Stephen A. Roosa
Steve Doty
Wayne Turner

9TH EDITION

Energy Management Handbook

River Publishers

Energy Management Handbook

Ninth Edition

Editors

Stephen A. Roosa
Editor-in-Chief of this edition
Louisville, Kentucky

Editors of the previous edition—
Steve Doty and Wayne C. Turner

Contributors

Following are contributing authors of the current edition.

Simon Baker
California Public Utilities Commission
San Francisco, California

Gary Berngard
Honeywell Building Solutions
Denver Colorado

Barney L. Capehart
Professor Emeritus
University of Florida
Gainesville, Florida

Kevin Carpenter
CEG Solutions
Arlington, Virginia

Gabriel Caunt
Colorado Springs Utilities
Colorado Springs, Colorado

Clint Christenson
Consultant
Monument, Colorado

David E. Claridge
Texas A&M University
College Station, Texas

Robert Cox
Jacobs, Engineering, Inc.
Raleigh, North Carolina

Charles Culp
Energy Systems Laboratory
Texas A&M University
College Station, Texas

Michael Dipple
City of New York, New York

Steve Doty
Colorado Springs Utilities
Colorado Springs, Colorado

Keith E. Elder
Seattle University
Seattle, Washington

Scott Frazier
Oklahoma State University
Stillwater, Oklahoma

Carol Freedenthal
Jofree Corporation,
Houston, Texas

Jairo A. Guttierrez
CSA Energy Consultants
Arlington, Virginia

Jeff Haberl
Texas A&M University
College Station, Texas

Jack L. Halliwell
Halliwell Engineering
Miami, FL

Michael R. Harrison
Johns-Mansfield Corporation
Denver, Colorado

Fred Hauber
Atlantic Consulting
Hammonton, New Jersey

Russell L. Heiserman
Oklahoma State University
Stillwater, Oklahoma

Arun G. Jhaveri
Seattle, Washington

William J. Kennedy, Jr.
Clemson University
Clemson, South Carolina

John M. Kovacik, Retired
GE Industrial & Power System Sales
Schenectady, New York

Roger G. Lawrence
Consultant Specialized Engineering Services
Raleigh, North Carolina

Mingsheng Liu
University of Nebraska
Lincoln, Nebraska

Konstantin Lobodovsky
Motor Manager
Penn Valley, California

William Mashburn
Virginia Polytechnic Institute and
State University
Blacksburg, Virginia

Paul Mehta
Bradley University
Peoria, Illinois

Javier Mont
Abbott Vascular
Santa Clara, California

S.A. Parker
Editor-in-Chief
Energy Engineering

David Pratt
Oklahoma State University
Stillwater, Oklahoma

Stephen A. Roosa
RPM Asset Holdings
Louisville, Kentucky

Philip S. Schmidt
University of Texas
Austin, Texas

Mark B. Spiller
Gainesville Regional Utilities
Gainesville, Florida

Nick Stecky
NJS Associates
Denville, New Jersey

Albert Thumann
Association of Energy Engineers
Atlanta, Georgia

Wayne C. Turner

Stan Walerczyk
Lighint Wizards
Walnut Creek, California

Richard A. Wakefield

B.K. Walker
Quik Water
Sand Springs, Oklahoma

Lynda J. White

Larry C. Witte
University of Houston
Houston, Texas

Jorge B. Wong
Editor-in-Chief
DGAE

Eric Woodroof
Profitable Green Solutions
Somerset, Kentucky

Energy Management Handbook

Ninth Edition

---

by

Stephen A. Roosa

Ph.D., CEM, CSDP, REP, CMVP

Steve Doty

Wayne C. Turner

River Publishers

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

Published 2020 by River Publishers
River Publishers
Alsbjergvej 10, 9260 Gistrup, Denmark
www.riverpublishers.com

Distributed exclusively by Routledge
4 Park Square, Milton Park, Abingdon, Oxon OX14 4RN
605 Third Avenue, New York, NY 10017, USA

Library of Congress Cataloging-in-Publication Data

Names: Roosa, Stephen A., 1952- editor. | Doty, Steve, editor. | Turner, Wayne C., 1942- editor.
Title: Energy management handbook / [edited] by Stephen A. Roosa, Steve Doty, Wayne C. Turner.
Description: Ninth edition. | Louisville, Kentucky : Fairmont Press, Inc., [2018] | Includes bibliographical references and index.
Identifiers: LCCN 2017054123 (print) | LCCN 2017059580 (ebook) | ISBN 9788770222655 (electronic) | ISBN 0881737860 (electronic) | ISBN 9780881737851 (hardcover) | ISBN 0881737852 (hardcover) | ISBN 9781138666979 (Taylor Francis distribution : alk. paper)
Subjects: LCSH: Power resources--Handbooks, manuals, etc. | Energy conservation--Handbooks, manuals, etc. | Buildings--Energy conservation--Handbooks, manuals, etc.
Classification: LCC TJ163.2 (ebook) | LCC TJ163.2 .E4827 2018 (print) | DDC 658.2/6--dc23
LC record available at https://lccn.loc.gov/2017054123

Energy management handbook ninth edition / by Stephen A. Roosa, Steve Doty and Wayne C. Turner
First published by Fairmont Press in 2018.

Routledge is an imprint of the Taylor & Francis Group, an informa business

10:0881737852 (The Fairmont Press, Inc.)
13:9781138666979 (print)
13: 9788770222655 (online)
13: 9781003151364 (ebook master)

Contents

Foreword to the Ninth Edition

The publishing of the ninth edition of the *Energy Management Handbook* coincides with the 40th Anniversary celebration of the Association of Energy Engineers (AEE), a nonprofit professional energy engineering society. The energy management journey began with the founding of the Association of Energy Engineers in 1977. During its 40-year history, the AEE has grown to over 18,000 members in over 80 countries. AEE is proud to sponsor this excellent work, which serves as an indispensable reference for preparing energy professionals for the Certified Energy Manager (CEM®) examination.

No other publication has been as influential in defining the energy management profession. The *Energy Management Handbook* was originally published in 1982. About that time, the Association of Energy Engineers started its most successful program, the Certified Energy manager (CEM®). To date, over 14,000 professionals have been recognized as CEMs. The *Energy Management Handbook* serves as the official reference book for the CEM® program.

The AEE embraces energy efficiency, energy conservation, plus both renewable and traditional energy resources. Our industry is poised for continued growth, and the *Energy Management Handbook* is a more important resource than ever before. I am happy to welcome Dr. Stephen A. Roosa, a widely recognized leader in the energy management profession and a past president of the AEE, as this edition's new editor-in-chief.

The ninth edition of the *Energy Management Handbook* will be the indispensable reference required to assist energy managers in meet the challenges that lay ahead.

Albert Thumann, P.E., CEM
Executive Director
Association of Energy Engineers
Atlanta, Georgia
www.aeecenter.org

Preface to the Ninth Edition

As a young professional working for a Fortune 100 company in the early 1980s, I was given the title of senior process engineer. It was my first job with the title of engineer. I actually don't recall my generic job description mentioning energy but I do know the company didn't have a job title for an energy manager or energy engineer. Meetings with my management seemed to conclude with messages to the effect of "go forth and reduce our energy use as much as you can, as long as it reduces our cost and doesn't require any funding." Our plant had about 1,800 buildings. As I settled into my new role, I quickly realized that most of the people I worked with had little interest in reducing energy use or cost. It usually seemed that the opposite was truer. I needed to develop an energy management program, get employee support and develop feasible projects.

The company was a chemical company and in addition to many other things was involved in making specialized explosives. I accepted my inexperience and knew that I had much to learn. While there were several talented and highly qualified engineers working in our department, not one had experience in energy management. For the young energy managers and engineers reading this, there were no cell phones, no computers, no internet connections, and electricity was about a penny a kWh. There were about 115 people in our three engineering departments. I was the first to get a computer, and that didn't happen until about 1983. Most engineers used handheld calculators in a leather case hanging from the belt, worn proudly, since they no longer needed slide rules (I still have one and remember how to use it to do multiplication and division). My direct supervisor, an engineer named Karl (a.k.a. Achtung) Betz, or something like that, called me into his office to scold me for having a computer at work. With less than clairvoyant emphasis, he told me flat-out that engineers would never, ever, need computers to perform their work. I explained that my work was different and involved lots and lots of calculations, and I wanted to make productive use of my time. He decided let me keep the computer, so long as I didn't show any of the other engineers how to use it, which he believed would be a waste their time. Later in life and nearing retirement, Karl lost a lot of money in the stock market. As Vonnegut would say… so it goes.

Armed with my computer, where might I turn to learn the skills I needed for my new job? I remember obtaining a new book, which became an invaluable resource. Titled *Energy Management Handbook*, its first edition was published in 1982, a 6" x 9" hardcover. In his preface, Wayne Turner said, "this is a handbook for the practicing engineer or highly qualified technician working in the area of energy management." He also stated that it provides the reader "with enough information to successfully accomplish most energy management activities." I remember thinking as I considered Wayne's statements that this was indeed the book I needed.

Why hadn't I encountered this sort of information in college? I talked to one of the older and highly experienced engineers in my department and posed this question after a lunchtime game of chess (he won). He was a brilliant guy who as a young engineer had worked on something called the Manhattan Project. I wasn't sure what he was talking about and he didn't offer details but it sounded like something that had once been important. He told me I didn't learn about energy efficiency in college because it was the field of the future. He was implying that architecture and engineering schools were teaching history, some of it literally quite ancient. He then added, "if you continue in this new profession of yours, you will be among those who will lead us to a new the future." Nuff said. I liked this guy much more than I did Karl.

