Chapter 1

Introduction to Energy Management

1.0 ENERGY MANAGEMENT

The phrase energy management means different things to different people. To us, energy management is:

> The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions

This rather broad definition covers many operations from product and equipment design through product shipment. Waste minimization and disposal also presents many energy management opportunities.

A whole systems viewpoint to energy management is required to ensure that many important activities will be examined and optimized. Presently, many businesses and industries are adopting a Total Quality Management (TQM) strategy for improving their operations. Any TQM approach should include an energy management component to reduce energy costs.

The primary objective of energy management is to maximize profits or minimize costs. Some desirable subobjectives of energy management programs include:

1. Inproving energy efficiency and reducing energy use, thereby reducing costs

2. Cultivating good communications on energy matters

3. Developing and maintaining effective monitoring, reporting, and management strategies for wise energy usage

4. Finding new and better ways to increase returns from energy investments through research and development

5. Developing interest in and dedication to the energy management program from all employees

6. Reducing the impacts of curtailments, brownouts, or any interruption in energy supplies

Although this list is not exhaustive, these six are sufficient for our purposes. However, the sixth objective requires a little more explanation.

Curtailments occur when a major supplier of an energy source is forced to reduce shipments or allocations (sometimes drastically) because of severe weather conditions and/or distribution problems. For example, natural gas is often sold to industry relatively inexpensively, but on an interruptible basis. That is, residential customers and others on noninterruptible schedules have priority, and those on interruptible schedules receive what is left. This residual supply is normally sufficient to meet industry needs, but periodically gas deliveries must be curtailed.

Even though curtailments do not occur frequently, the cost associated with them is so high—sometimes a complete shutdown is necessary—that management needs to be alert in order to minimize the negative effects. There are several ways of doing this, but the method most often employed is the storage and use of a secondary or standby fuel. Number 2 fuel oil is often stored on site and used in boilers capable of burning either natural gas (primary fuel) or fuel oil (secondary fuel). Then when curtailments are imposed, fuel oil can be used. Naturally, the cost of equipping boilers with dual fire capability is high, as is the cost of storing the fuel oil. However, these costs are minuscule compared to the cost of forced shutdown. Other methods of planning for curtailments include production scheduling to build up inventories, planned plant shutdowns, or vacations during curtailment-likely periods, and contingency plans whereby certain equipment, departments, etc., can be shut down so critical areas can keep operating. All these activities must be included in an energy management program.

Although energy conservation is certainly an important part of energy management, it is not the only consideration. Curtailment-contingency planning is certainly not conservation, and neither are load shedding or power factor improvement, both of which will be discussed later on in this chapter. To concentrate solely on conservation would preclude some of the most important activities—often those with the largest savings opportunity.

1.1 THE NEED FOR ENERGY MANAGEMENT

1.1.1 Economics

The American free enterprise system operates on the necessity of profits, or budget allocations in the case of nonprofit organizations. Thus, any new activity can be justified only if it is cost effective; that is, the net result must show a profit improvement or cost reduction greater than the cost of the activity. Energy management has proven time and time again that it is cost effective.

An energy cost savings of 5-15 percent is usually obtained quickly with little to no required capital expenditure when an aggressive energy management program is launched. An eventual savings of 30 percent is common, and savings of 50, 60, and even 70 percent have been obtained. These savings all result from retrofit activities. New buildings designed to be energy efficient often operate on 20 percent of the energy (with a corresponding 80 percent savings) normally required by existing buildings. In fact, for most manufacturing and other commercial organizations *energy management is one of the most promising profit improvement-cost reduction programs available today.*

1.1.2 National Good

Energy management programs are vitally needed today. One important reason is that energy management helps the nation face some of its biggest problems. The following statistics will help make this point.*

- Growth in U.S. energy use:
  It took 50 years (1900-1950) for total annual U.S. energy consumption to go from 4 million barrels of oil equivalent (MBOE) per day to 16 MBOE. It took only 20 years (1950-1970) to go from 16 to 32 MBOE. This rapid growth in energy use slowed in the early 1970's, but took a spurt in the late 1970's, reaching almost 40 MBOE in 1979. Energy use slowed again in the early 1980's and dropped to 35 MBOE in 1983. Economic growth in the mid 1980's returned the use to 40 MBOE in 1988. Energy use remained fairly steady at just over 40 MBOE in the late 1980's, but started growing in the 1990's. By the end of 1996, energy use was up to almost 45 MBOE, and in 2000, 49.4 MBOE per day.

- Comparison with other countries:
  With only 5 percent of the world's population, the United States

*These statistics come from numerous sources, mostly government publications from the Energy Information Administration or from the U.S. Statistical Abstract.

consumes about 25 percent of its energy and produces about 25 percent of the world's gross national product (GNP). However, some nations such as Japan, West Germany, and Sweden produce the same or greater GNP per capita with significantly less energy than the United States.

- U.S. energy production:
  Domestic crude oil production peaked in 1970 at just over 10 million barrels per day (MBD), and has fallen slowly since then to just over 5.8 MBD in 2000. Domestic gas production peaked in 1973 at just over 24 trillion cubic feet (TCF) per year. Gas production remained fairly steady between 1988 and 1992 at about 21-22 TCF per year. Deregulation has improved our domestic production in the short run, but in the long run we continue to face decreasing domestic output. Since 1992, production rose in 1998, and reached a level of 24.5 TCF per year. However, in 2000 it fell to 19 TCF per year.

- Cost of imported oil:
  Annual average prices per barrel for imported crude oil rapidly escalated from $3.00 in the early 1970's to $12 in 1973-1974 and to $37 in 1981. Since 1981 prices have fallen from this peak, and dropped to about $12 in 1986. From 1986 to 1996, prices ranged from about $12 to $22 a barrel, with a short spike in prices during the 1989-90 Gulf War. Prices dropped to $10 in 1998, and have since risen back to about $26.

- Reliance on imported oil:
  The United States has been a net importer of oil since 1947. In 1970 the bill for this importation was only $3 billion; by 1978 it was $42 billion; by 1979, $60 billion; and by 1981, $80 billion, even though the volume imported was less than in 1979. This imported oil bill has severely damaged our trade balance and weakened the dollar in international markets. In 1985 the bill for oil imports fell to a low of $37 billion. It climbed to almost $64 billion in 1990. In 1996 it was just over $61 billion, but with lower prices after 1996, it was just over $50 billion in 1998. But, with higher prices in 2000, it was $119 billion.

In addition to these discouraging statistics, there are a host of major environmental problems, as well as economic and industrial competitiveness problems, that came to the forefront of public concern in the late 1980's. Reducing energy use can help minimize these problems by:

- <u>Reducing acid rain</u>. Lake acidification and deforestation have been the greatest effects of acid rain from the combustion of fossil fuels containing significant amounts of sulfur, such as coal and some oil.

The Clean Air Act Amendments of 1990 will restrict the future emission of sulfur dioxide to the level emitted in 1980.

- Limiting global climate change. Carbon dioxide, the main contributor to potential global climate change, is produced by the combustion of fossil fuel, primarily to provide transportation and energy services. In 1992, many countries of the world adopted limitations on carbon dioxide emissions.

- Limiting ozone depletion. In the U.S., about half of the CFC's—which have been associated with ozone depletion—are used in providing energy services through refrigeration and air conditioning, and in manufacturing insulation. Recent international agreements will substantially phase out the use of CFC's in industrialized countries by the year 1996.

- Improving national security. Oil imports directly affect the energy security and balance of payments of our country. These oil imports must be reduced for a secure future, both politically and economically.

- Improving U.S. competitiveness. The U.S. spends about 9 percent of its gross national product for energy—a higher percentage than many of its foreign competitors. This higher energy cost amounts to a surtax on U.S. goods and services.

- Helping other countries. The fall of the Berlin Wall in 1989 and the emergence of market economies in many Eastern European countries is leading to major changes in world energy supplies and demands. These changes significantly affect our nation, and provide us an economic impetus to help these countries greatly improve their own energy efficiencies and reduce their energy bills.

There are no easy answers. Each of the possibilities discussed below has its own problems.

- Many look to coal as the answer. Yet coal burning produces sulfur dioxide and carbon dioxide, which produce acid rain and potential global climate change.

- Synfuels require strip mining, incur large costs, and place large demands for water in arid areas. On-site coal gasification plants associated with gas-fired, combined-cycle power plants are presently being demonstrated by several electric utilities. However, it remains to be seen if these units can be built and operated in a cost-effective and environmentally acceptable manner.

- Solar-generated electricity, whether generated through photovoltaics or thermal processes, is still more expensive than conventional sources and has large land requirements. Technological improvements are occurring in both these areas, and costs are decreasing. Sometime in the near future, these approaches may become cost-effective.

