FM carrier. Large, complex buildings have more complex hardware, and control signals are sent via dedicated telephone lines (or optic fiber cable). The large, complex buildings also tend to be clustered in a core area. Remote buildings are controlled via FM signal, so the division between small, simple and large, complex also includes remote vs core location. Overall control of all buildings is managed by the central EMCS.

This paper presents an overview of certain factors that appear to have an impact for the large scale EMCS concept, limited trend data available on energy and cost savings for the military systems that were evaluated, operational and maintenance considerations that impact use of the large scale EMCS, a discussion of some implications for potential future use of large scale EMCS, and recommendations for possible future work on study and implementation of such systems.

ENERGY AND COST SAVINGS TRENDS

Examination of annual energy consumptions for bases may offer some evidence of EMCS effectiveness. However, many extenuating circumstances must be considered. Raw consumption data may be misleading since weather or mission alterations are not considered. To what degree weather is a factor depends on what fraction of the total energy consumption is used for building conditioning and how envelope dominated the buildings are. A base's energy consumption may also change as a result of mission changes, including addition of equipment or new facilities. How savings at an Army base relate to potential savings for the private sector is open to question also, but indications of savings on the bases—which have significant constraints to saving energy (including problems with maintenance)—offer encouragement for application elsewhere. A large scale EMCS in the Washington, D.C., area is claimed to save 9% of energy (mostly electricity) use on average for large office buildings, with costs for the service unspecified (KSA, 1988).

On the cost side, the costs indicated for Army EMCS may be a factor of 2–4 above what a current installation would cost, and the costs may be 5–10 times above what simpler hardware might cost for the most used control functions (start/stop, duty cycling, demand limiting). With these factors in mind, present information on savings and costs for Army EMCS is presented below.

The plots which follow illustrate the history of energy consumption for four bases studied. Values are in Btu, with electrical consumption converted using 3.413 Btu/W-h. Raw consumption applies no adjustment for weather effects on the energy use. The goals plotted with the consumptions represent the annual targets for the bases as computed by their major command. Each command's method of computing the goals for their bases differs. The goals may contain factors accounting for base growth (both in physical size and number of personnel), mission changes, energy conservation projects implemented, and past performance. They show a measure of expected progress in energy conservation and may help reveal factors which otherwise would hide the effect of the EMCS. However, their complexity, or simplicity in other cases, and non-uniform manner of computation limit their use for comparisons.

Figure 1 shows historical energy consumption for a major base in the south from FY 1975 through FY 1987 and the energy goals for FY 1981 through FY 1987. The EMCS was partly operational in early 1986 and about 85% operational in early 1988. They expect to reach 90-95% operational status when their maintenance workload on the EMCS levelizes (probably by the end of CY 1988 or early CY 1989). Although small, a savings trend appears evident relative to the goals.

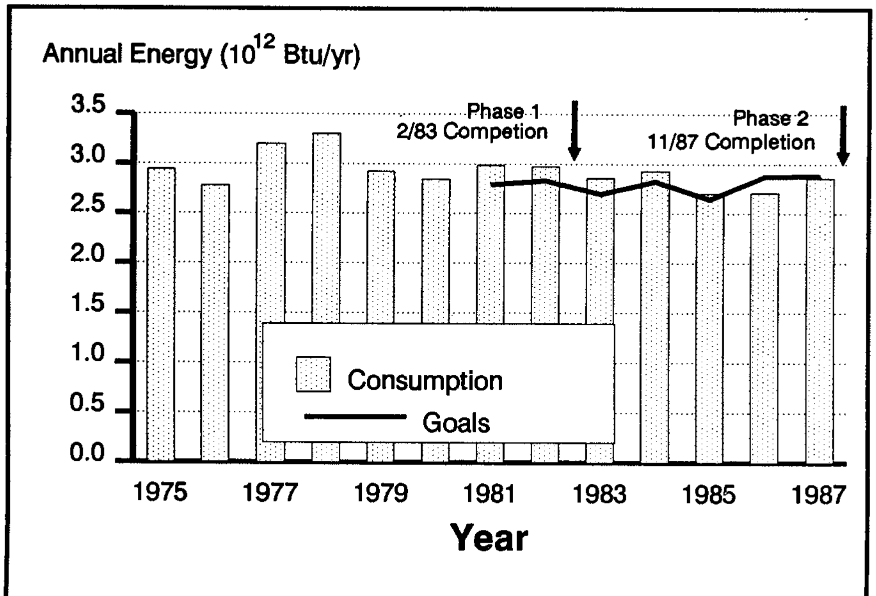

Fig. 1—Consumption and energy use targets for a first major base in the South.