Afterwards, the *Energy Management Handbook* had a permanent place on my desk. Due to my inexperience with many of the topics in its 18 chapters, I needed to read some parts over and over until I finally understood the methodologies in the book. Eventually, I gained a working knowledge of its topics which helped me launch a career. I also managed to obtain funding for projects—surprisingly, millions and millions of dollars of funding over the years. Why? Because the solutions were appropriate, timely and workable. I used the techniques I learned from this book to justify my projects.

Fast-forward 35 years and the role of energy managers has expanded, and become increasingly important. I still have my original copy of that first edition, and despite my overuse, annotations and highlighting, it is in remarkably good shape. I also have a few of its subsequent editions, a couple are in hardcopy and another on a CD. I recall being continually impressed by the teamwork that must have been required to assemble the book and create a mainstay resource.

I have enjoyed a lifelong profession enriched by the like-minded people I have met along the way. Yet today's energy managers are tasked with more than energy auditing and improving energy efficiency. They are concerned with the kinds of energy being used, strategic options, governmental incentives, sophisticated digital control systems, comparative benefits of HVAC solutions, energy purchasing, distributed generation, atmospheric greenhouse gas reduction, constantly changing technologies, commissioning, measurement and verification and greater use of renewable energy resources. While our field is evolving toward higher degrees of specialization, the core body of knowledge remains increasingly important.

This new edition's content retains its core focus yet follows these trends. In my view, the *Energy Management Handbook* always will be Wayne's book. I am taking care of it for a while. For me, it is a challenging task. As the editor for the 9th edition, I have focused on the goals that Wayne mentioned in his first edition's preface. This edition builds on the successes of those past editions and offers expanded chapters plus a number of new ones. By the way, as that younger engineer, I would never have dreamed that I would be asked one day to be the editor of a future edition of the *Energy Management Handbook*. My thanks to Wayne, Steve, all the contributors, the folks at The Fairmont Press, the CRC Press, and Taylor and Francis for this opportunity and their support.

Stephen A. Roosa
Editor-in-Chief

Photo by Stephen A. Roosa

Welcome to the ninth edition of the *Energy Management Handbook*. Inside you will find updates and several new sections that will confirm that this book is not standing still. For me, it's been 10 good years and now time to pass the steering wheel to the new editor, Stephen Roosa. My personal thanks to all the great authors and to Wayne for the chance to do it.

Steve Doty

I started working on this book in about 1978 (almost 40 years ago). When my gas tank ran dry, Steve Doty graciously took over and did an amazing job, proving once again that change can be good. Now he is ready to make a change. Stephen Roosa has agreed to take charge and, I'm sure, continue the tradition. Thank you from the bottom of my heart for your support over the years and stay in touch.

Many things are changing in our energy management world and I'd like to use my crystal ball to make predictions for you but yours is likely sharper than mine so I won't. Be prepared for big changes in renewable energy and grid management, such as the use of micro grids. May your path be rewarding.

Wayne Turner

CHAPTER 1
INTRODUCTION

STEPHEN A. ROOSA, Ph.D., CEM, CSDP, BEP, CMVP
Editor-in-Chief
Louisville, Kentucky

STEVE DOTY
Colorado Springs Utilities
Colorado Springs, Colorado

WAYNE C. TURNER, Ph.D., Regents Professor Emeritus
Oklahoma State University
Stillwater, Oklahoma

1.1 BACKGROUND

Al Thumann, executive director of the Association of Energy Engineers (AEE), said it well in an earlier edition foreword of this book: "The energy 'roller coaster' never ceases with new turns and spirals which make for a challenging ride." The purpose of this chapter is multifold. It provides a historic context and introduction to energy management, outlines policy development in the U.S., considers the value of energy management, provides basic principles of energy management and discusses barriers to energy conservation. Energy management has evolved to become a multi-disciplinary field. Mr. Thumann's analogy of the energy roller coaster ride is today more like amusement park, with franchises located throughout the world. Strap yourself in and buckle up! For the energy management profession, the future looks very promising.

Those professionals who boarded the coaster in the late 1970s and stayed onboard have experienced many ups and downs, some thrilling, others gut-wrenching. The environmental movement grew to worldwide status, reacting to polluted air, water and soils. In the U.S., new oil from wells placed in production after November 1975 was about $5.25 per barrel while that from old wells that exceeded base period output levels was controlled at $1 per barrel. With the oil price shocks, oil increased to the range of $29 to $34 per barrel in 1981, dropping by half by the late 1980s.

The 1980s plunge in energy prices caused some to wonder, "Do we really need to continue energy management?" Despite this perspective, many corporations decided that energy management was good business, and needed to be supported by professional staff. This is when many of us boarded that roller coaster. Trying to earn a living being an energy manager during a time when there was no such job title was a difficult time to begin working in this new profession. My company gave me the job title of senior process engineer, yet my duties and job description met all the qualifications of what today would be called an energy manager—reduce energy use, save money, do it with no budget and by the way, we have 1,800 buildings and no one knows how much energy they use. While many supported the concept of efficiency, the energy conservation ethic was just gaining traction. Energy costs were very low and electricity was a penny per kWh and less in some places.

In 1982, Wayne Turner thought it would be a good idea to publish a new book to provide energy managers with the knowledge they needed to be successful, which he titled *Energy Management Handbook*. It had 18 chapters with 714 pages, and I still have my copy. He has since retired and spends lots of time fly-fishing. This 9th edition is dedicated to Wayne, who made this book a life-long project.

Many believed that energy conservation was a fad and would soon become passé. They believed it would reach a point where the law of diminishing returns would cause additional efforts toward energy management and efficiency to reach a peak and then steadily decline. Economists of the day were touting the "energy-GDP link." This meant that energy and a country's gross domestic product (GDP) were so highly correlated that to improve economic growth, energy consumption needed to increase. It seems some of those economists were making conclusions about long-term trends using short-term databases. In fact, energy conservation was already making considerable contributions to the U.S. economy.

For the U.S., those paths began to slowly diverge. It seemed the more energy efficient the U.S. became, the more GDP increased, redefining that link's meaning. Energy costs continued to increase, enhancing the feasibility of measures such as lighting and insulation improvements (see Chapters 9, 13, and 15). Environmental drivers for energy efficiency kept surfacing. Meanwhile, Humble Oil ran a nationwide advertisement in leading magazines picturing a glacier with the tag line, "Each day Humble supplies enough oil to melt seven million tons of glacier!" Lacking federal-government leadership, carbon reduction programs were beginning to be considered regionally. Carbon markets were developing in California and New England, eventually creating additional sources of funds for mitigation efforts (see Chapter 21).

Oil costs stabilized through the 1990s, began to increase substantially beginning about the year 2000, and crashed again late in the decade. There were several rounds, but it was not just oil exhibiting price volatility (see **Figure 1-1**). Natural gas, coal and soon electrical energy began to increase substantially. Electric and natural gas utilities began changing pricing structures (see Chapter 24). Countries began taxing certain energy sources, some heavily, and particularly fossil fuels (renewables are difficult to tax). Soon the conversation wasn't only about energy efficiency and conservation, it was about grid stability, budgetary impacts and cost avoidance.

At the turn of the new century, the idea of "energy independence" became the call to action in the U.S. Energy managers became more creative, funding projects from cost avoidance and measuring and verifying the savings (see Chapters 25 and 27). Demand-side management, heat recovery, cogeneration, and thermal energy storage technologies were more widely adopted—more tools added to the energy manager's toolbox (see Chapters 7, 8 and 19). As an over-arching policy agenda, the concept of sustainable development became important. With the digital age, came energy monitoring and control systems that evolved into systems to control the energy use of entire campuses of buildings or managed facilities widely dispersed geographically (see Chapter 12). These evolving technologies created new opportunities for energy engineers and managers. Many found they could now assess energy flows and pricing in real time. Finding employment in the field was no longer a problem.

We began to realize that success was highly dependent upon creative ideas, concerted efforts and scalable methodologies. It was also a function of policies, programs and technologies, and success was most likely when these were aligned. Applications needed to be both workable and resilient. We became interested in the concept of appropriate technologies. Soon alternative and renewable energy systems were being planned and constructed (see Chapter 16). Today, energy managers are routinely making improvements on both sides of the meter.

Throughout the years, U.S. federal regulation has had an important role in the energy industry (see Chapter 20). A few of the more instrumental regulatory actions are shown in **Table 1-1**. While energy policy legislation dates back to the Industrial Revolution, things as we know them probably started with the National Energy Act (NEA) of 1978, which was a legislative response by the U.S. Congress to the 1973 energy crisis. It continued with the following statutes:

- Public Utility Regulatory Policies Act (PURPA) (Public Law 95-617)
- Energy Tax Act (Public Law 95-618)
- National Energy Conservation Policy Act (NECPA) (Public Law 95-619)
- Power Plant and Industrial Fuel Use Act (Public Law 95-620)
- Natural Gas Policy Act (Public Law 95-621).
- American Recovery and Reinvestment Act of 2009 (Public Law 115-5)

Figure 1-1. Price of crude oil in the U.S.

In 1978, amidst natural gas supply shortages, Congress enacted the Natural Gas Policy Act (NGPA), as part of the National Energy Act (NEA). It had become apparent that price controls put in place to protect consumers from monopoly pricing had begun to hurt consumers by creating natural gas shortages. The NGPA had three central goals:

- Create a single U.S. market for natural gas
- Match natural gas supply and demand
- Allow market pressure to establish the wellhead price of natural gas [15].

The NGPA granted the Federal Energy Regulatory Commission (FERC) authority over both intrastate, and interstate natural gas production. FERC succeeded the Federal Power Commission (FPC) in this authority [16]. An informative history of natural gas regulation has been prepared by the Natural Gas Supply Association [15].

