ARGUING FOR ENERGY ANALYSIS - EXPERIENCE OF THE U.S. ARMY CORPS OF ENGINEERS WITH ENERGY ANALYSIS DURING DESIGN

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ABSTRACT - Since 1977, the US Army Corps of Engineers has performed energy analysis simulations on thousands of building designs. While building design criteria continue to press energy conservation, in practice this thrust is often blunted by decision makers (e.g. building 'owners) with different orientations. This paper relates experiences the US Army Corps has had in energy conservation adaptation measures to both new and existing construction and analyzes these experiences in forecasting t he future of such attempts.

Experiences related include the Energy Conservation Investment Program and Energy Engineering Analysis Program results to date, the initiatives in new building energy conscious design, and the development / usage of various energy analysis tools and methods.

INTRODUCTION

The U.S. Army Corps of Engineers has pursued an aggressive campaign to reduce the energy consumption in Army owned buildings. These efforts stem from the requirements of Executive Order 12003 (1) dated 20 July 1977 to reduce the consumption of the total building inventory 20% by 1985 and 40% by 2000 when compared with 1975 consumption. The executive order further required that new buildings be designed with 45% energy reduction compared with 1975 vintage buildings.

Energy analysis played a key role in the various projects and programs the Army employed to achieve these goals. The Corps will have expended approximately $70 million by the end of FY86 on base wide energy studies and the retrofit designs. The annual energy savings achieved by the Army's Energy Engineering Analysis Program (EEAP) are estimated to exceed 15.4 trillion BTU at a cost avoidance of approximately $76.5 million per year. (2)

Energy analysis on new building designs has also been very successful. The ability to produce highly efficient building designs is attested by the fact that designs routinely meet energy budgets which include this 45% reduction target.

These significant energy savings were achieved despite the reluctance of the some building users who perceived energy saving initiatives as interfering with the function of the buildings and the mission of the occupants. Since these building users are not directly responsible for paying the energy bills of their buildings, much of the incentive to reduce consumption was missing as well. The Corps and Army installation commmanders used various means to overcome the initial resistance to building energy conservation.

The lessons learned by the Corps implementing Executive Order 12003 are related in this paper. Many of these findings and recommendations have application in government and private sectors alike.

THE ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP)

To comply with the 20% energy reduction goal of Executive Order 12003, the Department of Defense (DOD) recognized substantial reductions in energy consumption in existing buildings, as well as new buildings, was necessary. A major funding program was developed to retrofit energy conservation opportunities into these buildings. This Energy Conservation Investment Program as it is called provides a uniform set of engineering and economic guidelines on which the three services (Army, Air Force and Navy) evaluate the feasibility and order of accomplishment of various energy conservation retrofit options. (3)

The special funding potential of the ECIP program proved a boon to the Army's efforts to reduce energy consumption in existing buildings. As indicated in Figure 1, by the end of FY 80 the Army reduced the annual consumption in its facilities, which comprised 83% of total Army energy consumption at that time (4), by over 4 trillion BTU compared with a FY 76 base year. Further, had ECIP not come along, energy consumption would have risen an additional 4 trillion BTU resulting in an overall avoidance of over 8 trillion BTU. (Roughly a million barrels of #2 fuel oil yearly.) By the end of FY84 over 275 ECIP projects had been completed with energy savings exceeding 20 trillion BTU annually and with first year cost savings of over $94 million. (5)

THE ENERGY ENGINEERING ANALYSIS PROGRAM (EEAP)

In FY80 the Army built on experiences of the ECIP by developing a methodical base wide energy study program entitled the Energy Engineering Analysis Program. The EEAP was developed in recognition that the engineering capability at the installation (i.e. Army bases) level was insufficient to thoroughly analyze the potential of the all the retrofit options available. The EEAP consists of detailed base-wide energy studies which identify and rank the energy conservation options for each eligible building on Army bases around the world. These studies were conducted by private sector architectural / engineering (AE) firms under the overall management of the Corps Huntsville Division and the Office of the Chief of Engineers.

Under the scope of work for the EEAP contracts, AEs analyzed numerous energy conservation and alternative energy strategies as shown on Table 1. The AE also prepares the preliminary programming for the design and construction of energy conservation projects under the ECIP and other funding programs. Once Congress approved these projects detailed design and actual construction of the retrofits commenced.