- Biomass energy is also expensive, and any sort of monoculture would require large amounts of land. Some fear total devastation of forests. At best, biomass can provide only a few percentage points of our total needs without large problems.

- Wind energy has technological "noise" and aesthetic problems that probably can be overcome, but it too is very expensive. In addition, it is only feasible in limited geographic regions.

- Alcohol production from agricultural products raises perplexing questions about using food products for energy when large parts of the world are starving. Newer processes for producing ethanol from wood waste are just being tested, and may offer some significant improvements in this limitation.

- Fission has the well-known problems of waste disposal, safety, and a short time span with existing technology. Without breeder reactors we will soon run out of fuel, but breeder reactors dramatically increase the production of plutonium—a raw material for nuclear bombs.

- Fusion seems to be everyone's hope for the future, but many claim that we do not know the area well enough yet to predict its problems. When available commercially, fusion may very well have its own style of environmental-economical problems.

The preceding discussion paints a rather bleak picture. Our nation and our world are facing severe energy problems and there appears to be no simple answers.

Time and again energy management has shown that it can substantially reduce energy costs and energy consumption. This saved energy can be used elsewhere, so one energy source not mentioned in the preceding list is energy management. In fact, energy available from energy management activities has almost always proven to be the most economical source of "new" energy. Furthermore, energy management activities are more gentle to the environment than large-scale energy production, and they certainly lead to less consumption of scarce and valuable resources. Thus, although energy management cannot solve all the nation's problems, *perhaps it can ease the strain on our environment and give us time to develop new energy sources.*

The value of energy management is clear. There is an increased need for engineers who are adequately trained in the field of energy management, and a large number of energy management jobs are available. This text will help you prepare for a career which will be both exciting and challenging.

1.2 ENERGY BASICS FOR ENERGY MANAGERS

An energy manager must be familiar with energy terminology and units of measure. Different energy types are measured in different units. Knowing how to convert from one measurement system to another is essential for making valid comparisons. The energy manager must also be informed about the national energy picture. The historical use patterns as well as the current trends are important to an understanding of options available to many facilities.

1.2.1 Energy Terminology, Units and Conversions

Knowing the terminology of energy use and the units of measure is essential to developing a strong energy management background. Energy represents the ability to do work, and the standard engineering measure for energy used in this book is the British thermal unit, or Btu. One Btu is the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit. In more concrete terms, one Btu is the energy released by burning one kitchen match head, according to the U.S. Energy Information Agency. The energy content of most common fuels is well known, and can be found in many reference handbooks. For example, a gallon of gasoline contains about 125,000 Btu and a barrel of oil contains about 5,100,000 Btu. A short listing of the average energy contained in a number of the most common fuels, as well as some energy unit conversions is shown below in Table 1-1.

Electrical energy is also measured by its ability to do work. The

Table 1-1
Energy Units and Energy Content of Fuels

1 kWh	3412 Btu
1 ft^3 natural gas	1000 Btu
1 Ccf natural gas	100 ft^3 natural gas
1 Mcf natural gas	1000 ft^3 natural gas
1 therm natural gas	100,000 Btu
1 barrel crude oil	5,100,000 Btu
1 ton coal	25,000,000 Btu
1 gallon gasoline	125,000 Btu
1 gallon #2 fuel oil	140,000 Btu
1 gallon LP gas	95,000 Btu
1 cord of wood	30,000,000 Btu
1 MBtu	1000 Btu
1 MMBtu	10^6 Btu
1 Quad	10^{15} Btu
1 MW	10^6 watts

traditional unit of measure of electrical energy is the kilowatt-hour; in terms of Btu's, one kilowatt-hour (kWh) is equivalent to 3412 Btu. However, when electrical energy is generated from steam turbines with boilers fired by fossil fuels such as coal, oil or gas, the large thermal losses in the process mean that it takes about 10,000 Btu of primary fuel to produce one kWh of electrical energy. Further losses occur when this electrical energy is then transmitted to its point of ultimate use. Thus, although the electrical energy at its point of end-use always contains 3412 Btu per kWh, it takes considerably more than 3412 Btus of fuel to produce a kWh of electrical energy.

1. 2. 2 Energy Supply and Use Statistics

Any energy manager should have a basic knowledge of the sources of energy and the uses of energy in the United States. Both our national energy policy and much of our economic policy are dictated by these supply and use statistics. Figure 1-1 shows the share of total U.S. energy supply provided by each major source. Figure 1-2 represents the percentage of total energy consumption by each major end-use sector.

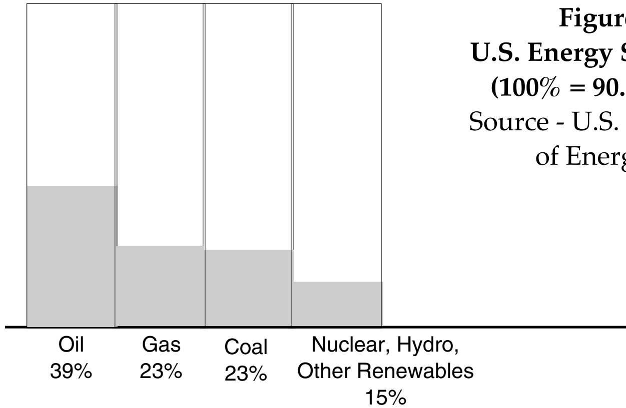

Figure 1-1
U.S. Energy Supply 1998
(100% = 90.94 Quads)
Source - U.S. Department of Energy EIA

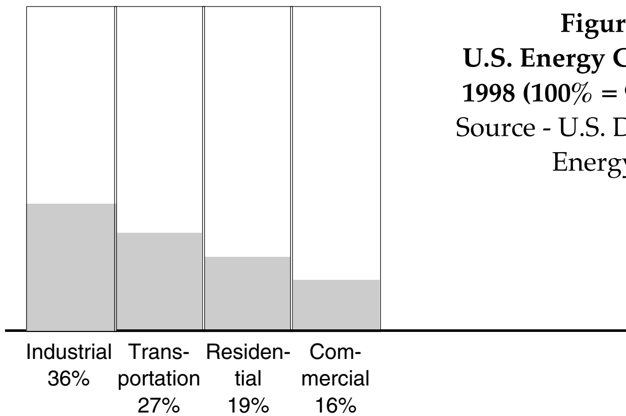

Figure 1-2
U.S. Energy Consumption 1998 (100% = 90.94 Quads)
Source - U.S. Department of Energy EIA

1.2.3 Energy Use in Commercial Businesses

One question frequently asked by facility energy managers is "How does energy use at my facility compare to other facilities in general, and to other facilities that are engaged in the same type of operation?" Figure 1-3 shows general energy usage in commercial facilities, and Figure 1-4 shows their electricity use. While individual facilities may differ significantly from these averages, it is still helpful to know what activities are likely to consume the most energy. This provides some basis for a comparison to other facilities—both energy wasting and energy efficient. In terms of priority of action for an energy management program, the largest areas of energy consumption should be examined first. The greatest savings will almost always occur from examining and improving the areas of greatest use.

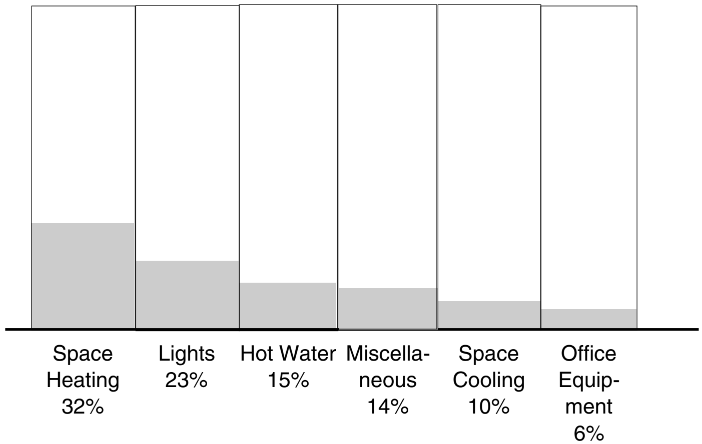

Figure 1-3
Commercial Energy Use 1995 (end-use basis)
Source - U.S. Department of Energy EIA

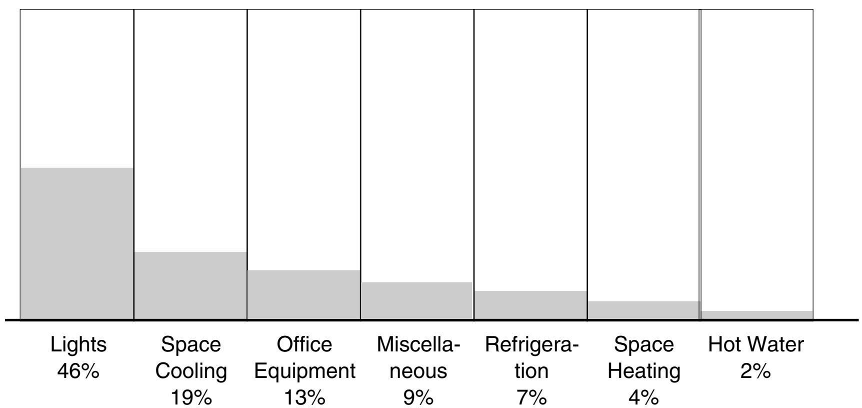

Figure 1-4
Commercial Electric Use 1995 (end-use basis)
Source - U.S. Department of Energy EIA

The commercial sector uses about 15 percent of all the primary energy consumed in the United States, at a cost of over 70 billion dollars each year [1]. On an end-use basis, natural gas and oil constitute about 50 percent of the commercial energy use, mainly for space heating. Over 47 percent of the energy use is in the form of electricity for lighting, air conditioning, ventilation, and some space heating. Although electricity provides slightly less than half of the end-use energy used by a commercial facility, it represents well over half of the cost of the energy needed to operate the facility. Lighting is the predominant use of electricity in commercial buildings, and accounts for over one-third of the cost of electricity.