All the legislation since then (EPAct 1992, EPAct 2005, and EISA 2007) is actually addenda or modifications to this original legislation, and each had a focus related to the needs of the time. EPAct 2005, for example, was similar in many ways to the 1992 Act but offered financial incentives, most highly qualified. Energy-related mandates for federal facilities are found in many of the energy policies. In terms of the number of pages, the federal facility mandates are a small portion of the total, but the concept of leading by example has been consistent; the Federal Energy Management Program (FEMP), charted in 1973, is still alive and well. Another common theme is the endorsement of the energy savings performance contracting (ESPC) delivery method, whereby a third party provides implementation services in exchange for payment via energy savings (see Chapter 25). In addition to these regulations, many presidents have signed executive orders that furthered energy management as good government business practices; however, only the current ones are relevant. Other federal government activities provide valuable support to the private sector for energy conservation. A few examples show how these efforts are enablers to the energy management industry:

- The Department of Energy (DOE) is the center for the country's energy interests. It is concerned with all aspects of energy, from sources to consumption habits, forecasts and politics. DOE's scope is vast, so various departments within it have been created with their respective focus.
- The Energy Information Administration (EIA), part of DOE, provides a wealth of statistical data, including typical energy use intensity (kBtu/sf-year) figures for business segments—a litmus test for determining where energy saving potential exists (your use compared to national average).
- Energy Star® is operated under EPA and DOE with private partners. Their appliance branding program has helped make energy usage part of the consumer purchasing decision process transforming markets in the U.S. and abroad. Their Portfolio Manager building rating system is a tool to assess the comparative energy use of buildings. The Energy Star program provides recognition to building owners who demonstrate a commitment to operating energy efficient buildings.
- The Office of Energy Efficiency and Renewable Energy (EERE) in the DOE has two main focuses. The energy efficiency (EE) section issues case studies to illustrate that energy savings can be a sound investment. This section also produces an array of technology tip sheets to serve as tools and counsel to industry practitioners. The renewable energy (RE) section evaluates emerging technologies and funds promising projects to accelerate their adoption.
- While these efforts have costs, they have been identified collectively as being in the national interest. Energy security goes beyond the monthly utility bill.

A number of federal regulations were established to enable de-regulation, a fundamental change in how energy is purchased and sold (see Chapter 24). Several states moved toward electrical deregulation, with some success. The prospect of electric deregulation and sharing grid infrastructure caused utilities to change their business view of their portion of the grid. Investment in expanding or upgrading this infrastructure became a risky business for individual utilities, and many chose a wait-and-see approach. One (now famous) energy trading company manipulated pricing in the new deregulated electric business environment, and this event gave many states and consumers pause. To regain the confidence of the consumers, a greater degree of oversight of business practices and the sharing of vital U.S. grid infrastructure was necessary. Other concerns that exist with the U.S. electrical grid infrastructure system include susceptibility to failure and terrorism. Despite the difficulties encountered when electricity deregulation was first attempted, some states are now deregulated, and wider-scale electric deregulation remains an exciting concept.

As private sector businesses and the federal gov-

Table 1-1. Some key federal regulations related to the energy industry.

Regulation	*Time Period*	*Action Taken*
Natural Gas Policy Act NGPA	1978	— Granted the Federal Energy Regulatory Commission (FERC) authority over intrastate, as well as interstate, natural gas production. — Set wellhead price ceilings by category. — Established rules for allocating the costs of certain high-cost gas to industrial customers served by interstate pipeline companies. — Provided authority to allocate gas to high priority users in times of gas supply emergency. — Put limits on curtailments of sales to high priority agricultural and industrial feedstock sectors. (A key date in the NGPA was January 1, 1985, when price ceilings on most new gas were removed.)
National Energy Conservation Policy Act NECPA	1978	— Provided for the regulation of interstate commerce, to reduce the growth in demand for energy in the United States, and to conserve nonrenewable energy resources produced in this nation and elsewhere, without inhibiting beneficial economic growth. — Prompted residential energy conservation. — Promoted energy conservation programs for schools, hospitals, buildings owned by units of local governments, and public care institutions. — Improved energy efficiency of certain products and processes. — Provided federal energy initiatives and additional energy-related measures.
Energy Policy Act EPAct-1992	1992	— Allowed states to choose de-regulation of electricity purchasing and wheeling through the grid. — Created aggressive efficiency goals for federal facilities. — Created higher motor and appliance efficiency standards. — Allowed federal facilities to utilize the energy services performance contracting (ESPC) project delivery method.
Energy Policy Act EPAct-2005	2005	— Provided tax incentives for efficiency and renewable measures, as well we for investments in electric transmission grid systems. — Created clean coal technology funding. — Required new federal facilities to achieve 30% better efficiency than required by ASHRAE 90.1 (better than energy code levels). — Established renewable energy use amounts.
Energy Independence and Sec¥urity Act EISA-2007	2007	— Provided loans for battery development. — Increased emphasis on bio fuels. — Created measures intended to phase out the use of incandescent lighting. — Extended life cycle cost periods to 40 years for federal facility projects. — Provided grants to determine viable options for carbon capture and sequestering. — Increased efficiency goals for federal buildings, with milestones to transition energy use away from fossil fuels.
American Recovery and Reinvestment Act of 2009	2009	— Appropriated $38 billion to the U.S. DOE for science, energy and environmental initiatives. — Increased the DOE's authority to make or guarantee energy-related loans by $60 billion. — Extended or enhanced many tax credits important to energy projects. — Appropriated $2.5 billion for applied research for energy efficiency and renewable energy. — Allowed use of funds in government buildings for solar, wind, fuel cells and biomass as renewable technologies. — Grants to local governments included provisions for distributed renewable energy technologies.

ernment expand their needs for energy management programs, opportunities are created for energy service companies (ESCOs), shared savings providers, performance contractors, and other similar organizations. These groups are providing assessments, energy and economic analyses, capital, and monitoring to help other organizations reduce their energy consumption, thus reducing their expenditures for energy services (see Chapter 25). By guaranteeing and sharing the savings from improved energy efficiency and improved productivity, both groups benefit and prosper.

Market transformation is a component of the energy management industry. Promising new technologies are often expensive initially due to embedded research and development (R&D) costs and limited sales volumes. Federal and state buildings and vehicle fleets are used as examples of the technology moving from the design phase to reality. Various subsidizing mechanisms are used to help accelerate the transition to new technologies, including tax incentives, research grants, state and federal incentives and rebates. The costs of these incentives are weighed against the benefit of the products achieving mainstream status sooner than they would if market forces prevailed. An example is a private utility operating under the State Public Utilities Commission (PUC), where requirements for rebates are given as well as permission to use ratepayer funds to support them.

Energy efficiency is good business and growing worldwide. Just a few ways this can be seen:

- The growing number of international AEE chapters.
- Energy efficiency, standards and legislation in Europe and Asia.
- The International Energy Conservation Code (IECC).
- International Standards Organization (ISO) energy efficiency standards.
- ESCO markets growing internationally.
- Air-Conditioning, Heating, and Refrigeration Institute (AHRI, formed when ARI and Gergy (WADE).

Quantifying costs and savings is often the missing connection between groups that want to see improvements and groups that need the numbers to make good financial choices; energy professionals provide this essential service every day. Understanding the customer's business is also crucial, especially when faced with business segments that may resist energy improvement proposals. The customer always chooses, but sometimes a fresh perspective can help (see **Table 1-2)**.

Energy managers have proven time and time again that energy management is cost effective. Furthermore, energy management is vital to our national security, environmental welfare, economic welfare and productivity.

1.2 THE VALUE OF ENERGY MANAGEMENT

Business, industry and government organizations are under constant economic and environmental pressures. Being economically competitive in the global marketplace and meeting increasingly stringent environmental standards to reduce air and water pollution have been the major driving factors in most of the recent operational cost and capital cost investment decisions for all organizations. Energy management has been an important tool to help organizations meet these critical objectives for their short-term survival and long-term success.

The problems that organizations face from both their individual and national perspectives include:

1.2.1 Meeting Environmental Quality Standards

Energy management helps improve environmental quality. Reduced energy consumption directly reduces upstream power plant emissions. For example, the primary culprits in global warming are greenhouse gases (GHGs). With the nation's current mix of power sources, most of our electricity comes from fossil fuel and is gen-

Table 1-2. Example use of creativity to unlock energy savings potential [14].

	Obstacle	*Suggestions*
Leased building spaces	Tenants have little interest in making capital improvements to building systems since it is not their building; landlords have little incentive to make efficiency improvements as long as they are able to pass the utility costs along.	Identify the *portion* of the cost and the *portion* of the savings that will occur during the period of the lease, allowing the tenant investment to prove itself within the period of the lease.
Normal replacement	Using entire cost of project overwhelms energy savings, producing very long paybacks.	If old, most or all of the value of the equipment has been used up, and new equipment is need soon anyway. Evaluate energy savings against the remaining value of the asset (early replacement), plus any upgrade costs to use more efficient equipment.
Buying and selling of buildings	Short business horizon causes no interest in energy improvements.	Value of the building is improved when the cost of operation is reduced
Cost allocation	Facilities that do not see the cost of their utility use tend to not care about improvements.	Allocate costs and accountability to individual buildings and departments.
Productivity	Energy is the fuel for manufacturing productivity, so using less 'sounds like' doing less.	Expressing savings in terms of productivity gains (more product output for the same facility).

erated by equipment that is roughly 35% efficient. Each pound of coal, therm of natural gas, or gallon of fuel oil combusted creates a predictable amount of carbon dioxide. Coal produces the most. Thus, energy efficiency and conservation improvements equate directly to carbon dioxide emission reductions. The same is true for other pollutants related to fuel combustion, and energy management efforts are an proven method of reducing SO_x, NO_x, CO_2, mercury and particulates.