The energy goals for this base included the expected savings from a solar pond, which was a major energy conservation project. However, the solar pond was not operational in 1987 (the increase in 1987 appears to be due to additional buildings coming on-line and additional training exercises being conducted for which goal adjustments did not compensate). The current trend indicates that the EMCS had an impact that could be seen in the energy totals for the base.

Monetary benefits from the EMCS at this base are derived significantly from their ability to control electric power within limits specified under a special rider negotiated with the utility (load management). Under this special rider, power must be curtailed upon notice during peak periods (7:00 am - 10:00 pm) of peak days (June - September) below the contract amount (39,800 kW). At other times higher power levels (up to 69,780 kW) are allowed. The total number of days per year when the base is under curtailment is in the range of 7-15 (10 in 1987). The cost savings for this special rider are in the range of \$500,000 per year. Energy savings from the EMCS are not known definitively, but from the figure savings may be 0.2×10^{12} Btu/yr and about \$800,000/yr (to our knowledge no other major energy-saving measures were installed). This would imply that the overall savings (minus maintenance and operations costs) may be in the range of \$900,000 per year (these values are very rough). There are not enough data to perform a fuel-by-fuel life cycle cost analysis, but it appears that even approximate life cycle cost benefits (about \$10 million for a 15 year life) exceed the costs for the system (about \$8 million).

Figure 2 shows the consumption and goal history for another base in the South. Implementation of the third phase of their EMCS in the middle of 1985 may have allowed them to again use less energy than their goal in 1986. The succeeding year, 1987, continues the trend of staying below the goal. Though the energy consumption increased from 1985 to 1986, the increase was less than the increase in their goal. Also, introduction of the first two phases of the EMCS in 1983 may have contributed to the steady decrease in energy seen in 1984 and 1985.

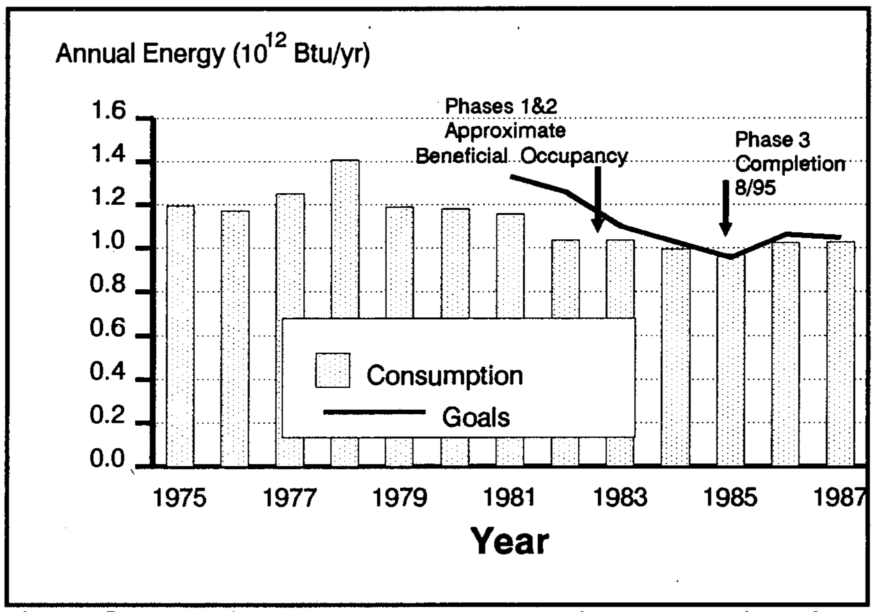

Fig. 2—Consumption and energy use targets for a second base in the South.

Other potential contributors to changes in this base's consumption history include the replacement of boilers in 1981, the shut down of one boiler plant and addition of a waste incinerator in 1983, and the connection of one boiler plant with a network of two others in 1985.