Commercial activity is very diverse, and this leads to greatly varying energy intensities depending on the nature of the commercial facility. Recording energy use in a building or a facility of any kind and providing a history of this use is necessary for the successful implementation of an energy management program. A time record of energy use allows analysis and comparison so that results of energy productivity programs can be determined and evaluated.

1.2.4 Energy Use in Industry

The industrial sector—consisting of manufacturing, mining, agriculture and construction activities—consumes over one-third of the nation's primary energy use, at an annual cost of $100 billion [2]. Industrial energy use is shown in Figure 1-5 and industrial electricity use is shown in Figure 1-6.

Manufacturing companies, which use mechanical or chemical processes to transform materials or substances into new products, account for about 85 percent of the total industrial sector use. The "big three" in energy use are petroleum, chemicals and primary metals; these industries together consume over one-half of all industrial energy. The "big five," which add the pulp and paper industry, as well as the stone, clay and glass group, together account for 70 percent of all industrial sector energy consumption.

According to the U.S. Energy Information Administration, energy efficiency in the manufacturing sector improved by 25 percent over the

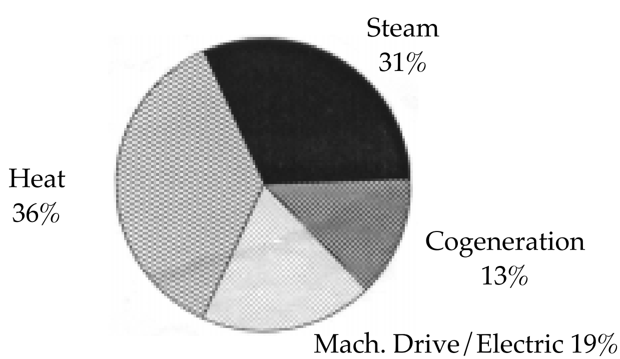

Figure 1-5
Industrial Energy Use (end-use basis)
Source - U.S. Department of Energy EIA

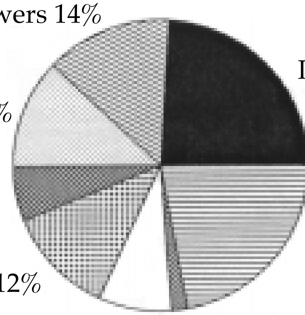

Figure 1-6
Industrial Electricity Use (end-use basis)
Source - Federal Energy Management Agency

period 1980 to 1985 [3]. During that time, manufacturing energy use declined 19 percent, and output increased 8 percent. These changes resulted in an overall improvement in energy efficiency of 25 percent. However, the "big five" did not match this overall improvement; although their energy use declined 21 percent, their output decreased by 5 percent—resulting in only a 17 percent improvement in energy efficiency during 1980-1985. This five year record of improvement in energy efficiency of the manufacturing sector came to an end, with total energy use in the sector growing by 10 percent from 1986 to 1988. Manufacturing energy use stayed constant for 1989 and 1990, and was still the same in 1998.

Restoring the record of energy efficiency improvements will require both re-establishing emphasis on energy management and making capital investments in new plant processes and facilities improvements. Reducing our energy costs per unit of manufactured product is one way that our country can become more competitive in the global industrial market. It is interesting to note that Japan—one of our major industrial competitors—has a law that every industrial plant must have a full-time energy manager [4].

1.3 DESIGNING AN ENERGY MANAGEMENT PROGRAM

1.3.1 Management Commitment

The most important single ingredient for successful implementation and operation of an energy management program is commitment to the program by top management. Without this commitment, the program will likely fail to reach its objectives. Thus, the role of the energy manager is crucial in ensuring that management is committed to the program.

Two situations are likely to occur with equal probability when designing an energy management program. In the first, management has decided that energy management is necessary and wants a program implemented. This puts you—the energy manager—in the *response* mode. In the second, you—an employee—have decided to convince management of the need for the program so you are in the aggressive mode. Obviously, the most desirable situation is the response mode as much of your sales effort is unnecessary; nonetheless, a large number of energy management programs have been started through the *aggressive* mode. Let's consider each of these modes.

In a typical scenario of the response mode, management has seen rapidly rising energy prices and/or curtailments, has heard of the results of other energy management programs, and has then initiated action to start the program. In this case, the management commitment already exists, and all that needs to be done is to cultivate that commitment periodically and to be sure the commitment is evident to all people affected by the program. We will discuss this aspect more when we talk about demonstrating the commitment.

In the aggressive mode, you, the employee, know that energy costs are rising dramatically and that sources are less secure. You may have taken a course in energy management, attended professional conferences, and/or read papers on the subject. At any rate, you are now convinced that the company needs an energy management program. All that remains is to convince management and obtain their commitment.

The best way to convince management is with facts and statistics. Sometimes the most startling way to show the facts is through graphs such as Figure 1-7. Note that different goals of energy cost reduction are shown. This graph can be done in total for all energy sources, or several graphs can be used—one for each source. The latter is probably better as savings goals can be identified by energy source. You must have accurate data. Past figures can use actual utility bills, but future figures call for forecasting. Local utilities and various state energy agencies can help you provide management with more accurate data.

Follow this data with quotes on programs from other companies showing these goals are realistic. Other company experiences are widely published in the literature; results can also be obtained through direct contacts with the energy manager in each company. Typical cost avoidance figures are shown in Table 1-2. However, as time progresses and the technology matures, these figures tend to change. For example, a short

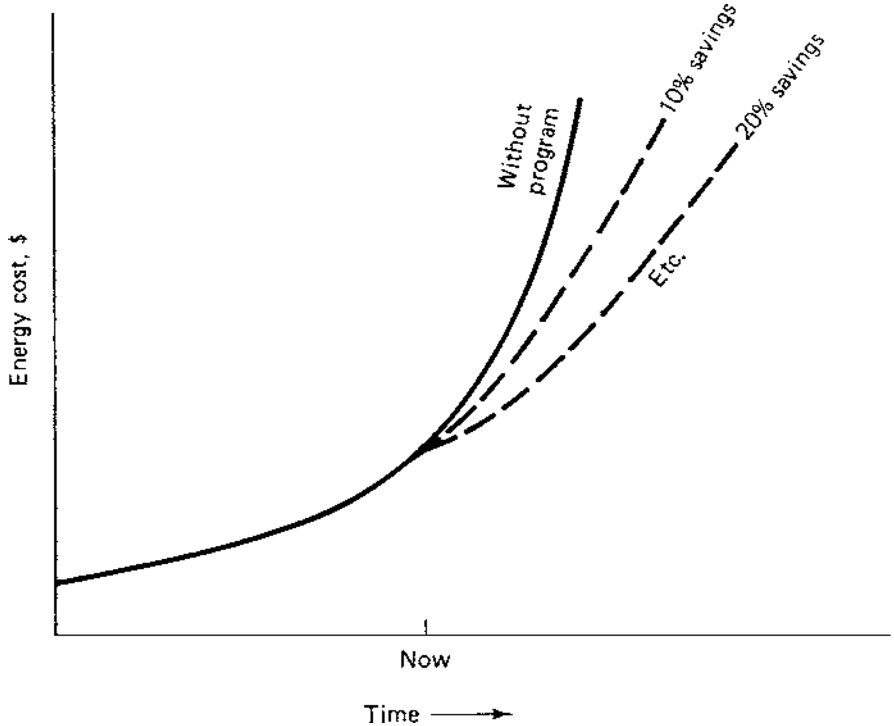

Figure 1-7 Energy costs—past and future.

time ago only a few people believed that an office building could reduce energy consumption by 70 percent or that manufacturing plants could operate on half the energy previously required, yet both are now occurring on a regular basis.