The environmental benefits from industry energy management efforts abound. Less energy consumption means less petroleum field development and less subsequent on-site pollution. Less electrical energy use in some parts of the U.S. means fewer polluted streams and less mountain-top removal. Lower natural gas consumption means less fracking. Less energy consumption means less thermal pollution and emissions at power plants and less cooling-water discharge. Less fossil fuel combustion means less greenhouse gas emissions. Less energy consumption extends the capacity of energy distribution infrastructure and prolongs the life span of fossil fuel resources. The list could go on, but the bottom line is that energy management improves environmental quality. With increased emphasis on environmental impact, the energy manager serves a vital role in quantifying both the dollar benefit and the emissions reduction for projects, as well as relating them to cost of implementation. The choices of how to proceed will remain with the customer; however, advice from a qualified energy manager will provide the necessary input for key business decisions. Thus, the certified energy manager (CEM) becomes a valuable business ally.

For facility owners focusing on sustainability, the energy manager can serve by linking improvements to current practice and facilities with associated carbon or other emission reductions, providing a path and options for the customer to achieve their goal. Carbon inventory, ranking of options, and other practical measures are brought to the building owner by the energy manager, as ideas are matched with solutions.

1.2.2 Economic Competitiveness

Continuing to be economically competitive in the global marketplace requires reducing the cost of production or services, reducing industrial energy intensity, and meeting customer service needs for quality and delivery times.

Substantial energy and dollar savings are available through energy management. Most modern facilities (manufacturing plants, schools, hospitals, office buildings, etc.) can reduce their energy use (see **Figure 1-2**). More savings have been accomplished by some of the more effective programs. Part of gaining support for energy projects is the accountability for achieving project success. *"You can't manage what you can't measure"* is a mantra that forms an essential ingredient in any energy management program. Energy savings often creates greater profits and higher returns on the dollars invested, making the difference between profit and loss for some businesses.

- √ Low cost activities first year or two: 5 to 15%
- √ Moderate cost, significant effort, three to five years: 15 to 30%
- √ Long-term potential, higher cost, more engineering: 30 to 50%

Figure 1-2. Typical Savings through energy management.

Energy management helps companies improve their productivity and increase their product or service quality. This is done by implementing new energy efficiency technologies, using new materials, instituting new manufacturing processes, and using these for business and industrial applications. Energy cost savings have an amplified effect on profits, and this is more pronounced as a greater fraction of total business expense comes from energy use, lowering the profit margin. A facility with energy cost at 8% of total operating cost and operating on a 5% net profit margin will experience a profit increase from 5% to 6.7% with a 20% reduction in energy use—*yielding a 34% increase in profits* (see **Figure 1-3)**.

1.2.3 Adding Value and Creating Negawatts

Well-trained energy professionals bring added value to customers when they can see the bigger picture. Consider a commercial building ripe for a lighting replacement. The quick answer may be to replace lighting on a one-for-one basis which often produces predictable savings. However, it may wise to pause and do a little homework.

Building sciences have evolved to the point that we can improve processes, modify existing facilities and construct new buildings in ways that substantially improve energy efficiency (see Chapter 18). For example, if the project building was designed in an era where twice the lighting per square foot was popular, redesigning the lighting to current illumination standards may produce savings well beyond the efficiency differential of the lighting hardware, amplifying the savings (see Chapter 13). Heating, ventilating and air conditioning (HVAC) are becoming much more energy

20% Energy Savings Table shows revised profit value										
Original Profit Margin	*Energy Cost % of Total Operating Cost*									
	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1%	1.2%	1.4%	1.6%	1.8%	2.0%	2.2%	2.4%	2.6%	2.9%	3.1%
2%	2.2%	2.4%	2.6%	2.8%	3.0%	32%	3.4%	3.7%	3.9%	4.1%
3%	3.2%	3.4%	3.6%	3.8%	4.0%	4.3%	4.5%	4.7%	4.9%	5.1%
5%	5.2%	5.4%	5.6%	5.8%	6.1%	6.3%	6.5%	6.7%	6.9%	7.1%
10%	10.2%	10.4%	10.7%	10.9%	11.1%	11.3%	11.6%	11.8%	12.0%	12.2%
20%	20.2%	20.5%	20.7%	21.0%	21.2%	21.5%	21.7%	22.0%	22.2%	22.4%
30%	30.3%	30.5%	30.8%	31.0%	31.3%	31.6%	31.8%	32.1%	32.4%	32.7%

Figure 1-3. Energy savings effect on profit [14].

efficient, yet justifying replacement is often difficult for existing buildings due to the high costs (see Chapter 10). Likewise, retrofitting water using fixtures, might produce more savings than installing a high efficiency water heater—of course doing both is best. Evaluating a series of manufacturing processes for opportunities to consume less energy would logically occur prior to focusing on equipment replacement. The golden rule for energy conservation measures is to begin by using less. For new construction, we see Leadership in Energy and Environmental Design (LEED) construction practices, net zero buildings, and carbon neutral buildings now becoming realities.

The golden rule for energy conservation measures is to *begin by using less*. Energy conservation is effective at offsetting the need for increased electrical generation capacity, including renewable energy use. It is usually more cost effective to reduce the electrical load through energy conservation measures than to increase the size of the generator, be it a photovoltaic (PV) panel or another generation system. The term "negawatts" was coined and introduced by Amory Lovins in 1989, and is effective at describing the symbiotic effects of energy conservation and efficiency improvements.

A useful principle is to control energy functions as a direct controllable cost rather than as an overhead cost (often a new paradigm for many customers). Tracking energy cost as a component of a manufactured item allows the energy cost to be compared directly to other product components; considered in this light, management will focus differently upon energy. In buildings, the indoor climate conditions can be equated to energy cost, and the management approach changes. Once energy is considered to be a controllable expense, awareness is raised, and there will be incentive to find new improvements. Energy managers have multiple roles, but helping to enlighten their customers is an important one.

Energy managers are employed by their customers. The customer's focus becomes the energy manager's focus—and usually that focus is profit or productivity. Energy efficiency is merely one more tool that allows a business to function and thrive. Usually, the expectation is to achieve energy savings transparently, improving existing processes or comfort conditions. One criterion for a customer selecting an energy professional for a task is often sufficient skill and experience to avoid creating new problems in the process. Thus, the successful energy manager will necessarily evolve to being knowledgeable of many trades, a strong team builder, and a skilled communicator. While we may believe it is interesting and rewarding that energy savings measures simultaneously reduce emissions and prolong non-renewable energy supplies, the reality for most customers is that energy conservation makes business sense when it improves profitability. This careful balancing act of priorities is an ongoing challenge to the energy manager, and finding the business case for energy projects is a special skill all its own (see Chapter 4).

Often, energy savings is not the primary consideration when companies decide to purchase new equipment, use new processes, or use new high-tech materials. However, the combination of increased productivity, increased quality, reduced environmental emissions, and reduced energy costs provide powerful incentives for companies and organizations to implement these new technologies.

Total quality management (TQM) is another emphasis that many businesses and other organizations have developed. TQM is an integrated approach to operating a facility, and energy cost control should be included in the overall TQM program. TQM is based on the principle that front-line employees should have the authority to make changes and other decisions at the lowest operating levels of a facility. If employees have energy management training, they can make informed decisions and recommendations about energy operating costs.

1.2.4 Dependence on Imported Energy

Energy management helps reduce the U.S. dependence upon imported energy sources. During the 1979 oil price crisis, the U.S. imported almost 50% of its total oil consumption. Petroleum includes crude oil, natural gas plant liquids, liquefied refinery gases, refined petroleum products such as gasoline and diesel fuel, and biofuels including ethanol and biodiesel. In 2007 about 58% of the petroleum consumed in the U.S. was imported from foreign countries [16]. According to data from The Energy Information Administration (EIA) in their 2014 Early Release Overview, oil imports decreased from 12.55 million barrels per day (MMb/d) in 2005, (60% of daily U.S. consumption), to 7.45 MMb/d, (40% of daily U.S. consumption), in 2012. In 2016, the United States imported approximately 10.1 million barrels per day (MMb/d) of petroleum from about 70 countries, led by Canada and Saudi Arabia [21]. About 78% of gross petroleum imports were crude oil. In 2016, the United States exported about 5.2 MMb/d of petroleum to 101 countries. Most of the exports were petroleum products. The resulting net imports (imports minus exports) of petroleum were about 4.9 MMb/d [21].

What was driving this reduction in the percentages of imported oil? Economics, technological advances and energy managers plying their trade. The U.S. was conserving energy, deploying energy conservation measures, switching fuels (e.g., from oil and coal to natural gas and biofuels) and developing renewable energy resources (see Chapter 16).

Energy managers are finding key roles in their organizations. Their efforts help to solve important issues. They are creating employment, improving trade imbalances and minimizing the potential effects of limited energy supply disruptions.

1.3 THE ENERGY MANAGEMENT PROFESSION

Energy management skills are important to people in many organizations, and certainly to people who perform duties such as energy auditing, facility or building management, energy and economic analysis, and maintenance. While these duties are important, energy managers are often tasked with doing more than baselining their facilities and performing energy audits (see Chapter 3). Their responsibilities are expanding. The number of companies employing professionally trained energy managers is large and growing. A partial list of job titles is given in **Figure 1-4**. Though this is only a partial list, the breadth shows the robustness of the profession.

• Plant energy manager	• Building/facility energy manager
• Utility energy auditor	• Utility energy analyst
• State agency energy analyst	• Federal energy analyst
• Consulting energy manager	• Consulting energy engineer
• DSM auditor/manager	• Green building engineer

Figure 1-4. Energy management professional titles.