ENERGY ENGINEERING ANALYSIS PROGRAM - INCREMENTS

A	ECIP Projects to Retrofit Existing Buildings
B	ECIP Projects to Retrofit Existing Distribution Systems and to Add or Expand EMCS
C	Feasibility of Renewable Energy Sources, Principally Solar & Biomass
D	Feasibility of Cogeneration and Solid Waste Plants
E	Feasibility of New Central Plants Fired With Solid Fuel or Conversion of Existing Plants to Solid Fuels
F	Low Cost/No Cost Modifications to be Implemented by the Installation
G	Programming Justification for Measures That Do Not Meet ECIP Criteria

Table 1.

The cost of the EEAP studies through FY86 are estimated to total $70 million. This amount is less than half the cost projected in 1977 by the Federal Energy Administration. Over 650 retrofit options costing $306 million have been constructed through the EEAP providing an annual savings 15.4 trillion BTUs and $76.5 million. (Note that the EEAP savings constitutes a large part of the total ECIP savings in the Army). The average simple pay back period for these projects is 4 years.

NEW BUILDING ENERGY CONSCIOUS DESIGN INITIATIVES IN THE ARMY

Parallel with the retrofit strategies in existing Army buildings, the Corps of Engineers developed and implemented ambitious new criteria by which its designers could achieve the second tasking of Executive Order 12003 (reduce the energy consumption of the new buildings by 45% compared to 1975 designs). This criteria required the designer perform each of the following steps on new building designs for the Army:

A. Using a design team approach consider in the design applicable energy conservation measures such as reducing window area, optimizing building orientation, and using night setback thermostats. (6) Included in this criteria were the energy saving devices being expounded by the General Accounting Office in their study of energy saving products recommended for Federal buildings. (7)

B. Perform an energy analysis using hand calculations or an hour by hour energy analysis computer program as required by the building size, cost or functional use. (8)

C. Calculate the design energy consumption of the building. Introduce energy reduction strategies such as increased insulation, or high efficiency HVAC equipment in the design as needed to meet a target design energy consumption called an Energy Budget. (9)

D. Perform an active solar system cost / benefit analysis and design same if the system proved cost effective. (10)

E. Attempt to further reduce energy consumption below the energy budget by energy and economic analysis techniques and tools. If the life cycle costs of these extraordinary energy reduction measures was lower than that for the more conventional design, these measures were incorporated into the design. (11)

This criteria was later accompanied by prescriptive standards which produced a very energy conscious shell design. (8) Although there is no authoritative documentation to indicate collectively the magnitude of the energy reductions achieved by this process, they are known to be considerable in case by case review.

THE DEVELOPMENT AND USE OF ENERGY ANALYSIS TOOLS AND METHODS

The energy studies performed for the designs of retrofit and new construction used a variety of building energy analysis tools. The emphasis placed on energy budget calculations in DOD criteria was a driving force behind the development and use of whole building energy analysis tools.

The Corps developed its Building Loads Analysis and System Thermodynamics (BLAST) computer program to cope with this whole building analysis requirement and to provide an R&D tool over which it exercised ownership control. At this early stage of development of energy simulation programs, whole building programs with a comprehensive loads simulation were nearly nonexistent. Over time, several other private and public domain energy analysis computer programs were developed several of which are now in general use on Corps designs. The loads portion of BLAST, though, is still considered by many to be unexcelled.

Congressional mandate, as interpreted by the DOD and the Army, forced energy design criteria to become so comprehensive that the level of effort in terms of design cost and time attributed to performing energy and economic analyses became burdensome on Corps and AE designers alike. Emphasis began shifting to finding or developing more cost effective methods of performing these analyses. The developers of BLAST, the Corps Construction Engineering Research Laboratory (USA-CERL), guided by input from the BLAST Users Group began enhancing their program with new text based and graphics input preprocessors (12), new systems models and executive type output summary reports (13). AEs were encouraged to run the latest version of BLAST on government computer time. This reduced the project design costs and enhanced the interplay with BLAST reviewers and the BLAST Support Office at the University of Illinois. All these measures significantly reduced the effort and investment required to perform a BLAST energy analysis. Modeling time was reduced from two man-weeks to less than one man-day for a typical Army building.

