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EVALUATING THE EFFECTIVENESS OF ENERGY CONSERVATION PROGRAMS

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Abstract

With increasing federal emphasis on energy and its conservation, programs to conserve energy are being proposed at all levels of industry, commerce, and government. Many of these programs promise results that can never be realized. This paper describes an operational methodology for estimating and measuring energy savings for these energy conservation programs. The assumptions and qualifications which form the basis of the methodology are discussed, and some techniques for interfacing the methodology with a company's energy conservation program are presented.

1. INTRODUCTION

The evaluation of proposed energy programs is one of the difficult tasks facing government officials at the local, state, and national levels. Each day brings new schemes for saving energy. Everyone wants in on the action, and many are willing to predict whatever is necessary to get some of that action. It appears that little thought is given to how these predictions are to be realized. Sometimes the sum of the predicted energy savings from multiple programs even exceeds the energy to be expended. Clearly, top government officials need a rational basis from which to make intelligent decisions on proposed energy conservation programs.

The "Energy Walk-Through Assessment Program" at North Carolina State University is one program that has recently come under government funding. The program was initiated in January of 1975 by the Industrial Extension Service (IES) of the School of Engineering at NCSU. During its first two and one-half years of operation, the program was conducted and supported by IES with in-house funds. The acquisition of outside support has enabled IES to extend the walk-through service to more business and industry in North Carolina. This recent experience with the funding process has caused IES to take another look at the problems associated with program evaluation. This paper discusses some of the perspectives gained from this re-examination process.

The purpose of the walk-through program is to help firms save energy by providing technical assistance in energy conservation areas. In specific terms, the walk-through focuses a client's attention on four major areas:

i) the establishment of a company-operated energy conservation program,

ii) the establishment of an operational energy accounting system,

iii) the identification of practices and/or operations which are energy wasteful, and

iv) the identification of practical techniques for reducing the energy waste associated with the above practices/ operations.

Although this service is available at no cost to all companies in North Carolina, the primary emphasis has been on the small companies with limited technical and financial resources. These companies have been among those most severely affected by the energy shortages, since they are least able to cope with the problems associated with these shortages.

As the demand for energy walk-throughs has increased, it has become necessary to evaluate the effectiveness of the service. After some experimentation with qualitative evaluations such as questionnaires, it was decided that a more meaningful measure of the effectiveness of the walk-through service was the actual energy saved by the participating companies. Since the small businessman may not have the time nor inclination to gather energy data on a department-by-department basis, the walk-through program has encouraged the use of simple (easily understood) energy accounting procedures which quantify energy consumption on a plant-wide basis. The implementation of such procedures would enable the small businessman to

-- get a better understanding of the nature of his energy use,

-- see more clearly the results of his energy conservation efforts, and

-- make more intelligent decisions with respect to his energy consuming operations.

The walk-through program has enable IES to study government sponsored programs for the private sector from two points of view:

i) What is a reasonable basis for predicting the effectiveness of a proposed program?

ii) What is a reasonable basis for evaluating the effectiveness of an already operating program?

It is out of this perspective that the following methodology -- as applied to the walk-through program -- was developed.

2. RATIONALE

The general approach used in the methodology was to develop a system of savings equations covering the energy utilization for industrial, commercial, and governmental establishments on a unit basis. The fundamental parameters were "energy consumed per unit of production" for industrial plants and "energy consumed per cubic foot of heated or cooled space" for commercial and governmental buildings. These parameters were chosen as the fundamental measure of the "energy conserved" because of the following considerations:

i) One of the first tasks in establishing a comprehensive company-operated energy conservation program is to set up energy record-keeping procedures. The parameters should grow out of and be consistent with these procedures.

ii) The parameters should be supportive of the company's energy conservation program, so that they provide an understandable measure of the company's progress in energy conservation.

iii) The parameters should not be unduly cumbersome or complex.

As an example, consider a textile plant which used 10,000 BTU per unit of production under previous operating practices. After receiving the walk-through and implementing a comprehensive company-operated energy conservation program, the plant's energy consumption dropped to 7200 BTU per unit of production. This "2800 BTU per unit" reduction in energy use, multiplied by the number of units produced by the company per year, yields the total annual energy savings for the company. It is important to recognize, however, that this figure represents the saved energy available at the company's meter, but does not represent the total raw energy saved at the source (well-head or mine). A determination of this latter quantity must take into consideration generation, transmission, and distribution losses associated in making the energy available at the meter.

3. ENERGY SAVING EQUATIONS

3.1 INDUSTRIAL PLANTS

$$E_{\underline{IA}} = U \times (E_u - E_u') \qquad (1)$$

where $E_{\underline{IA}}$ = annual energy savings for a given company in industry group A (in BTU).