For some, energy management is their primary duty, and they need to acquire in-depth skills in energy analysis, as well as knowledge about existing and new energy-using equipment and technologies. For others, such as maintenance managers, energy management skills are simply one more area to manage along with their other duties and expectations. Properly maintaining energy systems is important for successful installations (see Chapter 14). The editors and authors developed this *Energy Management Handbook* for both of these groups of readers and users.

In the 1980s, few university faculty members would have stated their primary interest was energy management, yet today there are numerous faculty who prominently list energy management as their principal specialty. In 2006, there were 26 universities in the U.S. listed by DOE as industrial assessment centers (IAC) [17]. Other universities offer coursework or perform research in energy management but do not have an IAC. Finally, numerous professional journals and magazines now publish exclusively for energy managers.

Utility company demand-side management (DSM) programs have experienced their own roller coaster ride. DSM efforts peaked in the late 1980s and early 1990s, then retrenched as utility deregulation and the movement to retail wheeling caused utilities to reduce staff and cut costs—including DSM programs—as much as possible. This short-term cost cutting was seen by many utilities as their way to become competitive, low-cost suppliers of electric power and thereby retain their large customers. Not all utility programs are being reduced. Utilities facing growth and high costs of additional generating capacity may create incentives that curb peak demand and prolong the expense of the next plant. For those, once the next plant is finally built, incentives to continue curbing the use may disappear. With national awareness focused on global warming, utility emissions are a certain first target; if emissions become taxed or traded, a new business case will appear for energy conservation programs.

When there is a reduction in electric utility incentive and rebate programs, the gap in energy service assistance is met by equipment supply companies and energy service consulting firms that are willing and able to provide the necessary technical and financial assistance. Energy management skills are extremely important to those companies that are in the business of identifying energy savings and providing a guarantee of the savings results.

Thus, the future for energy management is extremely promising. It is cost effective, it improves environmental quality, it helps reduce the trade deficit, and it helps reduce dependence on foreign fuel supplies. Energy management will continue to grow in size and importance.

1.4 THE PRINCIPLES OF ENERGY MANAGEMENT

Editor's note: *The material in this section is repeated from the first editions of this handbook published in 1982. Mr. Roger Sant, who was then director of the Energy Productivity Center of the Carnegie-Mellon Institute of Research in Arlington, Virginia, wrote this section for the first edition. It was unchanged for the second edition. The principles he offered remain applicable today.*

If energy productivity is an important opportunity for the nation as a whole, it is a necessity for the individual company. It represents an opportunity for creative management to reduce the component of product cost that has risen the most since 1973.

Those who have taken advantage of these opportunities have done so because of the clear intent and commitment of the top executive. Once that commitment is understood, managers at all levels of the organization can and do respond seriously to the opportunities at hand. Without that leadership, the best designed energy management programs produce few results. In addition, we would like to suggest *four basic principles* which, if adopted, may expand the effectiveness of existing energy management programs or provide the starting point of new efforts.

1.4.1 Principle #1

The ***first principle*** is to *control the costs of the energy function or service provided, but not the Btu of energy.* As most operating people have noticed, energy is just a means of providing some service or benefit. With the possible exception of feedstocks for petrochemical production, energy is not consumed directly. It is always converted into some useful function. The existing data are not as complete as one would like, but they do indicate some surprises. In 1978, for instance, the aggregate industrial expenditure for energy was $55 billion. Of that, 35% was spent for machine drive from electric motors, 29% for feedstocks, 27% for process heat, 7% for electrolytic functions, and 2% for space conditioning and light. As shown in **Table 1-3**, this is in blunt contrast to measuring these functions in Btu. Machine drive, for example, instead of 35% of the dollars, required only 12% of the Btu.

Table 1-3. Industrial energy functions by expenditure and Btu, 1978. Source: Technical Appendix, *The Least-Cost Energy Strategy,* Carnegie-Mellon University Press, Pittsburgh, Pennsylvania, 1979, Tables 1.2.1 and 11.3.2.

Function	*Dollar Expenditure (billions)*	*Percent of Expenditure*	*Percent of Total Btu*
Machine drive	19	35	12
Feedstocks	16	29	35
Process steam	7	13	23
Direct heat	4	7	13
Indirect heat	4	7	13
Electrolytic	4	7	3
Space conditioning and lighting	1	1	1
Total	55	100	100

In most organizations, it will pay to be more specific about the function provided. For instance, evaporation, distillation, drying, and reheating are all typical of the uses of process heating. In some cases, it has also been useful to break down the heat in terms of temperature, creating opportunities to match the heat sources to the work requirements.

In addition to energy costs, it is useful to measure the depreciation, maintenance, labor, and other operating costs involved in providing the conversion equipment necessary to deliver the services required. These costs add as much as 50% to the fuel cost.

It is the total cost of these functions that must be managed and controlled, not the total Btus of energy. The large difference in cost of the various Btus of energy can make the Btu measure extremely misleading. In November 1979, the cost of 1 Btu of electricity was nine times that of 1 Btu of steam coal.

Availabilities also differ, and the cost of maintaining fuel flexibility can affect the cost of the product. And as shown before, the average annual price increase of natural gas has been almost three times that of electricity. Therefore, an energy management system that controls Btus per unit of product may completely miss the effect of the changing economics and availabilities of energy alternatives and the major differences in usability of each fuel. Controlling the total cost of energy functions is much more closely attuned to one of the principal interests of the executives of an organization—controlling costs.

Clarifications to Principle #1: *Dollars are the bottom line for businesses, which is as it should be; fuel switching alternatives are a prime example of this. However, some energy management tasks are better done with Btus. Some examples:*

- *Building efficiency metrics and certifications are usually in units of kBtu/ft^2-year; as are industry benchmarks.*
- *Energy calculations may be viable for several years after an audit, but costs change each time the utility changes rates.*
- *Some buildings use electric resistance heating. Comparing such a building to one that uses gas heating might show the Btus per ft^2 to be "normal," while comparing dollars per ft^2 might suggest something is terribly wrong.*

One of the most desirable and least reliable skills for an energy manager is to predict the future cost of energy. To the extent that energy costs escalate in price beyond the rate of general inflation, investment paybacks will be shortened, but of course the reverse is also true. ***Figure 1-4*** *shows the pattern of energy prices over time. Even the popular conception that energy prices always increase is shown to be false when normalized to constant dollars. This volatility in energy pricing may account for some business decisions that appear overly conservative in establishing the rate of return on investments.*

1.4.2 Principle #2

The ***second principle*** of energy management is to *control energy functions as a product cost, not as a part of manufacturing or general overhead.* It is surprising how many companies still lump all energy costs into one general or manufacturing overhead account without identifying those products with the highest energy function cost. In most cases, energy functions must become part of the standard cost system so that each function can be assessed as to its specific impact on product cost.

The minimum theoretical energy expenditure to produce a given product can usually be determined while establishing a standard energy cost for that product. The seconds of 25-hp motor drive operation, the minutes necessary in a 2,200°F furnace to heat a steel part for fabrication, or the minutes of 5-V electricity needed to make an electrolytic separation, for example, can be determined as theoretical minimums and compared with the actual figures. As in all production cost functions, the minimum standard is often difficult to meet, but it can serve as an indicator of the size of the opportunity.

In comparing actual values with minimum values, four possible approaches can be taken to reduce the variance, usually in this order:

1. An hourly or daily control system can be installed to keep the function cost at the desired level.
2. Fuel requirements can be switched to a cheaper and more available form.
3. A change can be made in the process methodology to reduce the need for the function.
4. New equipment can be installed to reduce the cost of the function.

The starting point for reducing costs should be in achieving the minimum cost possible with the present equipment and processes. Installing management control systems can indicate what the lowest possible energy use is in a well-controlled situation. It is only at that point that a change in process or equipment configuration should be considered. Equipment changes prior to actually minimizing the expenditure under the present system may lead to oversizing new equipment or replacing equipment for unnecessary functions.

Clarifications to Principle #2: *Equipment and processes today are highly automated. Manufacturing processes often involve robotics, direct digital controls and sophisticated software to operate and analyze data instantaneously. Energy functions are typically subject to automated control systems, many created or customized for the specific applications. This creates new opportunities and roles for energy managers. Data can be used to determine production process functions so that the minimum inputs of energy are required for system optimization. In some situations, renewable energy has become both a means of providing energy at the specific times it is needed and the ultimate low-cost energy source.*

1.4.3 Principle #3

The ***third principle*** is to *control and meter only the main energy functions*—the roughly 20% that make up 80% of the costs. As Peter Drucker pointed out some time ago, a few functions usually account for a majority of the costs. It is important to focus controls on those that represent the meaningful costs and aggregate the remaining items in a general category. Many manufacturing plants in the United States have only one meter, that leading from the gas main or electric main into the plant from the outside source. Regardless of the reasonableness of the standard cost established, the inability to measure actual consumption against that standard will render such a system useless. Submetering the main functions can provide the information not only to measure but to control costs in a short time interval. The cost of metering and submetering is usually incidental to the potential for realizing significant cost improvements in the main energy functions of a production system.