Table 1-2
Typical Energy Savings

Low cost, no cost changes	5-10%
Dedicated programs (3 years or so)	25-35%
Long-range goal	40-50%

As the proponent of an energy management program, you could then talk about the likelihood of energy curtailments or brownouts and what they would mean to the company. Follow this with a discussion of what the energy management program can do to minimize the impacts of curtailments and brownouts.

Finally, your presentation should discuss the competition and what they are doing. Accurate statistics on this can be obtained from trade and professional organizations as well as the U.S. Department of Energy. The savings obtained by competitors can also be used in developing the goals for your facility.

1.3.2 Energy Management Coordinator/Energy Manager

To develop and maintain vitality for the energy management program, a company must designate a single person who has responsibility for coordinating the program. If no one person has energy management as a specific part of his or her job assignment, management is likely to find that the energy management efforts are given a lower priority than other job responsibilities. Consequently, little or nothing may get done.

The energy management coordinator (EMC) should be strong, dynamic, goal oriented, and a good manager. Most important, management should support that person with resources including a staff. The energy management coordinator should report as high as possible in the organization without losing line orientation. A multiplant or multidivisional corporation may need several such coordinators—one for each plant and one for each level of organization. Typical scenarios are illustrated in Figure 1-8.

1.3.3 Backup Talent

Unfortunately, not all the talent necessary for a successful program resides in one person or discipline. For example, several engineering disciplines may be necessary to accomplish a full-scale study of the plant steam production, distribution, usage, and condensate return system. For this reason, most successful energy management programs have an energy management committee. Two subcommittees that are often desirable are the technical and steering subcommittees.

The technical committee is usually composed of several persons with strong technical background in their discipline. Chemical, industrial, electrical, civil, and mechanical engineers as well as others may all be represented on this committee. Their responsibility is to provide technical assistance for the coordinator and plant-level people. For example, the committee can keep up with developing technology and research into potential applications company-wide. The results can then be filtered down.

While the energy management coordinator may be a full-time position, the technical committee is likely to operate part-time, being called

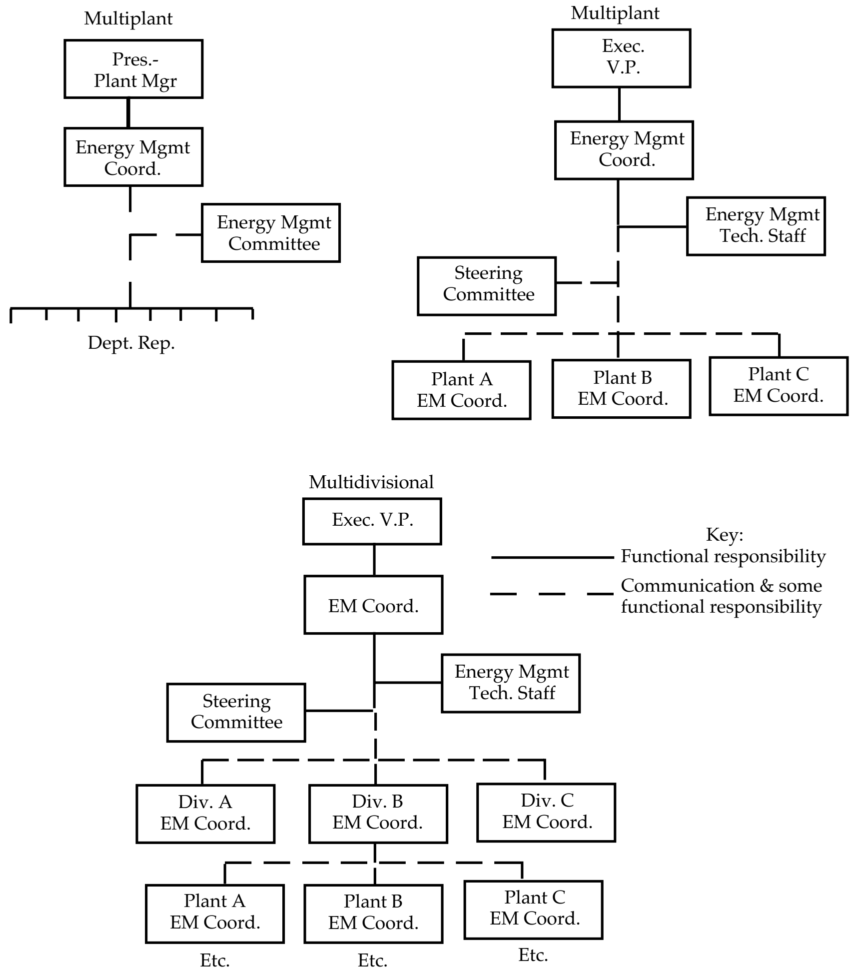

Figure 1-8
Typical organization designs for energy management programs

upon as necessary. In a multiplant or multidivisional organization, the technical committee may also be full time.

The steering committee has an entirely different purpose from the technical committee. It helps guide the activities of the energy management program and aids in communications through all organizational levels. The steering committee also helps ensure that all plant personnel are aware of the program. The steering committee members are usually chosen so that all major areas of the company are represented. A typical organization is presented in Figure 1-9.

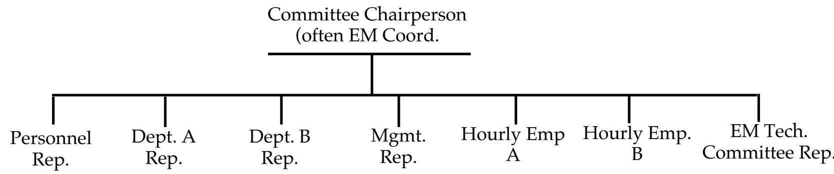

Figure 1-9
Energy management steering committee.

Steering committee members should be selected because of their widespread interests and a sincere desire to aid in solving the energy problems. Departmental and hourly representatives can be chosen on a rotating basis. Such a committee should be able to develop a good composite picture of plant energy consumption which will help the energy management coordinator choose and manage his/her activities.

1.3.4 Cost Allocation

One of the most difficult problems for the energy manager is to try to reduce energy costs for a facility when the energy costs are accounted for as part of the general overhead. In that case, the individual managers and supervisors do not consider themselves responsible for controlling the energy costs. This is because they do not see any direct benefit from reducing costs that are part of the total company overhead. The best solution to this problem is for top management to allocate energy costs down to "cost centers" in the company or facility. Once energy costs are charged to production centers in the same way that materials and labor are charged, then the managers have a direct incentive to control those energy costs because this will improve the overall cost-effectiveness of the production center.

For a building, this allocation of energy costs means that each of the tenants are given information on their energy consumption, and that they individually pay for that energy consumption. Even if a large building is "master metered" to reduce utility fixed charges, there should be a division of the utility cost down to the individual customers.

1.3.5 Reporting and Monitoring

It is critical for the energy management coordinator and the steering committee to have their fingers on the "pulse of energy consumption" in the plant. This is best achieved through an effective and efficient system of energy reporting.

The objective of an energy reporting system is to measure energy consumption and compare it either to company goals or to some *standard of energy consumption*. Ideally, this should be done for each operation or production cost center in the plant, but most facilities simply do not have the required metering devices. Many plants only meter energy consumption at one place—where the various sources enter the plant. Most plants are attempting to remedy this, however, by installing additional metering devices when the opportunity arises (steam system shutdowns, vacation downtime, etc.). Systems that should be metered include steam, compressed air, and chilled and hot water.

As always, the reporting scheme needs to be reviewed periodically to ensure that only necessary material is being generated, that all needed data is available, and that the system is efficient and effective.

1.3.6 Training

Most energy management coordinators find that substantial training is necessary. This training can be broken down as shown in Figure 1-10.

Personnel involved	Type of necessary training	Source of required training
1. Technical committee	1. Sensitivity to EM	1. In house (with outside help ?)
	2. Technology developments	2. Professional societies universities, consulting groups, journals
2. Steering committee	1. Sensitivity to EM 2. Other Industries' experience	1. See 1 above 2. Trade journals, energy sharing groups, consultants
3. Plant-wide	1. Sensitivity to EM 2. What's expected, goals to be obtained, etc.	1. In house 2. In house

Figure 1-10
Energy Management Training.

Training cannot be accomplished overnight, nor is it ever "completed." Changes occur in energy management staff and employees at all levels, as well as new technology and production methods. All these precipitate training or retraining. The energy management coordinator must assume responsibility for this training.