The last step in the process of performing a complete whole building energy analysis is the economic feasibility study of the alternatives under consideration. The Army, and for that matter the DOD, evaluates energy alternatives on the basis of their comparative life cycle cost or a Savings to Investment Ratio. Because of the frequent changes in criteria and the earlier emphasis on energy budget calculations, the swing to economic analysis indoctrination has been slow in coming to Corps and AE designers. The development of the Life Cycle Cost In Design (LCCID) computer program by USA-CERL (14) which will be released this summer incorporates the latest in the DOD economic criteria into the algorithms and data files of the program. This program takes the guesswork out performing economic analysis in design for the DOD's three services. LCCID will be available as a public domain program in FORTRAN 77 and implemented initially in Harris, Control Data Corporation (CDC) CYBERNET and microcomputer versions. Software vendors using LCCID as the basis for their own DOD economic analysis program will be able to secure a certification of compliance to DOD criteria through the Corps' Missouri River Division which serves as the Center of Expertise for Energy Analysis Computer Programs.

IMPEDIMENTS TO OBTAINING FURTHER ENERGY REDUCTIONS

The Army was fortunate that it was mandated to apply strict prescriptive energy standards and perform energy analysis routinely. The building project development system of the Army does not readily permit energy conscious considerations to take a lead role in the decision making process during planning and early design. As was discovered in several special research projects, attempts to infuse energy considerations into early design were generally unsuccessful. The decision makers at the installation level have little motivation other than achieving the immediate goals of functionality and architectural consistency of the design. The manner in which installations develop over time is a fairly routine, rigid process with little room left for the imaginative energy engineer / architect. The majority of energy savings realized by the Army, therefore, was a direct result of the equally rigid prescriptive and energy analysis design requirements.

The building category consuming the largest share of the Army's facilities energy is Family and Troop Housing. As shown in Figures 2 & 3, the living quarters of the troops and their families consumed between 30 to 50 percent of the electrical and heating energy at a typical Army installation in 1976. (15) Achieving substantial energy reductions in housing was an evasive undertaking. On Army installations, the housing energy use is usually not metered. The cost for energy consumed by housing occupants is paid as part of the installation's overall energy bill. The occupant does not know what he / she is contributing to the installation's or the taxpayer's energy bill. The result of this situation is a lack of leverage over the housing occupant for energy reduction initiatives.

The Army attempted to employ such energy saving devices as night setback thermostats and dollar saving strategies as air conditioner interruption for peak shaving in these housing areas. Most devices and strategies were typically defeated by the unwilling or uncomfortable occupants and the attempts were often later abandoned.

Installations that succeeded in substantially reducing housing energy consumption used other motivational and behavior modification approaches with the occupants. A primarily consideration in these efforts was to avoid the occupant gaining the perception that the energy reduction device or strategy would result in personal discomfort.

COMPARISON TO THE PRIVATE SECTOR

The Army's experiences with energy reduction are not atypical particularly when it comes to interfacing with the building owner and / or user. Although there is no Federal mandate like Executive Order 12003 forcing the private sector to reduce energy consumption (with the possible exception of the state of California), the relationship between the energy engineer / architect and the building owner / user is somewhat similar. Private sector building owners may resist energy initiatives because of a perception that the functional or space conditions requirements will be adversely affected. (16)

As with the Army, the primary decision parameter for the private sector building owner regarding energy saving opportunities is the cost avoidance associated with it. Because of the higher relative cost of fuel in building operations vis-à-vis the early 1970s, virtually all of the firms planning new construction place moderate to high priority on energy considerations of the building design. (17)

It seems clear that building owners and operators in and out of government will continue to demand that energy reduction efforts be focused on devices and strategies that clearly adapt or enhance the building use and environment. The motivating factor is cost avoidance or some other type of return on investment.

CONCLUSIONS AND RECOMMENDATIONS

The Army Corps of Engineers has helped the Army reduce facilities energy consumption dramatically through a series of initiatives that blended aggressive energy conscious design criteria for new construction and systematic retrofit programs for existing buildings.

