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EIGHTH EDITION

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Eighth Edition

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Preface to the Eighth Edition

The wild ride on the roller coaster of energy prices continues with the price of oil having soared to almost $150 a barrel in early 2008, and plunged to $35 a barrel in late 2008. In 2010, oil prices averaged about $80 a barrel. In 2014 oil was also about $80 a barrel, but dropped to $45 a barrel in August 2015. Some estimates of crude oil prices are as low as $30 a barrel in late 2015. In the spring of 2015, gasoline prices were about $2.50 a gallon, and both people and businesses are enjoying lower prices for a while. With significantly greater federal expenditures for energy efficiency and renewable energy over the last five years, our work as energy managers, facility managers, and other energy professionals has continued in high gear. Using our new opportunities for implementing more energy cost reduction projects, results have come in the form of huge cost savings for our companies and organizations. However, all of these past successes have not eliminated—or really even slowed—the continuing need to install new equipment, new technology and new processes to produce energy savings as well as help reduce pollution and improve quality and productivity. Energy managers and energy professionals are not going to work themselves out of a job!

One more reason that energy managers and energy professionals are not going to work themselves out of a job is that "the job" keeps changing. First it was just energy and energy cost, then it expanded to include water and sewer use and cost. Now our responsibilities have greatly expanded to include construction and operational aspects involving sustainability, green, LEED, Energy Star, renewable energy, and low carbon footprints. All of these new parts of our jobs are intimately related to our energy use, so we are the "usual suspects" to be asked to accomplish these tasks, too! Now we have a large set of additional drivers for our "old work" of making our facilities and operations more energy efficient and using more renewable energy. While this increases our work load and our need to learn new things, it also greatly expands our opportunities to find ways to make some of our "energy projects" far more cost effective. There will be many more win-win projects for us in the future.

The *Guide to Energy Management* continues as one of the leading educational resources for the person who is active as an energy manager or energy professional, as well as helping new people enter the fascinating and important field of energy management and energy engineering. *Guide to Energy Management* is the most widely used college and university textbook in this field, as well as one of the most widely used books for professional development training in the field. At the end of 2014 over 17,000 energy professionals had been trained using the first seven editions. In this eighth edition, we have added four new chapters with the extremely timely topics of electrical systems; motors and drives; commissioning (written by Wayne Robertson and Micheal Smith); and human behavior and facility energy management (written by Eric Mazzi, Kady Cowan, and Eileen Westervelt). We have also significantly updated two chapters on lighting, and on HVAC systems; and Paul Allen updated his chapter on web based building automation and control systems. Dr. Stephen Roosa updated his chapter on green buildings; and Dr. Eric Woodroof updated his chapter on green house gas management. And thanks to Mr. Klaus Pawlik for his help in coordinating the *Solutions Manual* with the problems contained in Appendix I of this book.

Thanks to the many energy professionals who have suggested improvements to this book, and have helped point out errors or inconsistencies. There is always room for improvement, so please let us know if you find any parts of the book needing improvement. We always appreciate hearing constructive criticism.

Good luck to all of you in your search for new, green, energy cost savings opportunities! And may we all be successful in providing an energy future for our country and our grandchildren that is efficient and sustainable.

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August 2015

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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 efficient and effective use of energy to maximize profits (minimize costs) and enhance competitive positions

This rather broad definition covers many operations from services to product and equipment design through product shipment. Waste minimization and disposal also presents many energy management opportunities. Our main focus in this book is energy management in buildings, manufacturing, and industry.

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. Improving energy efficiency and reducing energy use, thereby reducing costs

2. Reduce greenhouse gas emissions and improve air quality.

3. Cultivating good communications on energy matters

4. Developing and maintaining effective monitoring, reporting, and management strategies for wise energy usage
5. Finding new and better ways to increase returns from energy investments through research and development
6. Developing interest in and dedication to the energy management program from all employees
7. Reducing the impacts of curtailments, brownouts, or any interruption in energy supplies

Although this list is not exhaustive, these seven are sufficient for our purposes. However, the seventh 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 often minuscule compared to the cost of forced shutdowns. 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 book. 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 can operate on 20 percent of the energy (with a corresponding 80 percent savings) normally required by existing buildings. In fact, for most manufacturing, industrial, 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 40 MBOE in 1979. Energy use slowed again in the early 1980's and dropped to about 37 MBOE in 1983. Economic growth in the mid 1980's returned the use to 40 MBOE in 1987. Energy use remained fairly steady at just over 42 MBOE in the late 1980's, but started growing in the 1990s. By the end of 1994, energy use was up to almost 45 MBOE, and in 2004, just under 50 MBOE per day. Energy use

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

remained around 50 MBOE per day for 2005 and 2006. After that, the world-wide economic slowdown dropped energy use to 47 MBOE in 2009. For 2010, this increased to 49 MBOE, per day; and for 2014, 48.5 MBOE.

- Comparison with other countries:
  With only 4.4 percent of the world's population, the United States consumes about 18 percent of its energy and produces about 22 percent of the world's gross national product (GNP). However, some nations such as Japan and Germany 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 under 10 million barrels per day (MBD), and has fallen slowly since then to about 5.6 MBD in 2006, and 5.3 MBD in 2009. For 2010, this increased to about 5.85 MBD; and then in 2014 with fracking, new oil production was 9.2 MBD. Most likely in several more years, US oil production with be greater than 10 MBD. Domestic gas production peaked in 1973 at just over 21.7 trillion cubic feet (TCF) per year. Gas production slowly declined until 1987 when it fell to 16.1 TCF. Since 1988, gas production increased very slowly, and in 2003 was 19.7 TCF, and in 2006 it was 19.1. Deregulation has improved our domestic production. Since 1988, gas imports have been over 1 TCF per year, and have been increasing rapidly. In 2006, we imported over 4 TCF of natural gas.

  In 2009, net U.S. imports of natural gas were the lowest since 1994, representing just 12 percent of total consumption. The primary underlying cause for the lower level of net imports was continued strong levels of natural gas production in the lower 48 states. Dry natural gas production increased 3.3 percent compared with 2008 and was nearly 9 percent higher than in 2007. With these recent gains in domestic production, the United States is now the largest producer of natural gas in the world. U.S. domestic consumption decreased in 2009, which in turn contributed to a reduced demand for imports. Although liquefied natural gas (LNG) gross imports increased almost 30 percent (from a 5-year low established in 2008), LNG remains a very small source of supplies for the United States, accounting for less than 2 percent of consumption.

  In 2010, the domestic production of natural gas reached 22.1 TCF due to expanded shale gas production; and in 2014 it had increased to 27.3 TCF. Natural gas imports were down slightly to 3.78 TCF in 2010, and were 2.7 TCF in 2014.