U = number of units of production produced during the year.

E_u = energy used per unit of production prior to the implementation of an energy conservation program (in BTU per unit of production).

E_u' = energy used per unit of production after implementation of program (in BTU per unit of production).

3.2 COMMERCIAL BUILDINGS

$$E_{\underline{CA}} = V \times (E_v - E_v') \qquad (2)$$

where $E_{\underline{CA}}$ = annual energy savings for a given building of type A (in BTU).

V = volume of building in "cubic feet."

E_v = energy used per cubic foot of building volume prior to the implementation of an energy conservation program (in BTU per cubic foot).

E_v' = energy used per cubic foot of building volume after implementation of program (in BTU per cubic foot).

4. ASSUMPTIONS, RESTRICTIONS AND QUALIFICATIONS

The foregoing equations assume that data on the total plant energy consumption can be found, whereas separate energy quantities for plant heating versus process heating is more difficult to identify. The initial figures -- in BTU per unit of production -- will, in all likelihood, represent the total energy consumed. However, plants should evaluate their energy use from a process as well as a plant heating point of view. This method implies that some estimates of plant heating (and perhaps cooling) must be made. One approach to estimating plant heating requirements -- if measurement is not practical -- is to compare the total energy consumption of one winter month with another month having a similar production output (e.g., a spring or fall month when neither heating nor cooling are important). The difference between the energy inputs for these months is an approximation of the energy required for heating. Dividing this figure by the degree days for the month in question and the plant volume yields "BTU per cubic foot per degree day" -- a measure of the efficiency by which the plant is heated. If this procedure is repeated for a number of cases, a representative parameter for heating will be identified for a given plant on a monthly degree-day basis.

Similar indices for companies having large air conditioning loads are not as accurate. Although air conditioning requirements vary from month to month, the amount of air conditioning required for a given summer cooling season (May through September) is assumed to be relatively constant. Since most air conditioning systems are electrically driven, the BTU per unit of production can be compared on a summer cooling season basis.

As a consequence of these calculations, the "BTU per unit of production" figure will now reflect the total energy consumed minus those BTU consumed for plant heating and/or cooling. The implication of this approach is that the "PROCESS BTU per unit of production" can now be compared on a year-round basis.

5. CONSERVATION POTENTIAL

The information generated by the above equations can also be useful in predicting the energy conservation potential of an entire industry -- on a state, regional, or national level. As companies gain experience with record-keeping procedures (energy accounting), common units of production for each industry group will emerge. For example, experience with the brick industry indicates that "1000 brick" (of a defined dimension and weight) is an accepted unit of production for that industry. Typical percentage reductions relating to particular conservation measures for each industry group will also begin to emerge. How a given industry uses its energy -- the percent oil, gas, coal, wood, and electricity it uses -- will also become known and typical industry averages developed. With this information, more accurate predictions of the energy conservation potential of various industry groups can then be made.

5.1 INDUSTRY

$$E_{T_{\underline{IA}}} = E \times \frac{\overline{E}_u - \overline{E}'_u}{\overline{E}_u} \qquad (3)$$

where $E_{T_{\underline{IA}}}$ = potential annual energy saving for industry group A as a consequence of a particular conservation measure (in BTU).

E = total present annual energy consumed by industry group A in a given region (in BTU).

$\overline{E}_u$ = average energy used per unit of production for industry group A prior to adoption of the subject measure (in BTU per unit of production).

$\overline{E}'_u$ = predicted energy used per unit of production for industry group A after adoption of the subject measure (in BTU per unit of production).

5.2 COMMERCIAL AND GOVERNMENT BUILDINGS

$$E_{T_{\underline{CA}}} = E \times \frac{\overline{E}_v - \overline{E}'_v}{\overline{E}_v} \qquad (4)$$

where $E_{T_{\underline{CA}}}$ = potential annual energy savings for type A buildings as a consequence of a particular conservation measure (in BTU).

E = total present annual energy consumed by type A buildings in a given region (in BTU).

$\overline{E}_v$ = average energy used per cubic foot of building volume prior to adoption of the subject measure (in BTU per cubic foot).

$\overline{E}'_v$ = predicted energy used per cubic foot of building volume after adoption of the subject measure (in BTU per cubic foot).

6. PREDICTED SAVINGS THE ENERGY WALK-THROUGH PROGRAM

In many states, comprehensive data on the "average energy used per unit of production" by each major industry is not available. The "before" or present value, $\overline{E}_u$, is widely variable and depends on many factors -- not the least of which is the choice of the unit production. The "after" value, $\overline{E}'_u$, is not available, since it is a figure that will be generated as a result of the program. Under these circumstances, the prediction of energy savings must involve some assumptions. The following illustrate the assumptions made in a special program in North Carolina -- the walk-through program.