Clarifications to Principle #3: *Capturing the 80% meter is a good strategy when aiming directly at savings and tracking the results. Obviously, when comparing to a benchmark value expressed in kBtu/ft^2-year, the comparison is only valid when all energy and all ft^2 are incorporated. This can be especially challenging in campus properties with multiple buildings and a history of add-ons; the power from one building may serve two others and the steam supply may serve other, different buildings. The energy use per ft^2 metric is also important for any facility whose energy manager reports carbon emissions.*

1.4.4 Principle #4

The ***fourth principle*** is to put *the major effort of an energy management program into installing controls and achieving results.* It is common to find general knowledge about how large amounts of energy could be saved in a plant. The missing ingredient is the discipline necessary to achieve these potential savings. Each step towards saving energy needs to be monitored frequently by the manager or first-line supervisor to see noticeable changes. Logging of important fuel usage or behavioral observations are almost always necessary before any particular savings results can be realized. Therefore, it is critical that an energy director or committee have the authority from the chief executive to install controls, not just advise line management. Those energy managers who have achieved the largest cost reductions actually install systems and controls; they do not just provide good advice.

As suggested earlier, the overall potential for increasing energy productivity and reducing the cost of energy services is substantial. The 20% or so improvement in industrial energy productivity since 1972 is just the beginning. To quote the energy director of a large chemical company: "Long-term results will be much greater."

Although no one knows exactly how much we can improve productivity in practice, the American Physical Society indicated in their 1974 energy conservation study that it is theoretically possible to achieve an eightfold improvement of the 1972 energy/production ratio [9]. Most certainly, we are a long way from an economic saturation of the opportunities (see reference 10). The common argument that not much can be done after a 15 or 20% improvement has been realized ought to be dismissed as baseless. Energy productivity provides an expanding opportunity, not a last resort. The chapters in this book provide the information that is necessary to make the most of that opportunity in each organization.

Clarifications to Principle #4: *It is very common and natural for habits to be lax without accountability. "If it's free, I don't care" may be blunt, but underscores the point. The concept of 'controls' in this principle include accountability so that both energy use and are being monitored. This gives rise to:*

- *Being sure the utility use and bills are shared with operations staff.*
- *Tracking energy use and cost in all buildings.*
- *Submetering tenant use.*
- *Submetering discrete functions on a property, such as the main boiler house, kitchen or data center.*

1.4.5 Need for Creating Solutions

While the principles remained valid, energy engineers and managers began to be tasked with greater responsibilities.

Beginning in 2001, Executive Order 13123, Section 403(d), instructed federal agencies to develop sustainable design principles and apply them in planning and building new facilities [13]. This order also instructed agencies to optimize life-cycle costs, mitigate environmental impacts and reduce energy costs associated with the construction, life-cycle operation, and decommissioning of a facility. The order's chief goals are to reduce the greenhouse gas emissions associated with Federal facility energy use by 30% by 2010 in comparison to 1990 levels, to reduce energy consumption by 35% between 1985 and 2010, and to increase water conservation and the cost-effective use of renewable energy [13]. The U.S. Department of Energy's (DOE)

Federal Energy Management Program (FEMP) has supported several federal facilities working to meet these goals through a process called greening [13]. In 2011, a summary of the results was provided by Chris Tremper of FEMP, baselined to 1975. Regardless, the results for federal government energy use have been impressive. For the period 1975 to 2007, the federal government had reduced its energy use by 31%, that's 35% less energy used in the facility sector and 28% less in the mobility sector [18]. As of 2015, the federal government has decreased building energy intensity by more than 47% compared to 1975 and by 25% compared to a new 2003 baseline (see https://energy.gov/eere/femp for details).

Success has not been limited to federal governmental efforts. Commercial enterprises and corporations are incorporating energy efficiency programs in the corporate sustainability plans. Energy managers know that energy, environment and economy are linked. Beginning in about 2000, the results of their efforts were being felt throughout the country. The theoretical correlation between energy and gross national product had been decoupled. Despite increases in U.S. population, productivity and GNP, energy use was leveling off. The quantities of imported energy supplies being imported in the U.S. are declining. Natural gas now provides more energy for electricity than coal.

Energy-consuming systems account for 95% of man-made CO_2 emissions [19]. According to Kenneth Cohen, Vice President of Public Affairs for Exxon Mobile Corporation, the real issue is "how to provide the energy needed to improve global living standards while also reducing greenhouse gas emissions" [20].

When creative solutions are needed the backdrop of conflicting influences, political stalemates and economic turmoil makes long-term solutions more difficult to implement.

Mankind's misuse of carbon-based fuels has created a new climate of uncertainty. While there are both natural and man-made sources of atmospheric carbon, natural endowments that reduce atmospheric carbon levels are under attack by our activities [22]. Formed over hundreds of millions of years, carbon compounds were stored by natural processes that worked very slowly. These processes gradually reduced atmospheric concentrations by storing the carbon underground and beneath the seas. There are currently no substitutes for these natural processes that have gradually and effectively sequestered massive quantities of carbon for eons [22].

The seminal inconvenient truth is that a consensus regarding how to proceed remains elusive. Regardless, governments are creating policies, corporations are reconstructing strategic plans, and institutions are redefining their missions. Agendas are changing and new programs are being launched and implemented. There is an evolving consensus on the horizon; one that will change how we prioritize our efforts to become more sustainable. The time has come to refocus our resources toward finding solutions that not only reduce energy use, but also reduce or eliminate carbon emissions.

1.5 BREAKING THE BARRIERS TO ENERGY CONSERVATION

Quantifying costs and savings is often the missing piece between groups that want to see improvements and groups that need the numbers to make good financial choices. Energy professionals provide this essential service. Understanding the customer's business is also needed, especially when faced with business segments that resist energy improvement proposals. The customer always chooses, but sometimes a fresh perspective helps. The key is the link between energy savings and dollar savings, with the goal of demonstrating that energy is a controllable cost.

Leased building spaces represent a huge commercial business sector. Lease terms vary, but often the tenants lack interest in making capital improvements to building systems since they are not owners. Landlords may lack incentive to make efficiency improvements since they are able to pass the utility costs to the tenants. Various attempts are being made to address this barrier, with the goal of each party seeing benefit. One solution is to identify the portion of the cost and the portion of the savings that will occur during the period of the lease, allowing the tenant investment to prove itself in the short term. Key to this topic is the will of the tenant and tenants in general: if utility costs per ft^2 (or total cost of leasing) are shown to be important in consumer choices, the market will respond and find ways to accommodate.

> *Note*: To help spur this change, federal agencies have requirements for leasing private building space that include energy use that meets Energy Star levels.

Buying and selling buildings is very common. This gives rise to the term *business horizon* and the reality that a payback of five years is not viable if the building will likely change hands in three. Leaving major capital upgrades for the next owner to accomplish is predictable. Measures with medium or short payback periods can be viable to these customers due to the ways property value is determined by the buyer. If buying a business, the cost of the building and the cost to operate it are both considered. In this case, the value of the building is improved when the cost of operation is reduced, compared to a similar building with higher utility cost.

Normal replacement describes what happens when your car is so old the wheels are about to fall off: You need a new one. The same concept applies to equipment. Why should energy savings be tasked with paying for a normal replacement? If normal replacement is not considered, calculating the simple payback of replacing a 50-year-old boiler against the savings of a 90% efficient versus an 80% efficient replacement unit may yield the conclusion that it is not a good idea to replace the boiler. A more appropriate use of the economic methods is to consider the remaining life of the asset, since replacing it early has a cost of forfeiting that residual value. Thus, the energy savings is pitted against the early replacement cost and the efficiency upgrade costs. The do-nothing option considers leaving it in place until it fails and replacing it with a similar boiler. Another approach is to also compare the added incremental cost of the more efficient boiler to the increased incremental savings (see Chapter 4). Key to this measure is the educational topic for customers that equipment has a life span, and equipment replacement is a normal occurrence.

Cost allocation addresses the natural human response that if I don't see the cost, I really don't care about it. If an apartment advertises "utilities included," then the cost of those utilities is part of the rent. The perception is that there is no cost for utilities which is reflected in the behavior of the tenants who assure occupancy. In many large organizations, individual building managers do not see the utility bills. It is unsurprising that there is usually a lack of enthusiasm in responding to requests for changing habits and using energy more effectively. Everyone responds to price signals (when I'm paying for it, I care about it). Thus, apportioning utility costs to each building on campus is a necessary step for energy management, and a barrier will exist without it. Whether apportioning by unit areas, submeters, or separate utility connections, making sure each business unit sees and pays for their utility cost is very important.

Productivity is the mission of all manufacturers. Energy is the fuel for manufacturing productivity, so using less sounds like doing less. When changes are made to infrastructure (the lighting system, the building envelope, or mechanical systems), there is no better way to show the benefits than by calculating energy savings. However, when changes are made to processes, it is possible to improve productivity as well. Avoiding the cost of the next air compressor, tempering oven, uninterruptable power supply (UPS), inverter, or plating line means that if the sales are there, that plant can produce more orders. The key is to manage energy costs like any other ingredient in the final product.

Likely, the greatest barriers to energy conservation have little to do with technologies or cost. They are inertia, and the seeming ease of doing nothing. This values the perception that the way something has always been done in the past is adequate, and improvements to the status quo are unnecessary. While these types of barriers are often normal human tendencies and sometimes socially supported, they should not be overlooked. Progress rarely happens when they are enforced. When faced with these barriers, energy managers have learned to highlight the multiple benefits of their initiatives, find champions in their organizations, and work with those who believe their proposal is simply the right thing to do [24]. Energy managers have learned that all barriers can be overcome with patience and persistence.

1.6 PROFESSIONAL ASSOCIATIONS RELATED TO ENERGY

AEE continues to grow in membership and stature. The AEE promotes the scientific and educational interests of those engaged in the energy industry and fosters action for sustainable development. Today, the AEE has more than 18,000 members in more than 100 countries with a network of 96 chapters in the U.S. and abroad [23].