This base has a situation similar to the previous base's. Their system is fully developed, having had several phases implemented in addition to extensions and modifications. Their energy personnel estimate the annual monetary savings from peak demand reduction due to EMCS to be approximately

$870,000. Here the approximate life cycle cost benefits (for peak demand reduction alone), with some reduction for maintenance and operations costs, of $7 million exceed the installation costs of about $2 million by over a factor of three. It is of interest to note the feeling of operations personnel at this base that over 60% of the savings comes from points controlled remotely by FM (which were about 10% of total installed cost). These control points are mainly for start/stop control, also used to achieve duty cycling and demand limiting of HVAC units in small, simple buildings. Of the roughly 3600 points attached to their EMCS, about 2000 are FM. For the previous base, 4100 of a total 8100 are FM, and more FM points are planned.

Figure 3 shows the energy consumption and goal history for a medical center in the West. The plot indicates potential evidence for the effectiveness of the EMCS system. Completed in September of 1985, the system is most likely responsible for the decrease in energy consumption for fiscal year 1986. This is the first year the base demonstrated a consumption less than its goal and the lowest absolute consumption recorded. The jump back in 1987 may be due to curtailment of the use of the EMCS, but a specific cause cannot be cited. An earlier conservation project in 1983 and 1984 installed individual steam valves in apartment complexes. This change most likely contributed to the decreased consumption in FY 1984 (which appears to have been substantial). For this installation the savings are presently low, perhaps because the system is not being used to the extent that the previous two bases did. At present rates of savings the EMCS will probably not pay for itself.

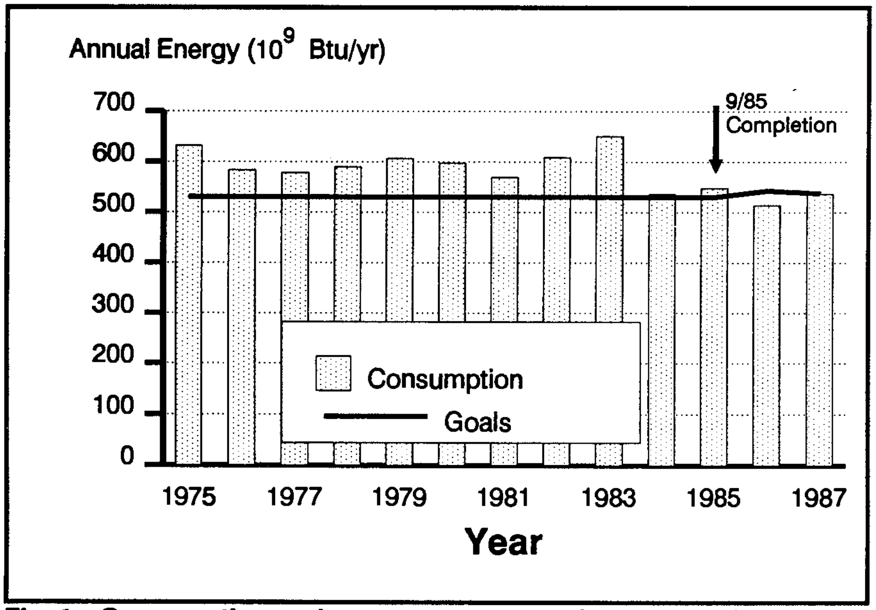

Fig. 3—Consumption and energy use targets for a medical center in the West.

The energy consumption history for a base in the Ohio River valley area (Fig. 4) indicates an EMCS system assisting the base in widening their successful decline below the command's goals. With beneficial occupancy estimated at the end of 1985, the EMCS is likely responsible for the decrease in consumption in 1986 and 1987. This base could not provide an estimated savings for the system at present, because they are still trying to move the system toward full operational capabilities. Indications are that savings will exceed costs for this base.

