GUIDE TO ENERGY MANAGEMENT

7TH EDITION

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Guide to Energy Management

Seventh Edition

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Preface to the Seventh 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. For 2010, oil prices have averaged about $80 a barrel. In the spring of 2011, gasoline prices are now over $4.00 a gallon again, and both people and businesses are suffering some economic consequences. The cost of oil is now over $100 a barrel again. With the cost of most of our energy sources remaining at high levels, and having significantly greater federal expenditures for energy efficiency and renewable energy over the last two 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. It 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 2010 over 15,000 energy professionals had been trained using the first six editions of the *Guide to Energy Management*. In this seventh edition, we have added one new chapter with the extremely timely topic of green house gas emissions management, and we have updated two chapters that help prepare people to address the new areas of web based energy information and control systems, and creating green buildings.

The authors wish to thank Dr. Eric Woodroof for his contribution of the new Chapter 17, where he discusses the importance of green house gas emissions impact on global climate change, and our need to manage these emissions from our buildings and other facilities. He explains how to measure and report green house gas emissions, how to reduce them, and how to mitigate or offset them. The authors wish to thank Dr. Diane Schaub for her contribution of the Compressed Air section to Chapter 12. Also, thanks go to Mr. Paul Allen for updating Chapter 15 on Web Based Building Automation Controls and Energy Information Systems; and Dr. Steven Roosa for updating Chapter 16 on Creating Green Buildings. 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. Special thanks go to Mr. Joseph Dussault for his careful review and identification of some errors in this book. 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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May 2011

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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

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

almost 45 MBOE, and in 2004, just under 50 MBOE per day. Energy use 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.

- Comparison with other countries:
  With only 4.5 percent of the world's population, the United States consumes about 25 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. 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. Natural gas imports were down slightly to 3.78 TCF.

- 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 $36 in

1981. After 1981, prices dropped to about $12 in 1986. From 1986 to 1999, prices ranged from about $12 to $20 a barrel, with a short spike in prices during the 1989-90 Gulf War. Prices dropped to $10 in 1998, and rose back to about $26 in 2003. The 2004 cost was about $24, but in early 2005, spot prices shot up to $58 a barrel. In 2006 prices averaged around $60 a barrel, and in 2007 spot prices for oil reached almost $100 a barrel. In 2008 spot prices for oil spiked to almost $150 a barrel before crashing back to $35 a barrel later in the year. For 2009 the average cost for oil was almost $60 per barrel. For 2010, the average cost of oil was about $80 per barrel.

- 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 1977 it was $42 billion; by 1979, $57 billion; and by 1980, almost $80 billion. This imported oil bill has severely damaged our trade balance and weakened the dollar in international markets. In 1986 the bill for oil imports fell to a low of $35 billion. It climbed to almost $62 billion in 1990. In 1996 it was just over $72 billion, and with lower prices after 1996, it was just over $50 billion in 1998. But, with higher prices starting in 2000, it was $119 billion in 2000, $132 billion in 2003, and $179 billion in 2004. With the higher prices in 2005 and 2006, the total was $300 billion in 2006! The cost continued to rise to over $350 billion in 2008, but then dropped to less than $200 billion in 2009 with the U.S. and global recession significantly reducing the use and cost of oil. In 2010, our cost of imported oil jumped 33% to $251 billion.

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

- <u>Reducing acid rain</u>. Acid rain has been reduced mainly through national and regional environmental policies around the world. The United States adopted the Clean Air Act Amendments of 1990, and the Clear Skies Act of 2003 which established a new trade program for sulfur oxides and nitrous oxides and mercury emissions from power plants. Canada has worked closely with the United States on acid rain reduction. The EU has adopted several policies related to the reduction of acid rain. The Asian development Bank has worked closely with China to help it make significant reductions in its potential for acid rain.

- 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. Reducing fossil energy use through energy efficiency improvements and the use of renewable energy is without doubt the quickest, most effective, and most cost-effective manner for reducing greenhouse gas emissions, as well as improving air quality, in particular in densely populated areas.

  The first international treaty to address climate change was the United Nations Framework Convention on Climate Change (UNFCCC), which entered into force in 1994 and has been ratified by 186 countries, including the United States. Delegates to the UNFCCC then met in Kyoto, Japan, in 1997 to adopt a more significant treaty calling for binding targets and timetables, eventually agreeing on the Kyoto Protocol (KP). Delegates rejected language requiring participation by developing countries, thus damping U.S. enthusiasm. Nevertheless, the Kyoto Protocol entered into force in 2005, having been ratified by EU countries, Canada, Japan, Russia, and most developing countries. The United States and Australia are currently not parties to the KP.

  The U.S. considered legislation to control carbon emissions with a cap and trade approach in 2009 and 2010, but no formal control was approved. Currently, this legislation appears very unlikely to be approved anytime in the near future.

- Reducing ozone depletion. The Montréal Protocol of 1987, and its subsequent updates, is one of the most successful environmental protection agreements in the world. The Protocol sets out a mandatory timetable for the phase out of ozone depleting substances. This timetable has been under constant revision, with phaseout dates accelerated in accordance with scientific understanding and technological advances. Chlorofluorocarbon (CFC) production by developed countries was phased out at the end of 1995. Starting in 1996, hydrochlorofluorocarbons (HCFCs) began to be phased out by developed countries with a 65% reduction by 2010, and complete phase out by 2020.

- 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. In 1973 our net imports were 34.8% of our use. In 1977 they were 46.5%, and in 1998 hit 50%. The percentage of our oil use that is imported continues to climb—56.1% in 2003, 57.8% in 2004, and 59.5% in 2006. In 2009, import levels reached almost 63%. Preliminary data for 2010 show a 61% level of oil imports.

- 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 most Eastern European countries have led 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. Research and development on "clean coal" technology is currently underway.

- 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, with the current cost of large-scale solar PV generation under $4000 per kW in 2010.

- 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 is only feasible in limited geographical areas where the wind velocity is consistently high, and there are also some noise and aesthetic problems. However, the cost of wind generation systems has come down to $1000-$2000 per kW, and they are cost-effective in windy areas of the U.S. Operating costs are very low, and with new wind turbine technologies, large wind farms are being constructed in the midwest, southwest, and western regions of the U.S.

- Fuel cells and their ability to cleanly produce electricity from hydrogen and oxygen are what make them and hydrogen attractive. However, hydrogen is not a primary source of energy. It is made from other forms of energy; most hydrogen production today is by steam reforming natural gas. Natural gas is a fossil fuel, so the carbon dioxide released in the reformation process adds to the greenhouse effect. Only when hydrogen is made cost effectively from renewable energy sources does it have any significant value as a fuel source for a fuel cell. Then fuel cells will be of great interest and use. 2010 prices for fuel cells were around $4500 per kW.

- 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 alcohol from wood waste are still being tested, and may offer some significant improvements in this limitation. In the meantime, quite a few new ethanol plants are being started up to produce this alternate energy fuel. Brazil has a very large and successful ethanol production industry from sugar cane.

- Fission has the well-known problems of waste disposal, safety, and a short time span with existing technology. Without breeder reactors or nuclear fuel reprocessing, we will soon run out of fuel, but breeder reactors dramatically increase the production of plutonium—a raw material for nuclear bombs. Nuclear fuel reprocessing could provide many years of fuel by recycling partially used fuel now being kept in storage. Newer reactor designs appear to be safer and porentially cheaper.

- 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 through improved energy efficiencies. 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.

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	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

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 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