In the process the Corps has come to appreciate the need to interface closely with a sometimes reluctant building owner or occupant if conservation efforts are to be realized. Although the primary consideration in the process is one of reducing facilities life cycle cost, the energy saving opportunity must not be included at the expense of the user's perceived functional and environmental objectives. The designer must also take the maintainability of the energy saving feature into full account in any alternative analysis. The energy engineer / architect and the user must understand each other well so that the energy analysis and its conclusions reach a receptive audience.

The economic considerations of energy analysis extend beyond the cost of the construction of the energy saving feature. In the life cycle of the building, the operation and maintenance costs, ease of operation and reliability of the energy feature play significant roles in the selection of design alternatives.

The actual cost of the analysis itself is another factor to be considered in the analysis to be undertaken. The Corps is required to weigh the cost of performing an energy study against the expected benefits it may produce. To comply with DOD criteria, the study must promise to pay for itself prior to it being performed. (8) The early, easy energy savings now behind us and the marginal life cycle savings of additional energy saving initiatives is falling. Therefore, to assure these energy studies are paying for themselves the Corps will continue to study and implement more cost effective energy analysis tools and methods.

The implications to private sector energy engineers and architects and energy analysis software vendors should be clear as well. It will be very advantageous to be in a position to offer the Corps cost effective energy analysis tools and approaches that can analyze the common and the more elusive energy saving strategies, devices and systems. Because the federal government is the largest purchaser of AE services and the Corps the largest contractor of same in the federal sector, it will probably be worth one's while to do so. And, despite federal budget cutbacks, the amount of work contracted by the federal sector and the Corps is expected to continue growing. (18)

Because of our close relationship with Army building owners and operators, the Corps should be approached by private sector AEs as they would approach a private building owner / operator. The AE and the Corps need to have a meeting of the minds over the objectives of the energy analysis as well as the criteria on which the analysis will be judged. "The key to winning an award" with the Corps "is to be intimately familiar with its needs." (18)

Congressional pressure to have the DOD adopt more private sector construction standards will induce the Corps to look and act even more like its private sector counterparts. The DOD is currently developing draft energy conservation criteria that incorporates to a large extent the requirements of ASHRAE Standard 90. Should this criteria be adopted, it will be easier for AEs to communicate with us on energy analysis requirements. It should also make the professional experiences gained with us more directly applicable to the rest of their customer base.

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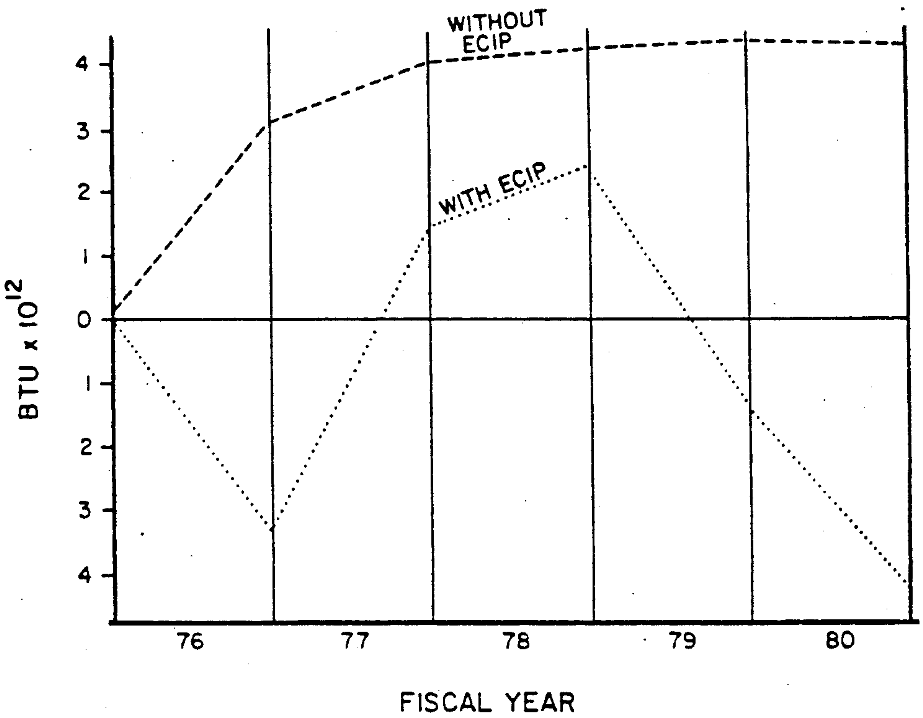