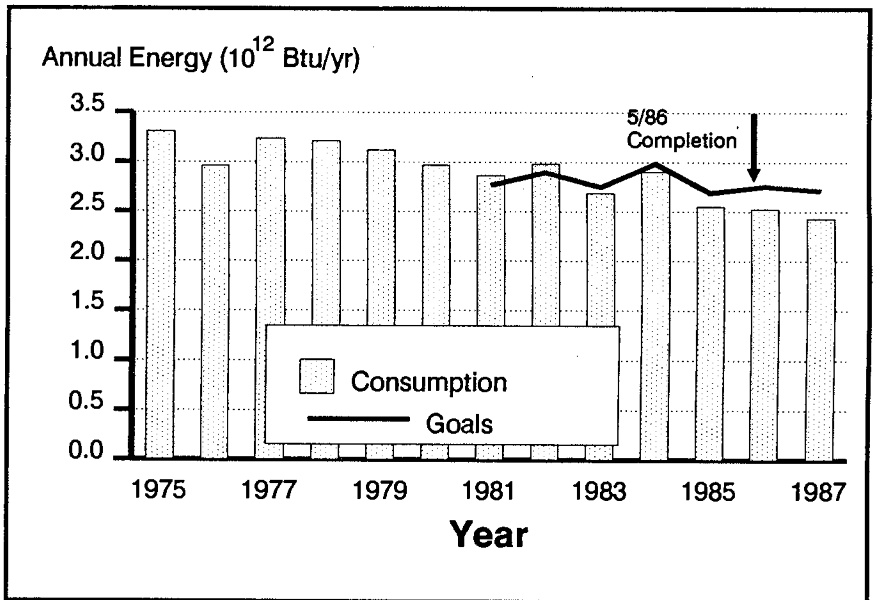

Fig. 4—Consumption and energy use targets for a base in the Ohio River valley area.

For the 8 bases studied: 2 appeared to have savings benefits justifying the costs; 3 had more uncertain savings but it appeared savings would justify the costs; 2 did not appear to have savings to justify the costs; and 1 had substantial savings that were negated by maintenance costs.

DISCUSSION

Although the energy savings and cost trends do not provide a solid picture of life cycle benefits, the indications are positive. We suspect additional savings could be achieved if base EMCS personnel knew more about how energy is used in specific buildings or groups of buildings (e.g., lighting is typically not controlled). Lower installed costs and increased savings appear possible. Important factors affecting possible implementation of large scale EMCS are presented below.

Evolution

The current process for installation of an EMCS on an Army base is guided by an impressive series of documents that have been generated within the Army Corps of Engineers (almost entirely by the Huntsville Division). They cover specifications, mandatory procedures, and guide procedures for the complicated process of defining, procuring, installing, and testing an EMCS (see the USACE-HND entries under **References** for examples). This current process has evolved over several years as functionality and use of EMCS have been improved. With the rate of change in microprocessor and communications technologies, further potential improvements continually emerge.

With the rapid changes in electronic hardware and software, the EMCS *must* be thought of as an evolutionary system. As an example, a document that is 4 years old (ACEC, 1984), is already outdated because it does not cover the types of distributed control prevalent in current buildings. The use of direct digital control (DDC) has changed overall control schemes dramatically and has led to the use of distributed control, whereby the control "intelligence" or logic is contained at many different levels in the control system. A recent paper (Int-Hout, 1986) provides a good description:

> The use of sophisticated electronics in zone control has been the last part of the system to be included in modern digital control systems. As the cost of microprocessors has dropped, and as the number of modern skilled microchip programmers has risen, we are finally seeing complex logic applied at the zone level.
>
> Modern microprocessor-based units are now being introduced at installed costs comparable to those of the more complex pneumatic systems, and they offer much greater flexibility, accuracy, and capability than their predecessors. The choice of control now available ranges from completely centralized, main frame computer-based controls to stand-alone sub-microcomputer zone units. The digital designs allow the capability of remote reprogramming for optimum performance and flexibility. Linkage with building system computers allows the possibility of true local load management and control. Building diagnostics is simplified, and much of the system maintenance may be performed from a keyboard.

One source estimated that, starting in 1987, 80-90% of all new large office buildings had DDC controls (USI, 1988). All this technology is not without problems though (e.g., increased knowledge required of operators and maintenance personnel, large variety of control programs to remember and track, increased difficulty in tracing software problems, incompatibility between manufacturers is increased). Part of the Army's effort has been to standardize on a capable system that they can expect to have installed and operated with reasonable success. Incompatibility between manufacturers remains a problem for the Army as well as others, and current work has been directed toward finding solutions to problems of incompatibility (Cornell, 1988; USI, 1988).