The certified energy manager (CEM) program, AEE's first certification program, was created in 1981 and began a very steep growth curve. Today, the AEE sponsors a number of professional education and certification programs. These include: certified business energy professional (BEP), carbon reduction manager (CRM) certified energy auditor (CEA), certified green building engineer (GBE), certified measurement and verification professional (CMVP), renewable energy professional (REP), certified sustainable development professional (CSDP), and indoor air quality (IAQP), among many others. A few of these certification programs have been recognized by the U.S. Department of Energy or the American National Standards Institute (ANSI).

As interest in energy engineering, energy management and energy solutions continue to grow, there are many national and international organizations that have evolved to satisfy the particular interests of their membership in supporting and achieving related goals. All of those listed below fulfill important niches, as energy-related professionals continue to increase their engagement. Their efforts are to be applauded and supported.

Most primary engineering associations now have an energy sub-organization or have integrated energy into their missions. Examples are:

- The Association of Energy Engineers (AEE)
- The American Institute of Architects (AIA)
- The American Society of Mechanical Engineers (ASME)
- The Association of Heating Refrigeration and Air Conditioning Engineers (ASHRAE)
- The Illumination Engineers Society of North America (IESNA)
- The Institute of Electrical and Electronic Engineers (IEEE)

Product and trade groups that include a focus on energy include:

- Air-Conditioning, Heating, and Refrigeration Institute (AHRI, formed when ARI and GAMA merged)
- American Gas Association (AGA)
- Edison Electric Institute (EEI)
- Electric Power Research Institute (EPRI)
- National Electrical Manufacturers Association (NEMA)
- North American Insulation Manufacturers Association (NAIMA)

Associations related to energy policy, energy supply, energy conservation, renewable energy and energy financing include:

- Alliance to Save Energy (ASE)
- American Council for an Energy Efficient Economy (ACEEE)
- American Council on Renewable Energy (ACORE)
- American Solar Energy Society (ASES)
- American Wind Energy Association (AWEA)
- Association of Energy Service Professionals (AESP)
- Biomass Energy Research Association (BERA)
- Building Owners and Managers Association (BOMA)
- Council of American Building Officials (CABO)
- Geothermal Heat Pump Consortium (GHPC)
- International District Energy Association (IDEA)
- International Ground Source Heat Pump Association (IGSHPA)
- National Association of State Energy Officials (NASEO)
- U.S. Combined Heat and Power Association (USCHPA)
- U.S. Green Building Council (USGBC)
- World Alliance for Decentralized Energy (WADE)

***Editor's Note**: These lists show many of the organizations that are involved in the field of energy. These lists are not intended to be complete, and our apologies to any organizations not mentioned. Some of those listed are industry trade groups, while others are professional societies that offer energy professionals membership and participation opportunities.*

1.7 CONCLUSION

Energy efficiency is characterized as providing opportunities for businesses to create multiple benefits by deploying individual solutions [24]. These benefits include energy, water and environmental improvements while yielding savings in energy and water costs. The energy management industry has become integral to the workings of a country's economy and the environment the world shares. For newcomers to energy management, emerging professionals and seasoned veterans alike, it holds exciting opportunities for the professionals that pursue energy management as their career. Through professional advancement and texts like ours, new challenges and developments will be effectively met.

1.7.1 Energy Technologies and Current Events

Books are a snapshot in time. Some energy-related topics are well established, while others see rapid change. Of the latest technology, some will become accepted and mainstream, and others will not. This presents a dilemma: to explain and promote all emerging technology and news, knowing some of it will fade, or to limit discussion to only proven and widely accepted information with a track record. Many new developments will make a marked change in how we do business and use energy. Others will fall by the wayside when tested. Like extrapolation versus interpolation, history is always accurate but predictions are risky.

This text chooses to be conservative and focus on proven principles and solutions, presuming most energy managers may not wish to test new ideas on their customers. Our authors are experts in their chosen fields and pay close attention to promising technology. Thus, you may find brief descriptions of emerging technologies or industry-shaping news. In context, we believe you will find them useful in this exciting industry. Often, we have highlighted these in a special section.

1.7.2 About the 9th Edition

A primary goal of the *Energy Management Handbook* is to provide valuable information for energy management professionals as practitioners and subject matter experts, offering references and tools they can use in their daily activities. This edition builds on the success of previous editions. Many chapters contain similar information to past editions, yet it is updated and newly edited for easier use and access. The editing style used for this edition is intentionally meant to help clarify some of the more complex subjects and offer a somewhat more relaxed read. In chapters written by the same authors who contributed to the 8th edition, the editing style is intended to achieve greater clarity of the author's intentions using less text.

Several chapters have substantial revisions and updates. Most are incorporated in the text in sections associated with the topics. Other chapters discuss similar subject matter but have been entirely rewritten and updated. Many chapters have updated references and appendices where you will find new material supporting the primary subject matter. A few of the chapters are almost entirely new (e.g., Chapters 16, 21, and 22), consider newer technologies, and reflect the evolving interests of the energy management profession.

The index has been entirely updated and includes references to all the new information in the book. Revisions in this edition include references to on-line information and calculation tools when appropriate, assuming they have demonstrated resilience. References to figures and tables are noted in bold to make it easy for the reader to locate the related text.

Our thanks to Barney Capehart, Steve Parker and the previous editors of past editions for their contributions to this chapter.

If you have ideas or suggestions as to how future editions of this book can be improved, please contact the editor.

References

1. U.S. Government Printing Office (1999). *Statistical Abstract of the United States.* Washington, D.C.
2. *Energy User News* (1980, January 14).
3. Winger, J. et al. (1972). O*utlook for Energy in the United States to* 1985. The Chase Manhattan Bank. New York. Page 52.
4. Meadows, D. et al. (1972). *The Limits to Growth.* Universe Books, New York. Pages 153-154.
5. Carter, J. (1979, July 16). Address to the Nation. *Washington Post,* page A14.
6. U.S. Department of Energy (1980, January). *Monthly Energy Review.* Washington, D.C. Page 16.
7. U.S. Department of Energy (1980, January 20). *Monthly Energy Review.* Washington, D.C., page 8; *U.S.* Government Printing Office (1979). *Statistical Abstract of the United States.* Washington, D.C. Table 1409; *Energy User News,* page 14.
8. American Association for the Advancement of Science (1978, April 14). U.S. Energy Demand: Some Low Energy Futures. S*cience,* page 143.
9. Carnahan, W. et al. (1974). American Physical Society Summer Study on Technical Aspects of Efficient Energy Utilization. *Efficient Use of Energy, a Physics Perspective,* from NTIS PB- 242-773, or in *Efficient Energy Use,* Vol. 25 of the American Institute of Physics Conference Proceedings.
10. Sant, R. (1979). *The Least-Cost Energy Strategy.* Carnegie-Mellon University Press. Pittsburgh, Pennsylvania.
11. U.S. Congress Office of Technology Assessment (1991, May). Energy Efficiency in the Federal Government: Government by Good Example? OTA-E-492, U.S. Government Printing Office, Washington D.C.
12. U.S. Air Force (1993, April). *DOD Energy Manager's Handbook* Volume 1: Installation Energy Management. Washington D.C.
13. U.S. Department of Energy (2001, May). *Greening federal facilities—an energy, environmental, and economic resource guide for federal facility managers and designers*, second edition page vii. http://www.nrel.gov/docs/fy01osti/29267.pdf, accessed June 3, 2017.
14. Doty, S. (2011). *Commercial energy auditing reference handbook*. The Fairmont Press, Inc., Lilburn, Georgia.
15. Natural Gas Supply Association. http://www.naturalgas.org/regulation/history.asp.
16. U.S. Energy Information Administration. www.eia.doe.gov.
17. U.S. Department of Energy. Industrial Technology Program, www. eere1.energy.gov.
18. Data.gov (2011, October 31). Historical federal government energy use data. https://www.data.gov/energy/blog/historical-federal-government-energy-use-data-available, accessed 3 June 2017.
19. Mega, V. (2005). *Sustainable development, energy and the city: a civilization of visions and actions*. Springer: New York. Page 60.
20. Cohen, K. (2007, September 3). Letters. *Newsweek*. Page 18.
21. Energy Information Administration (2017, April 4). Frequently asked questions. https://www.eia.gov/tools/faqs/faq.php?id=727&t=6, accessed 12 June 2017.
22. Roosa, S. and Jhaveri, A. (2009). *Carbon reduction: policies, strategies and technologies*. The Fairmont Press, Inc., Lilburn, Georgia. Page 3.
23. Association of Energy Engineers (2017). www,aeecenter.org, accessed 13 June 2017.
24. Russell, C. (2017). Discerning the multiple business benefits of energy efficiency. *Strategic Planning for Energy and the Environment*, 36(4), pages 24-40.

CHAPTER 2

EFFECTIVE ENERGY MANAGEMENT

WILLIAM H. MASHBURN, P.E., CEM
Professor Emeritus
Mechanical Engineering Department
Virginia Polytechnic Institute and State University
Blacksburg, Virginia

2.1 INTRODUCTION

Some years ago, a newspaper headline stated, "Lower energy use leaves experts pleased but puzzled." The article also stated, "Although the data are preliminary, experts are baffled that the country appears to have broken the decades-old link between economic growth and energy consumption."

For those involved in energy management, this was not surprising. We have seen organizations, companies and governments becoming more efficient in their use of energy, and it's showing in the data. Those that have extracted all possible savings from downsizing are now looking for other ways to become more competitive. Better energy management is viable, so there is an upward trend in the number of companies that are establishing an energy management program. Management is now beginning to realize they are leaving money on the table when they fail to instigate good energy management plans.

With the new technologies and alternative energy sources now available, the U.S. can reduce its energy consumption by 50%—if there were no barriers to the implementation. Of course there are barriers, mostly economic. Therefore, we might conclude that managing energy is not a just technical challenge, but one of how to best implement those technical changes within economic limits, and with a minimum of disruption.