1.4 STARTING AN ENERGY MANAGEMENT PROGRAM

Several items contribute to the successful start of an energy management program. They include:

1. Visibility of the program start-up
2. Demonstration of management commitment to the program
3. Selection of a good initial energy management project

1.4.1 Visibility of Start-up

To be successful, an energy management program must have the backing of the people involved. Obtaining this support is often not an easy task, so careful planning is necessary. The people must:

1. Understand why the program exists and what its goals are;
2. See how the program will affect their jobs and income;
3. Know that the program has full management support; and
4. Know what is expected of them.

Communicating this information to the employees is a joint task of management and the energy management coordinator. The company must take advantage of all existing communications channels while also taking into consideration the preceding four points. Some methods that have proven useful in most companies include:

- Memos. Memos announcing the program can be sent to all employees. A comprehensive memo giving fairly complete details of the program can be sent to all management personnel from first-line supervision up. A more succinct one can be sent to all other employees that briefly states why the program is being formed and what is expected of them. These memos should be signed by local top management.

- News releases. Considerable publicity often accompanies the program start-up. Radio, TV, posters, newspapers, and billboards can all be used. The objective here is to obtain as much visibility for the program as possible and to reap any favorable public relations that might be available. News releases should contain information of interest to the general public as well as employees.

- Meetings. Corporate, plant, and department meetings are sometimes used, in conjunction with or in lieu of memos, to announce the program and provide details. Top management can demonstrate commitment by attending these meetings. The meeting agenda must provide time for discussion and interaction.

- Films, video tapes. Whether produced in-house or purchased, films and video tapes can add another dimension to the presentation. They can also be reused later for new employee training.

1.4.2 Demonstration of Management Commitment

As stressed earlier, management commitment to the program is essential, and this commitment must be obvious to all employees if the program is to reach its full potential. Management participation in the program start-up demonstrates this commitment, but it should also be emphasized in other ways. For example:

- Reward participating individuals. Recognition is highly motivating for most employees. An employee who has been a staunch supporter of the program should be recognized by a "pat on the back," a letter in the files, acknowledgment at performance appraisal time, etc. When the employee has made a suggestion that led to large energy savings, his/her activities should be recognized through monetary rewards, publicity, or both. Public recognition can be given in the company newsletter, on bulletin boards, or in plant-department meetings.

- Reinforce commitment. Management must realize that they are continually watched by employees. Lip service to the program is not enough—personal commitment must be demonstrated. Management should reinforce its commitment periodically, although the visibility scale can be lower than before. Existing newsletters, or a separate one for the energy management program, can include a short column or letter from management on the current results of the program and the plans for the future. This same newsletter can report on outstanding suggestions from employees.

- Fund cost-effective proposals. All companies have capital budgeting problems in varying degrees of severity, and unfortunately energy projects do not receive the same priority as front-line items such as equipment acquisition. However, management must realize that turning down the proposals of the energy management team while accepting others with less economic attractiveness is a sure way to kill enthusiasm. Energy management projects need to compete with others fairly. If an energy management project is cost effective, it should be funded. If money is not available for capital expenditures, then management should make this clear at the outset of the program and ask the team to develop a program which does not require capital expenditures.

1.4.3 Early Project Selection

The energy management program is on treacherous footing in the beginning. Most employees are afraid their heat is going to be set back, their air conditioning turned off, and their lighting reduced. If any of these actions do occur, it's little wonder employee support wanes. These things might occur eventually, but wouldn't it be smarter to have less controversial actions as the early projects.

An early failure can also be harmful, if not disastrous, to the program. Consequently, the astute energy management coordinator will "stack the deck" in his or her first set of projects. These projects should have a rapid payback, a high probability of success, and few negative consequences.

These ideal projects are not as difficult to find as you might expect. Every plant has a few good opportunities, and the energy management coordinator should be looking for them.

One good example involved a rather dimly lit refrigerator warehouse area. Mercury vapor lamps were used in this area. The local energy management coordinator did a relamping project. He switched from mercury vapor lamps to high pressure sodium lamps (a significantly more efficient source) and carefully designed the system to improve the lighting levels. Savings were quite large; less energy was needed for lighting; less "heat of light" had to be refrigerated; and, most important, the employees liked it. Their environment was improved since light levels were higher than before.

Other examples you should consider include:

1. Repairing steam leaks. Even a small leak can be very expensive over a year and quite uncomfortable for employees working in the area.

2. Insulating steam, hot water, and other heated fluid lines and tanks. Heat loss through an uninsulated steam line can be quite large, and the surrounding air may be heated unnecessarily.

3. Install high efficiency motors. This saves dramatically on the electrical utility cost in many cases, and has no negative employee consequences. However, the employees should be told about the savings since motor efficiency improvement has no physically discernible effect, unlike the lighting example above.

This list only begins to touch on the possibilities, and what may be glamorous for one facility might not be for another. All facilities, however, do have such opportunities. Remember, highly successful projects should be accompanied by publicity at all stages of the program—especially at the beginning.

1.5 MANAGEMENT OF THE PROGRAM

1.5.1 Establishing objectives in an Energy Management Program

Creativity is a vital element in the successful execution of an energy management program, and management should do all it can to encourage creativity rather than stifle it. Normally, this implies a laissez-faire approach by management with adequate monitoring. Management by objectives (MBO) is often utilized. If TQM is being implemented in a facility, then employee teams should foster this interest and creativity.

Goals need to be set, and these goals should be tough but achievable, measurable, and specific. They must also include a deadline for accomplishment. Once management and the energy management coordinator have agreed on the goals and established a good monitoring or reporting system, the coordinator should be left alone to do his/her job.

The following list provides some examples of such goals:

- Total energy per unit of production will drop by 10 percent the first year and an additional 5 percent the second.

- Within 2 years all energy consumers of 5 million British thermal units per hour (Btuh) or larger will be separately metered for monitoring purposes.

- Each plant in the division will have an active energy management program by the end of the first year.

- All plants will have contingency plans for gas curtailments of varying duration by the end of the first year.
- All boilers of 50,000 lb/hour or larger will be examined for waste heat recovery potential the first year.

The energy management coordinator must quickly establish the reporting systems to measure progress toward the goals and must develop the strategy plans to ensure progress. Gantt or CPM charting is often used to aid in the planning and assignment of responsibilities.

Some concepts or principles that aid the EMC in this execution are the following:

- Energy costs, not just Btus, are to be controlled. This means that any action that reduces energy costs is fair game. Demand shedding or leveling is an example activity that saves dollars but does not directly save Btus.
- Energy needs should be recognized and billed as a direct cost, not as overhead. Until the energy flow can be measured and charged to operating cost centers, the program will not reach its ultimate potential.
- Only the main energy functions need to be metered and monitored. The Pareto or ABC principle states that the majority of the energy costs are incurred by only a few machines. These high-use machines should be watched carefully.

1.5.2 A Model Energy Management Program

An excellent example of a longtime successful energy management program in a large corporation is that of the 3M Company, headquartered in St. Paul, Minnesota [5]. 3M is a large, diversified manufacturing company with more than 50 major product lines; it makes some fifty thousand products at over fifty different factory locations around the country. The corporate energy management objective is to use energy as efficiently as possible in all operations; the management believes that all companies have an obligation to conserve energy and all other natural resources.

Energy productivity at 3M improved over 60 percent from 1973 to 1996. They saved over $70 million in 1996 because of their energy management programs, and saved a total of over $1.2 billion in energy expenses from 1973 to 1996. Their program is staffed by six people who educate and motivate all levels of personnel on the benefits of energy management.

The categories of programs implemented by 3M include: conservation, maintenance procedures, utility operation optimization, efficient new designs, retrofits through energy surveys, and process changes.

Energy efficiency goals at 3M are set and then the results are measured against a set standard in order to determine the success of the programs. The technologies that have resulted in the most dramatic improvement in energy efficiency include: heat recovery systems, high efficiency motors, variable speed drives, computerized facility management systems, steam trays maintenance, combustion improvements, variable air volume systems, thermal insulation, cogeneration, waste steam utilization, and process improvements. Integrated manufacturing techniques, better equipment utilization and shifting to non-hazardous solvents have also resulted in major process improvements.

The energy management program at 3M has worked very well, but management is not yet satisfied. They have set a goal of further improving energy efficiency at a rate of 3 percent per year for the next five years, from 1996 to 2000. They expect to substantially reduce their emissions of waste gases and liquids, to increase the energy recovered from wastes, and to constantly increase the profitability of their operations. 3M continues to stress the extreme importance that efficient use of energy can have on their industrial productivity.

1.6 ENERGY ACCOUNTING

Energy accounting is a system used to keep track of energy consumption and costs. "Successful corporate-level energy managers usually rank energy accounting systems right behind commitment from top corporate officials when they list the fundamentals of an ongoing energy conservation program. If commitment from the top is motherhood, careful accounting is apple pie."*

A basic energy accounting system has three parts: energy use monitoring, an energy use record, and a performance measure. The performance measure may range from a simple index of Btu/ft^2 or Btu/unit of production to a complex standard cost system complete with variance reports. In all cases, energy accounting requires metering. Monitoring the energy flow through a cost center, no matter how large or small, requires the ability to measure incoming and outgoing energy. The lack of necessary meters is probably the largest single deterrent to the widespread utilization of energy accounting systems.