Incremental Control Functions

A major area that must still be addressed is evaluation of the appropriate control functions that should be provided for different buildings. Our experience with Army EMCS indicates that scheduled and optimal start/stop, demand limiting, and duty cycling control are the most widely used. However, these capabilities could probably have been provided using simpler hardware. Information on the incremental benefits vs costs of different control functions and on hardware and software to achieve those functions is needed.

Operators

Operators evolve in their expertise for using the monitoring and control capabilities of the EMCS. As experience is gained, operations personnel typically become knowledgeable enough to operate heating and cooling systems with the EMCS in what is perceived as a "better" fashion than some local control loops can. This could happen when the local control loops are malfunctioning and difficult to fix without major improvements or when design flaws in the heating and cooling system can be overcome by EMCS control. The personnel come to understand that control by the EMCS can be an improvement over existing conditions. Analyzing the need for this type of control adaptation is not a function software handles well.

Some Army personnel are using the monitoring capabilities of the EMCS to develop "expert" capabilities for intelligent start/stop control and methods of diminishing problems caused by inherent flaws in existing HVAC systems. As their expertise outstrips some of the software capabilities installed with the system, they quit using certain control algorithms that are not likely to save as much energy as the operator can using start/stop (or other) control strategies. Again, control adaptation appears to be important.

Use of the EMCS was extended at one base to interface with sophisticated electrical and gas metering for monitoring daily (and potentially hourly) consumption for the whole base. The objective is to compare daily energy use to an expected target for the day. As mentioned in the **Introduction**, this monitoring using a large scale EMCS together with an expert system offers interesting research and development opportunities, and operator knowledge plays an important role in development.

Overall, the roles and benefits of and costs for operators need to be understood better. Our experience with Army EMCS and other control systems indicates that qualified operators are essential to continued success of the system. Evaluation of roles, benefits, and costs would help in understanding the value of operators and operator experience, and large scale EMCS would allow operator costs (for more knowledgeable operators) to be spread over many buildings.

Maintenance

Proper maintenance of an EMCS is also essential to success of the system. Proper maintenance of the systems being controlled is needed too. Feedback on the operational status of system control points and temperatures and monitoring of energy use can provide important information about the need for maintenance. Keeping an EMCS connected to the systems being controlled can be a challenge when unrelated repair work is performed and EMCS communications are disabled in the process (as is the case for many Army installations). Feedback on point status and energy use can be used to identify problems that arise. Some companies sell maintenance management as an integral part of energy saving strategies (Servidyne, 1986; USI, 1988). Maintenance also offers an important area for expert systems development (Richardson, 1985). The challenge of proper and improved methods of maintenance will always be part of energy system improvements.

Related Systems

Large scale energy control and monitoring systems are also in use outside the military. Two examples are mentioned here. A company in the Washington, D.C., area provides control and monitoring of energy use for large office buildings (about 8% of all non-Federal office space in the area) over a wide geographical area from a central control location (KSA, 1988). This service is an outgrowth of building security services. As mentioned previously, average energy savings are claimed to be 9% and costs for achieving these savings are not known. Signal transmission is over dedicated phone lines, and the service is typically for buildings 200,000 ft^2 and larger.

Another company in Florida uses a system based on a microcomputer (80286 or AT-type) to provide a menu of schedules for scheduled start/stop and other types of control functions via FM transmission, cable TV lines, or other means to residences in a metropolitan area (TII, 1988). Use of this approach in commercial buildings is also being considered. This system is capable of handling small, simple buildings, and an enhanced system is being developed for larger buildings. Costs for this system are typically much less than current EMCS installations. Large area systems are emerging, further improvements are likely, and their impact will probably be important in the 1990's.

IMPLICATIONS FOR UTILITIES, CITIES, AND ENERGY SERVICES

The current generation of military EMCS have shown that large scale systems are possible, that benefits may be important, and that some important issues should be addressed as large scale EMCS use is expanded. The evolution of EMCS and other controls technologies, together with software advances, indicate dramatic changes are possible in the next decade. Large scale EMCS have the potential for significant impacts on utilities, cities, and energy services as these changes occur.