1. Each professional can provide energy-related technical assistance to approximately 125 companies per year (this includes the initial visit, report, followup visit, final evaluation, and travel).

2. The average energy consumption per manufacturing company in North Carolina is 32.5 billion BTU per year. This figure can be misleading because the industries that consume 85% of the energy in the industrial sector average 61 billion BTU per company per year. It is assumed that the majority of the requests for walk-throughs will come from this group of larger consumers, and therefore the latter figure 61 billion BTU will be used in the predictions.

3. If all walk-through suggestions are implemented, it is assumed that participating companies would realize energy savings of approximately 20%.

4. Since it is unreasonable to expect all suggestions to be implemented, it is further assumed that those measures that are implemented will save approximately 60% of the potential energy savings stated in assumption (3) above. The product, (.60) x (.20), is analogous to $\frac{\bar{E}_u - \bar{E}'_u}{\bar{E}_u}$ used in equation (3).

Thus, the predicted energy saving resulting from the walk-through program on a per professional basis is the product of the following four terms:

i) 125 companies served per year,
ii) 61 billion BTU per company per year,
iii) assumed potential energy conserved as a consequence of walk-through, and
iv) assumed energy conserved as a percent of the potential.

The method and rationale for estimating energy savings in the commercial sector essentially parallels the above procedure for the industrial sector. As might be expected, however, the assumed energy conservation potential or assumed implementation rate may, in certain instances, differ from those used previously -- simply because of inherent differences in the energy consuming character of the two sectors.

7. NATIONAL IMPLICATIONS

A perspective which is often overlooked at the local level deals with the broader national implications of energy conservation efforts. For example, many people are unaware that one BTU of electrical energy saved at their meter is approximately equivalent to three BTU at the well or mine. The type of fuel and energy utilized by each industry must be considered in order to relate energy savings at the plant to raw energy savings at the source. Since each industry is likely to use its energy in different percentages, a formula of the following form will be required for each energy consuming group:

$$E_{TS} = E_{T_{IA}} \times \left[\frac{\%O}{\%e_O} + \frac{\%NG}{\%e_{NG}} + \frac{\%E}{\%e_E} \right] \quad (5)$$

where E_{TS} = annual energy savings on a raw source basis for the stated industry (in BTU).

$E_{T_{IA}}$ = potential annual energy saving for industry A (in BTU).

$\%O, \%NG, \%E$ = percent of oil, natural gas, and electricity used by industry A.

$\%e_O = 81$ = percent of energy available in oil after transmission losses have been deducted.

$\%e_{NG} = 93$ = percent of energy available in natural gas after transmission losses have been deducted.

$\%e_E = 30$ = electrical energy available as a percent of raw energy after generation and transmission losses have been deducted.

It is important to note that this equation considers those energy sources most commonly used by industry and commerce today. If coal, wood, or some other fuel is used, this equation can be easily expanded to include these fuels.

The assessment of the overall energy savings at the state, regional, or national level requires the summation of the E_T's defined above for all energy users.

8. SUMMARY

The underlying theme of this paper is: "Government sponsored energy conservation programs for the private sector should be evaluated by methodologies that can be characterized by simplicity, clarity, and straightforwardness." In the future -- as business and industry become more mature in their energy conservation efforts -- more complex and discriminating methodologies can be considered. For the present, the prediction and evaluation of energy savings should relate to the actual energy saved by the participating companies (or clients). This implies that an energy conservation program must have -- as one of its first objectives -- the establishment of an effective energy accounting system by all participating companies.

The fundamental parameters of energy conservation suggested in this paper are "BTU per unit of production" for industrial plants and "BTU per cubic foot of volume" for buildings. These units are sufficiently elemental to provide both management and employees with an understandable measure of progress in energy conservation. Subsequent success in energy conservation programs will then lead to an increased awareness among top management of the significant savings that can be realized by effective energy management programs. This awareness will lead to increased top-management support -- support which is absolutely essential if company-operated energy conservation programs are to be successful.

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BIOGRAPHY

Dr. Herbert M. Eckerlin is Associate Professor and Extension Specialist of Mechanical and Aerospace Engineering at North Carolina State University. He received his B.S. in Mechanical Engineering from Virginia Polytechnic Institute and his M.S. and Ph.D. from North Carolina State University. Dr. Eckerlin has a broad range of industrial experience, including service with Virginia Electric and Power Company, Combustion Engineering, and Corning Glass Works. He has considerable industrial experience in the design and operation of special purpose type heat exchangers, is the author of a number of technical papers, and holds 11 basic patents in fluidics and heat exchanger design. He is Co-Director of the Energy Walk-Through Assessment Program and has presented educational programs on energy conservation to numerous industrial audiences.