Figure 1.
Annual Change in Installation Energy Consumption With and Without ECIP Projects

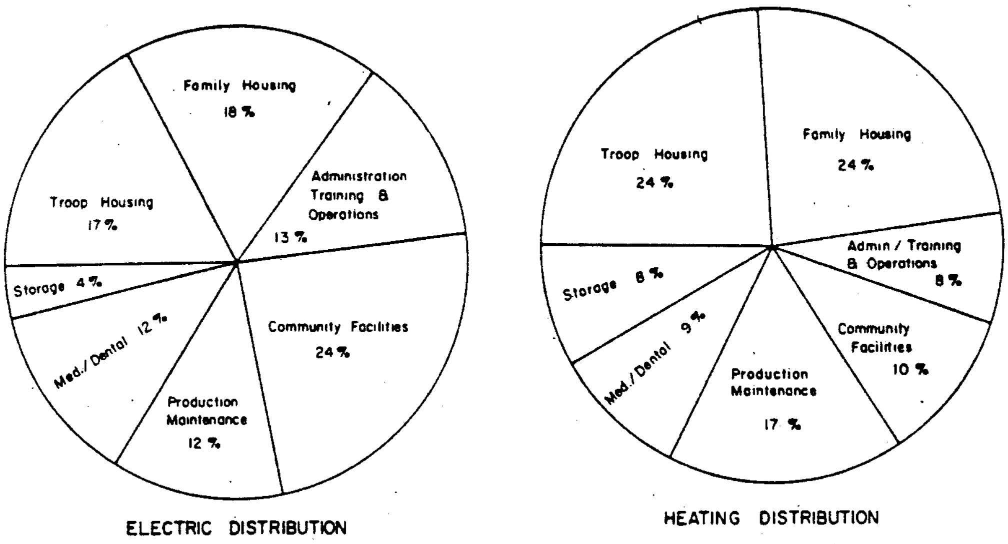

Figure 2.
Energy Distribution among Consumer Groups at Fort Carson

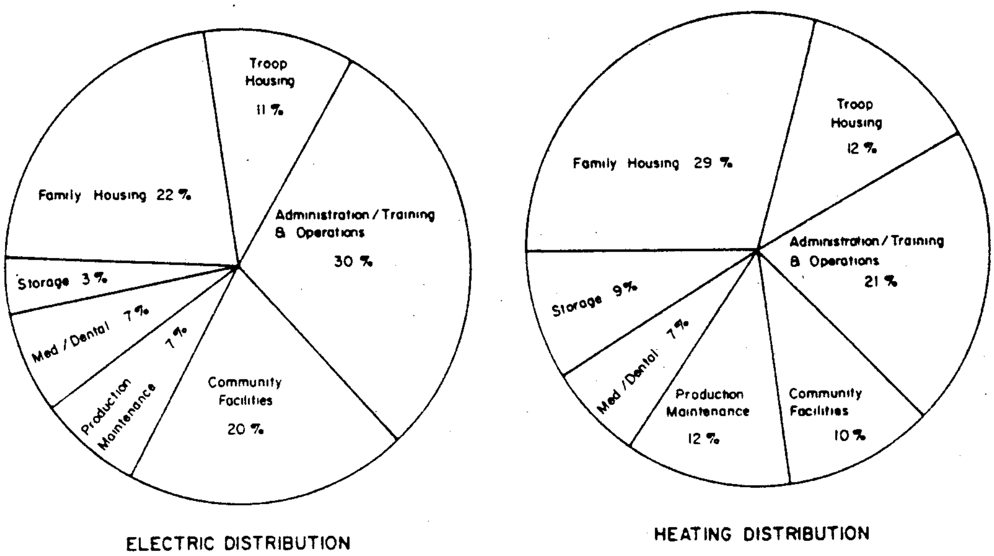

Figure 3.
Energy Distribution among Consumer Groups at Fort Belvoir