If large scale EMCS become prevalent over the next decade, utilities may be faced with systems that have control over a significant part of their load. Depending on utility objectives for their system loads, large scale EMCS could have important effects that support or hinder those objectives. One Army base is lowering peak demand from about 60 MW to just under 40 MW on critical days in return for a special rate. Utilities interested in peak clipping should consider the potential that large scale EMCS together with special rates might offer. If utilities are interested in overall energy cost reductions for their customers, large scale EMCS should be considered as an important emerging alternative. The potential impacts of extensions of EMCS should be evaluated carefully by utilities to determine impacts on overall loads of application by outside organizations vs potential direct or cooperative application by the utility.

The concept of providing a menu of EMCS schedules that customers choose from (TII, 1988) is also an example where early utility involvement could have important utility benefits. If the schedules are developed to keep equipment off during problem periods, utility needs and objectives could be communicated to customers in an indirect manner while attempting to provide customer energy cost savings.

Cities should also consider potential impacts of large scale EMCS. Cities with existing energy programs in place should be interested, and the potential for benefitting the overall business climate by reducing expected utility costs may also be of interest. Cities may be faced with decisions regarding implementation of large scale EMCS, such as the need to award a single franchise (similar to cable TV). A driving force behind the franchise issue is the planned upgrading of the telephone system in the 1990's to allow multiple digital channels over existing lines (SWBell, 1988). It is likely that only one channel will be available for energy management, and large scale EMCS implementation is a likely candidate for use of that channel.

Some cities might wish to have large scale EMCS operated by a special agency (e.g., quasi-autonomous non-governmental organization). Small cities and towns will in many cases have fewer potential services available to them. The choices for implementation may affect overall benefits, and some evaluation of implementation methods and requirements appears needed.

Large scale EMCS offer important potential for energy service businesses, and the potential magnitude of the energy and building control impact means that the needs of and potential benefits to many groups may have to be considered. Some companies already market services like these, but the evolution of these services is what must be tracked and evaluated. Experience with Army EMCS indicates that significant load management benefits may be possible through staggered control of residential and commercial/industrial buildings, by taking advantage of the mix of energy system use schedules in these buildings. In addition, extending high level control of energy schedules to both residential and commercial/industrial buildings may allow significant aggregate energy savings to be obtained, while allowing a central pool of knowledgeable operations and maintenance specialists to work with the systems for which they are most qualified. This could partially address existing problems with wide variations in these skills. Finally, the potential for real time diagnostics of many buildings on a large scale, based on automated analysis of building performance relative to historic performance or compared to similar buildings may present an important opportunity for advances in energy services. Existing companies and organizations are bringing large scale EMCS into use, and now decisions must be made concerning how to best use or refine these emerging technologies.

Many ideas have been presented in this paper, and additional discussion in other areas could be added. The purpose of this paper is to present developments related to emerging EMCS applications. We feel that the concept of large scale EMCS offers important challenges and opportunities for utilities, cities, and energy services to advance the art and science of building energy and comfort control. We hope the large scale EMCS concept can lead to useful, real applications that provide benefits for many people and organizations.

RECOMMENDATIONS

We recommend that large scale EMCS technologies be studied as emerging applications for utilities, cities, and energy services. The benefits and costs for existing systems and extensions of existing systems should be analyzed in more detail. Possible benefits from a mix of residential and commercial/industrial buildings should be quantified.

Appropriate control functions for best incremental benefits should be evaluated, together with the types of hardware and software configurations needed to provide those functions. Methods for dealing with present communications incompatibilities should be evaluated to see if multiple vendor systems can be implemented. The roles and benefits of central operations and maintenance specialists should be evaluated. The potential for expert system analysis of energy systems performance and maintenance needs should also be studied. Finally, methods of implementation of large scale EMCS should be analyzed for utilities, cities, companies or organizations offering such services, and cooperative arrangements between these entities should be developed and evaluated. Significant benefits appear possible for extensions of present EMCS technologies, and significant work is needed to understand and promote these potential benefits.

ACKNOWLEDGEMENTS

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