*"Accounting of Energy Seen Corporate Must," *Energy User News,* Aug. 27, 1979, p. 1.

1.6.1 Levels of Energy Accounting

As in financial accounting, the level of sophistication or detail of energy accounting systems varies considerably from company to company. A very close correlation can be developed between the levels of sophistication of financial accounting systems and those of energy accounting systems. This is outlined in Figure 1-11.

Most companies with successful energy management programs have passed level 1 and are working toward the necessary submetering and reporting systems for level 2. In most cases, the subsequent data are compared to previous years or to a particular base year. However, few companies have developed systems that will calculate variations and find causes for those variations (level 3). Two notable exceptions are General Motors and Carborundum. To our knowledge, few companies have yet completely developed the data and procedures necessary for level 4, a standard Btu accounting system. Some examples of detailed energy accounting can be found in [6].

Financial	Energy
1. General accounting	1. Effective metering, development of reports, calculation of energy efficiency indices
2. Cost accounting	2. Calculation of energy flows and efficiency of utilization for various cost centers; requires substantial metering
3. Standard cost accounting historical standards	3. Effective cost center metering of energy and comparison to historical data; complete with variance reports and calculation of reasons for variation
4. Standard cost accounting engineered standards	4. Same as 3 except that standards for energy consumption are determined through accurate engineering models

Figure 1-11
Comparison between financial and energy accounting.

1. 6. 2 Performance Measures

1.6.2.1 Energy Utilization Index

A very basic measure of a facility's energy performance is called the Energy Utilization Index (EUI). This is a statement of the number of Btu's of energy used annually per square foot of conditioned space. To compute the EUI, all of the energy used in the facility must be identified, the total Btu content tabulated, and the total number of square feet of conditioned space determined. The EUI is then found as the ratio of the total Btu consumed to the total number of square feet of conditioned space.

Example 1.1—Consider a building with 100,000 square feet of floor space. It uses 1. 76 million kWh and 6.5 million cubic feet of natural gas in one year. Find the Energy Utilization Index (EUI) for this facility.

Solution: Each kWh contains 3412 Btu and each cubic foot of gas contains about 1000 Btu. Therefore the total annual energy use is:

$$\text{Total energy use} = (1.76 \times 10^6 \text{ kWh}) \times (3412 \text{ Btu/kWh}) + (6.5 \times 10^6 \text{ ft}^3) \times (1000 \text{ Btu/ft}^3)$$

$$= 6.0 \times 10^9 + 6.5 \times 10^9$$
$$= 1.25 \times 10^{10} \text{ Btu/yr}$$

Dividing the total energy use by 10^5 ft^2 gives the EUI:

$$\text{EUI} = (1.25 \times 10^{10} \text{ Btu/yr})/(10^5 \text{ ft}^2)$$
$$= 125{,}000 \text{ Btu/ft}^2\text{/yr}$$

The average building EUI is 80,900 Btu/ft^2/yr; the average office building EUI is 101,200 Btu/ft^2/yr. Figure 1-12 shows the range of energy intensiveness in 1000 Btu/ft^2/yr for the twelve different types of commercial facilities listed [7].

1.6.2.2 Energy Cost Index

Another useful performance index is the Energy Cost Index or ECI. This is a statement of the dollar cost of energy used annually per square foot of conditioned space. To compute the ECI, all of the energy used in the facility must be identified, the total cost of that energy tabulated, and

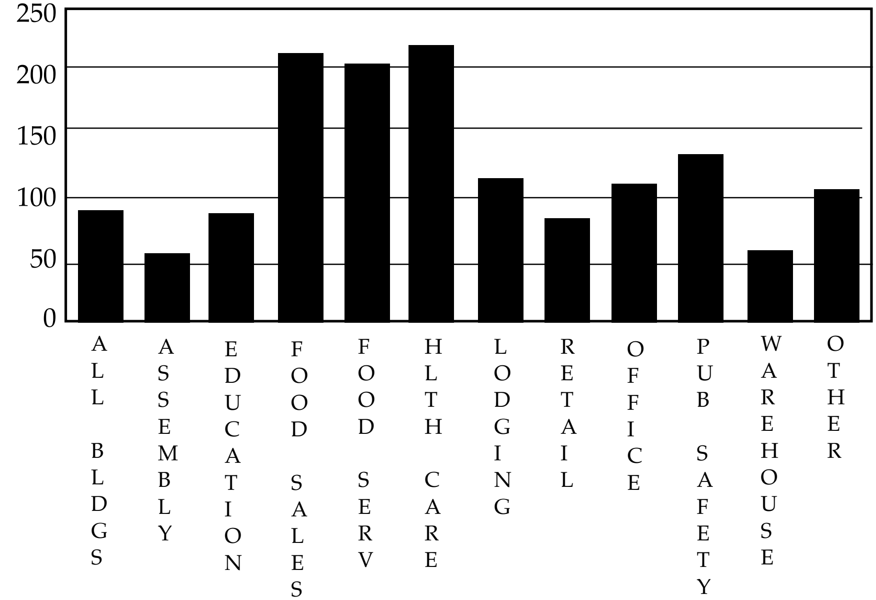

Figure 1-12
Building energy utilization index.
(In Thousand Btu per Square Foot per Year)
Source - U.S. Department of Energy EIA

the total number of square feet of conditioned space determined. The ECI is then found as the ratio of the total annual energy cost for a facility to the total number of square feet of conditioned floor space of the facility.

Example 1.2 Consider the building in Example 1.1. The annual cost for electric energy is \$115,000 and the annual cost for natural gas is \$32,500. Find the Energy Cost Index (ECI) for this facility.

Solution: The ECI is the total annual energy cost divided by the total number of conditioned square feet of floor space.

$$\text{Total energy cost} = \$115{,}000 + \$32{,}500 = \$147{,}500/\text{yr}$$

Dividing this total energy cost by 100,000 square feet of space gives:

$$\text{ECI} = (\$147{,}500/\text{yr})/(100{,}000\ \text{ft}^2) = \$1.48/\text{ft}^2/\text{yr}$$

The Energy Information Administration reported a value of the ECI for the average building as $\$1.19/\text{ft}^2/\text{yr}$ from 1995 data. The ECI for an average office building was $\$1.51/\text{ft}^2/\text{yr}$.

1.6.2.2 One-Shot Productivity Measures

The purpose of a one-shot productivity measure is illustrated in Figure 1-13. Here the energy utilization index is plotted over time, and trends can be noted.

Significant deviations from the same period during the previous year should be noted and explanations sought. This measure is often used to justify energy management activities or at least to show their effect. For example, in Figure 1-13 an energy management (EM) program was started at the beginning of year 2. Its effect can be noted by comparing peak summer consumption in year 2 to that of year 1. The decrease in peaks indicates that this has been a good program (or a mild summer, or both).

Table 1-3 shows some often-used indices. Some advantages and disadvantages of each index are listed, but specific applications will require careful study to determine the best index.

Table 1-4 proposes some newer concepts. Advantages and disadvantages are shown, but since most of these concepts have not been utilized in a large number of companies, there are probably other advantages and disadvantages not yet identified. Also, there are an infinite number of possible indices, and only three are shown here.

1.6.3 An Example Energy Accounting System

General Motors Corporation has a strong energy accounting system which uses an energy responsibility method. According to General Motors, a good energy accounting system is implemented in three phases: (1) design and installation of accurate metering, (2) development of an energy budget, and (3) publication of regular performance reports including variances. Each phase is an important element of the complete system.

1.6.3.1 The GM system

Phase 1—Metering. For execution of a successful energy accounting program, energy flow must be measured by cost center. The designing of cost center boundaries requires care; the cost centers must not be too large or too small. However, the primary design criterion is how much

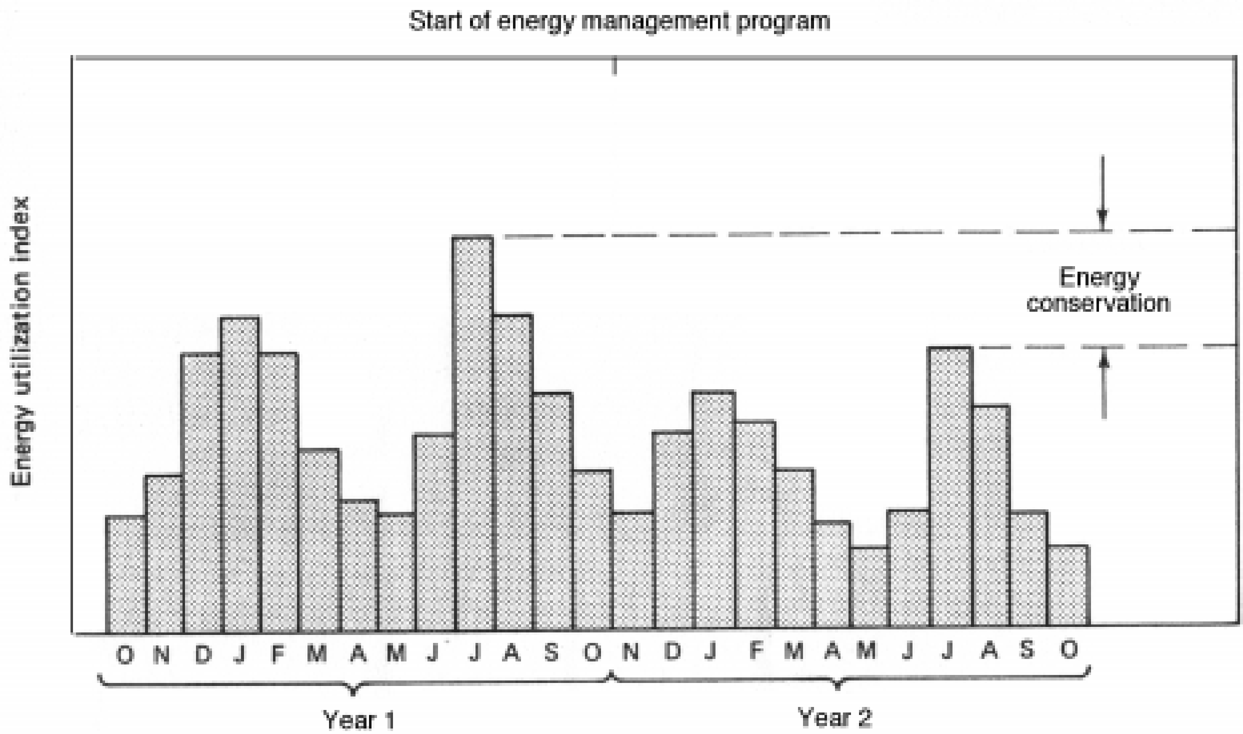

Figure 1-13
One-shot energy productivity measurement.

Table 1-3. Commonly Used Indices

Productivity indicator	Advantages	Disadvantages
1. Btu/unit of production	1. Concise, neat 2. Often accurate when process energy needs are high 3. Good for interplant and company comparison when appropriate	1. Difficult to define and measure "units" 2. Often not accurate (high HVAC* and lighting makes energy nonlinear to production)
2. Btu/degree day	1. Concise, neat, best used when HVAC* is a majority of energy bill 2. Often accurate when process needs are low or constant 3. Very consistent between plants, companies, etc. (all mfg can measure degree days)	1. Often not accurate (disregards process needs) 2. Thermally heavy buildings such as mfg plants usually do not respond to degree days
3. Btu/ft^2	1. Concise, neat 2. Accurate when process needs are low or constant and weather is consistent 3. Very consistent (all mfg can measure square feet) 4. Expansions can be incorporated directly	1. No measure of production or weather 2. Energy not usually linearly proportional to floor space (piecewise linear?)
4. Combination, e.g., Btu/unit-degree day-ft^2 or Btu/unit-degree day	1. Measures several variables 2. Somewhat consistent, more accurate than above measures 3. More tailor-made for specific needs	1. Harder to comprehend

*Heating, ventilating, and air conditioning.

Table 1-4
Proposed Indices

	Productivity indicator		Advantages		Disadvantages
1.	Btu/sales dollar	1.	Easy to compute	1.	Impact of inflation
2.	$\frac{\$\ \text{energy}}{(\$\ \text{sales})\ \text{or}\ (\$\ \text{profit})\ \text{or}\ (\$\ \text{value added})}$	1. 2. 3.	Really what's desired Inflation cancels or shows changing relative energy costs Shows energy management results, not just conservation (e.g., fuel switching, demand leveling, contingency planning)	1. 2.	Very complex, e.g., lots of variables affect profit including accounting procedures Not good for general employee distribution
3.	Btu/DL hour (or machine hour or shift) where DL = direct labor	1. 2. 3. 4.	Almost a measure of production (same advantage as in Table 1-3) Data easily obtained when already available Comparable between plants or industries Good for high process energy needs	1. 2.	More complex, e.g., can't treat a DL hour like a unit of production Energy often not proportional to labor or machine input, e.g., high HVAC and lighting

energy is involved. For example, a bank of large electric induction heat-treating furnaces might need separate metering even if the area involved is relatively small, but a large assembly area with only a few energy-consuming devices may require only one meter. Flexibility is important since a cost center that is too small today may not be too small tomorrow as energy costs change.

The choice of meters is also important. Meters should be accurate, rugged, and cost effective. They should have a good turndown ratio; a turndown ratio is defined as the ability to measure accurately over the entire range of energy flow involved.

Having the meters is not enough. A system must be designed to gather and record the data in a useful form. Meters can be read manually, they can record information on charts for permanent records, and/or they can be interfaced with microcomputers for real-time reporting and control. Many energy accounting systems fail because the data collection system is not adequately designed or utilized.

Phase 2—Energy Budget. The unique and perhaps vital aspect of General Motors' approach is the development of an energy budget. The GM energy responsibility accounting system is somewhere between levels 3 and 4 of Figure 1-11. If a budget is determined through engineering models, then it is a standard cost system and it is at level 4. There are two ways to develop the energy budget: statistical manipulation of historical data or utilization of engineering models.

The Statistical Model. Using historical data, the statistical model shows how much energy was utilized and how it compared to the standard year(s), but it does not show how efficiently the energy was used. For example, consider the data shown in Table 1-5.

The statistical model assumes that the base years are characteristic of all future years. Consequently, if 1996 produced 600 units with the same square footage and degree days as 1995, 1000 units of energy would be required. If 970 units of energy were used, the difference (30 units) would be due to conservation.

We could use multiple linear regression to develop the parameters for our model, given as follows:

$$\text{energy forecast} = a(\text{production level}) + b(\text{ft}^2) + c(\text{degree days}) \quad (1\text{-}1)$$

Table 1-5
Energy Data for Statistical Model[a]

	1995	1996	1997
Total energy (units)	1,000	1,100	1,050
Production (units)	600	650	650
Square feet	150,000	150,000	170,000
Degree days (heating)	6,750	6,800	6,800

[a]Taken, in part, from R.P. Greene, (see the Bibliography).

We can rewrite this in the following form:

$$X_4 = aX_1 + bX_2 + cX_3$$

where X_1= production (units)
X_2 = floor space (ft^2)
X_3 = weather data (degree days)
X_4 = energy forecast (Btu)

Degree days are explained in detail in Chapter Two, section 2.1.1.2. Their use provides a simple way to account for the severity of the weather, and thus the amount of energy needed for heating and cooling a facility. Of course, the actual factors included in the model will vary between companies and need to be examined carefully.

Multiple linear regression estimates the parameters in the universal regression model in Equation 1-1 from a set of sample data. Using the base years, the procedure estimates values for parameters a, b, and c in Equation 1-1 in order to minimize the squared error where

$$\text{squared error} = \sum_{\substack{\text{base}\\\text{years}}} \left(X_4^i \pm X_4\right)^2 \tag{1-2}$$

with X_4 = energy forecast by model

X_4^i = actual energy usage

The development and execution of this statistical model is beyond the scope of this book. However, regardless of the analytical method used, a statistical model does not determine the amount of energy that ought to be used. It only forecasts consumption based on previous years' data.

The engineering model. The engineering model attempts to remedy the deficiency in the statistical model by developing complete energy balance calculations to determine the amount of energy theoretically required. By using the first law of thermodynamics, energy and mass balances can be completed for any process. The result is the energy required for production. Similarly, HVAC and lighting energy needs could be developed using heat loss equations and other simple calculations. Advantages of the engineering model include improved accuracy and flexibility in reacting to changes in building structures, production schedules, etc. Also, computer programs exist that will calculate the needs for HVAC and lighting.

Phase 3—Performance Reports. The next step is the publication of energy performance reports that compare actual energy consumption with that predicted by the models. The manager of each cost center should be evaluated on his or her performance as shown in these reports. The publication of these reports is the final step in the effort to transfer energy costs from an overhead category to a direct cost or at least to a direct overhead item. One example report is shown in Figure 1-14.

Sometimes more detail on variance is needed. For example, if consumption were shown in dollars, the variation could be shown in dollars and broken into price and consumption variation. Price variation is calculated as the difference between the budget and the actual unit price times the present actual consumption. The remaining variation would be due to a change in consumption and would be equal to the change in consumption times the budget price. This is illustrated in Example 1.3. Other categories of variation could include fuel switching, pollution control, and new equipment.

	Actual	Budget	Variance	% variance
Department A				
Electricity	2000	1500	+500	+33.3%
Natural gas	3000	3300	–300	–9.1%
Steam	3500	3750	–250	–6.7%
Total	8500	8550	–50	–0.6%
Department B				
Electricity	1500	1600	–100	–6.2%
Natural gas	2000	2400	–400	–16.7%
Fuel oil	1100	1300	– 200	–15.4%
Coal	3500	3900	– 400	–10.2%
Total	8100	9200	– 1100	– 11.9%
Department C				
•				
•				
•				

Figure 1-14
Energy performance report (10^6Btu)

Example 1.3

The table shown in Figure 1-15 portrays a common problem in energy management reporting. The energy management program in this heat treating department was quite successful. When you examine the totals, you see that the total consumption (at old prices) was reduced by $5631. The total energy cost, however, went up by $500, which was due to a substantial price variation of $6131. Consequently, total energy costs increased to $34,000.

	[A]	[B]	[C]	[D]	[E]	[F]	[G]
	Actual $	Budget $	Unit price (budget)	Unit price (actual)	A - B[a] variance	(D - C)A[b] price variance	E – F or (B[b] – A[b])C consumption variance
Department (source)	10^6 Btu	10^6 Btu	$/$10^6$ Btu	$/$10^6$ Btu			
Heat treating (electricity)	$9,000	$8,500	$4.00	$4.50	+$500	+$1000	–$500
	2,000	2,125	—	—	—	—	—
(natural gas)	15,000	16,000	2.50	3.12	–1000	+2980	–3980
	4,808	6,400	—	—	—	—	—
(steam)	10,000	9,000	3.50	4.46	+1000	+2151	–1151
	2,242	2,571	—	—	—	—	—
(total)	$34,000	$33,500	—	—	+$500	+$6131	–$5631

[a]Measured in $
[b]Measured in 10^6 Btu

Figure 1-15
Energy cost in dollars by department with variance analysis.

However, had energy consumption not been reduced, the total energy cost would have been:

$$2125(4.50) + 6400(3.12) + 2571(4.46) = \$40{,}997.$$

The total cost avoidance therefore was:

$$\$40{,}997 - \$34{,}000 = \$6997$$

which is the drop in consumption times the actual price or

$$(2125 - 2000)\ 4.5 + (6400 - 4808)\ 3.12 + (2571 - 2242)\ 4.46 = \$6997$$

This problem of increased energy costs despite energy management savings can arise in a number of ways. Increased production, plant expansion, or increased energy costs can all cause this result.

1.7 SUMMARY

This chapter has discussed the need for energy management, the historical use of energy, and the design, initiation, and management of energy management programs. The chapter emphasizes energy accounting, especially cost center accounting and necessary submetering.

We defined an energy management activity as any decision that involves energy and affects the profit level. Anything that improves profits and/or enhances competitive positions is considered effective energy management, and anything else is poor energy management. The motivation for starting energy management programs is multi-faceted and varies among companies. The following outline lists the major reasons:

- Economic—Energy management will improve profits and enhance competitive positions.
- National good—Energy management is good for the U.S. economy as the balance of payments becomes more favorable and the dollar stronger.

  Energy management makes us less vulnerable to energy cutoffs or curtailments due to political unrest or natural disasters elsewhere.

  Energy management is kind to our environment as it eases some of the strain on our natural resources and may leave a better world for future generations.

In designing an energy management program, several ingredients are vital:

- Top Management commitment. Commitment from the top must be strong and highly visible.
- One-person responsibility. The responsibility for the energy management program must lie in one person who reports as high in the organization structure as possible.
- Committee backup. The energy management coordinator must have the support of two committees. The first is a steering committee, which provides direction for the program. The second is a technical committee, which provides technical backup in the necessary engineering disciplines.

- Reporting and monitoring. An effective monitoring and reporting system for energy consumption must be provided.

- Training. Energy management is a unique undertaking. Hence, training and retraining at all levels is required.

To successfully start an energy management program, some publicity must accompany the early stages. This can be achieved with news releases, films, plant meetings, or a combination of them. Early project selection is a critical step. Early projects should be visible, and should have good monetary returns, with few negative consequences.

Management and creative personnel are always critical components of an energy management program. Tough, specific, and measurable goals need to be developed. Once the goals are established, management should carefully monitor the results, but the energy management staff should be allowed to perform its functions. Staff and management need to realize that (1) energy costs, not consumption, are to be controlled (2) energy should be a direct cost—not an overhead item, and (3) only the main energy consumers need be metered and monitored closely.

Energy accounting is the art and science of tracing Btu and energy dollar flow through an organization. Cost center orientation is important, as are comparison to some standard or base and calculations of variances. Causes for variances must then be sought. General Motor's energy responsibility accounting system was discussed in some detail. However, no accounting system is a panacea, and any system is only as accurate as the metering and reporting systems allow it to be.

REFERENCES

1. The National Energy Strategy, Interim Report, *Chapter on Commercial Energy Use*, U.S. Department of Energy, Washington, D.C., April 2, 1990, p. 26.

2. The National Energy Strategy, Interim Report, *Chapter on Industrial Energy Use*, U.S. Department of Energy, Washington, D.C., April 2, 1990, p. 31.

3. Energy Information Administration, *Manufacturing Energy Consumption Survey: Changes in Energy Efficiency 1985-1991*, U.S. Department of Energy, Washington, D.C., October, 1995.

4. The National Energy Strategy, *Chapter on Industrial Energy Use*, U.S. Department of Energy, Washington, D.C., April 2, 1990, p. xx.

5. Aspenson, R.L., *Testimony to the U.S. Department of Energy on the National Energy Strategy, Hearing on Energy and Productivity*, Providence, RI, December 1, 1989.

6. Applebaum, Bruce and Mark Oven, "Energy Management Skills for Energy Engineers," *Energy Engineering*, Vol. 89, No. 5, 1992, pp. 52-80.

7. Energy Information Administration, *Commercial Buildings Consumption and Expenditures 1992*, Energy Information Administration (EIA), U.S. Department of Energy, Washington, D.C., April, 1995.

BIBLIOGRAPHY

Barrett, John A., "Energy Accounting Systems for Existing Buildings," ASHRAE Journal, January 1979, p. 56.

"Btu Accounting," client newsletter, Seidman and Seidman, Certified Public Accountants, Grand Rapids, MI, 1980.

Capehart, Barney L., "Energy Management," Chapter 70 in the *Handbook of Industrial Engineering*, Second Edition, John Wiley and Sons, Inc., New York, 1992.

Capehart, Barney L. and Mark Spiller, "Energy Auditing," Chapter 3 in the *Energy Management Handbook*, Second Edition, Fairmont Press, 1993.

Energy Conservation and Program Guide for Industry and Commerce, GPO, Washington, DC, September 1974.

Energy Conservation Trends—Understanding the Factors That Affect Conservation in the U.S. Economy, U.S. Department of Energy, DOE/PE-0092, September, 1989.

Energy Management for the Year 2000, A Handbook prepared by the National Electrical Contractors Association and the National Electrical Manufacturers Association, Washington, DC, First Edition, 1993.

Grant, Eugene L. and Richard S. Leavenworth, Statistical Quality Control, Sixth Edition, McGraw-Hill Company, New York, NY, 1988.

Greene, Richard P., "Energy Responsibility Accounting, an Energy Conservation Tool for Industrial Facilities," unpublished working paper, General Motors Corporation, date unknown.

Millhone, John P., John A. Beldock, Barney L. Capehart, and Jerome Lamontagne, "United States Energy Efficiency: Strategy for the Future," Strategic Planning for Energy and the Environment, Vol. 11, No. 3, Winter, 1992.

Schultz, Steven, 3M Corporation, St. Paul, MN, personal correspondence, 1997.

Shirley, James M., and W.C. Turner, "Industrial Energy Management—First Steps Are Easy," Industrial Engineering, May 1978, pp. 3441.

Stobaugh, Robert, and Daniel Yergin, *Energy Future*, Second Edition, Random House, New York, 1983.

Turner, W. C., Editor, *Energy Management Handbook*, Third Edition, Fairmont Press, Atlanta, GA, 1997.

Turner, W.C., and B.W. Tompkins, "Productivity Measures for Energy Management," in IIE National Meeting, Detroit, MI, Proceedings, May 1981.

Witte, Larry C., Phillip S. Schmidt, and David R. Brown, *Industrial Energy Management and Utilization*, Hemisphere Publishing Corporation, Washington, DC, 1988.