Unlike other management fads that have come and gone, such as value analysis and quality circles, the need to manage energy will be permanent within our society.

There are several reasons for this:

- There is a direct economic return. Many opportunities found in energy surveys often have less than a two-year payback. Some are immediate, such as load shifting or changing to a new electric rate schedule.
- Most manufacturing companies are looking for a competitive edge. A reduction in energy costs to manufacture products can be immediate and permanent. In addition, products that use energy, such as motor driven machinery, are being evaluated to make them more energy efficient, and therefore more marketable. Many foreign countries, where energy is more critical, now want to know the maximum power required to operate a piece of equipment.
- Energy technology is changing so rapidly that state-of-the-art techniques have a half life of ten years at the most. Someone in the organization must be in a position to constantly evaluate and update this technology.
- Energy security is a part of energy management. Without a contingency plan for temporary shortages or outages, and a strategic plan for long range plans, organizations risk major problems without immediate solutions.
- Future price shocks will occur. When world energy markets swing wildly with only a five percent decrease in supply, as has happened repeatedly over the last 4 decades, it is reasonable to expect that such occurrences will happen again.

Those people who choose—or in many cases are drafted—to manage energy will do well to recognize this continuing need and to exert the extra effort to become skilled in this important and dynamic profession.

The purpose of this chapter is to provide the fundamentals of an energy management program that can be, and have been, adapted to organizations large and small. Developing a working organizational structure may be the most action an energy manager can take.

2.2 ENERGY MANAGEMENT PROGRAM

All the basic components of a comprehensive energy management program are depicted in **Figure 2-1**. These components are the organizational structure, a policy, and plans for audits, education, reporting and strategies. It is hoped that by understanding the fundamentals of managing energy, energy managers can then adapt good working programs to the existing organizational structures. Each component is discussed in detail below.

2.3 ORGANIZATIONAL STRUCTURE

A generic organizational chart for energy management is shown in **Figure 2-1**. It must be adapted to fit into an existing structure for each organization. For example, the presidential block may be the general manager, and vice presidential blocks may be division managers, but the fundamental principles are similar.

The main feature of the chart is the location of the energy manager. This position should be high enough in the organizational structure to have access to key players in management, and to have a knowledge of current events within the company. For example, the timing for presenting energy projects can be critical. Funding availability and other management priorities should be known and understood. The organizational level of the energy manager is also indicative of the support management is willing to give to the position.

2.3.1 Energy Manager

One very important feature of an energy management program is to have top management support. More important is the selection of the energy manager, who can, among other things, secure this support. The person selected for this position should be one with a vision of how managing energy can provide benefits for the organization. Every successful program has one thing in common—one person who is successful at making things happen. The energy management program is built around this person.

There is a great tendency for the energy manager to become an energy engineer and attempt to conduct the entire effort alone. Much has been accomplished in the past with such individuals working alone, but for the long haul, managing the program by involving everyone at the facility is much more productive and permanent. Developing a working organizational structure may be the most important thing an energy manager can do.

The role and qualifications of the energy manager have changed substantially in the past few years, affected by required certification of federal energy managers, deregulation of the electric utility industry, and performance contracting which requires both business and engineering skills. In her book titled *Performance Contracting: Expanded Horizons*, Dr. Shirley Hansen provides the following requirements for energy management professionals:

- Create and maintain an energy management plan
- Establish energy records
- Identify outside assistance
- Assess future energy needs
- Identify financing sources
- Make energy recommendations
- Implement recommendations
- Provide liaison for the energy committee

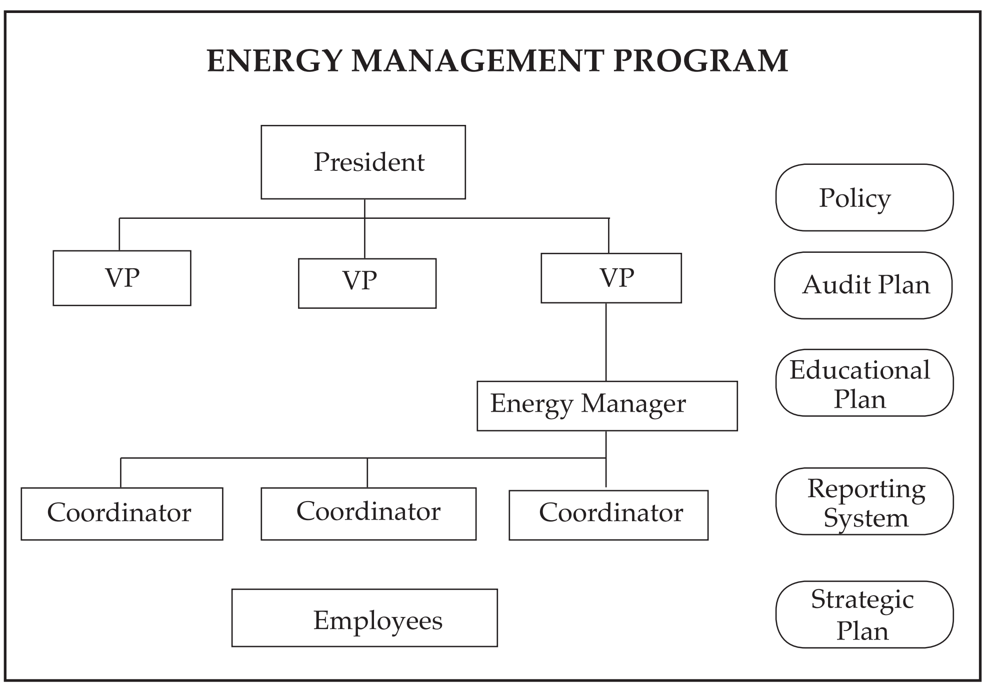

Figure 2-1. Sample organizational chart for an energy management program.

- Plan communication strategies
- Evaluate program effectiveness

Energy management programs can and have originated within divisions of large corporations. The division, by example and savings, motivates people at the corporate level to become interested in the program and make energy management corporatewide. Many programs also originate at the corporate level with people who have facilities management responsibility and have implemented corporate facilities programs. They then see the importance and potential of an energy management program and take a leadership role in implementing one. In every case observed by the author, good programs have been instigated by one individual who has recognized the potential, is willing to put forth the effort (in addition to regular duties), will assume the risk of advocating new concepts, and is motivated by a seemingly higher calling to save energy.

If initiated at corporate level, there are advantages and precautions. Some of the advantages are:

- More resources are available to implement the program, such as budget, staff and facilities.

- If top management support is secured at the corporate level, obtaining management support at division level is easier.

- Personnel expertise throughout the corporation is better known, identifiable and available to division energy managers.

- Expensive test equipment can be purchased and maintained at corporate level for use by divisions as needed.

- A unified reporting system can be initiated.

- Creative financing may be the most needed and the most important assistance to be provided from corporate level.

- Impacts of energy and environmental legislation can best be evaluated at the corporate level.

- Electrical utility rates and structures, and effects of unbundling of electric utilities, can be evaluated at corporate level.

Some precautions include:

- Many people at the division level may have already done a good job of saving energy and may be cautious about corporate level staff taking credit for their work.

- Not all divisions progress at the same speed. Work with those who are most interested first, then use the organization's reporting system to top management to see that they are credited for their successes. Others will then request assistance.

2.3.2 Energy Team

The coordinators shown in **Figure 2-1** represent the energy management team within one given organizational structure, such as one company within a corporation. This group is the core of the program. The main criteria for membership should be an indication of interest. The best teams include a representative from the administrative group, such as accounting or purchasing, someone from facilities or maintenance, and representatives from major departments.

This energy team of coordinators should be appointed for a specific time period, such as one year. Rotating the coordinators brings new participants with new ideas, providing a mechanism for tactfully removing non-performers, and involving greater numbers of people in the program in meaningful ways.

Coordinators should be selected to supplement skills the energy manager lacks, since it is unrealistic to believe that one energy manager can have all the qualifications needed. Total skills for the team, including the energy manager, might be defined as follows:

- Have adequate technical knowledge within the group to either understand the technology used by the organization or be trainable in that technology.

- Have a knowledge of potentially new technologies that may be applicable to the program.

- Have planning skills that will help establish the organizational structure, plan energy surveys, determine educational needs, and develop a strategic energy management plan.

- Understand the economic evaluation system used by the organization, particularly payback and life cycle cost analysis.

- Have good communication and motivational skills since energy management involves everyone within the organization.

The strengths of each team member should be evaluated in light of the above desired skills.

2.3.3 Employees

Employees are part of the organizational structure, and are perhaps the greatest untapped resource in an energy management program. A structured method of soliciting their ideas for more efficient use of energy will likely prove to be the most productive effort of the energy management program. A good energy manager will devote about 20% of total time working with employees. Too often employee involvement is limited to posters that say "Save Energy." When this is the case, greater employee involvement is needed.

Employees who operate equipment in manufacturing plants generally know more about the equipment than anyone else in the facility. They know how to make it more efficient. When there is no mechanism in place for them to provide input, their ideas will not lead to process improvements. Involving these employees improves energy management programs.

An understanding of the psychology of motivation is necessary before an employee involvement program can be successfully conducted. Motivation may be defined as the amount of physical and mental energy that workers are willing to invest in their jobs. Three key factors of motivation are listed below:

- Motivation is already within people. The task of the supervisor is not to provide motivation, but to know how to release it.

- The amount of energy and enthusiasm people are willing to invest in their work varies with the individual. Not all are over-achievers, but not all are disinterested either.

- The amount of personal satisfaction to be derived determines the amount of energy an employee will invest in the job.

Achieving personal satisfaction has been the subject of research by industrial psychologists, and revealing facts have emerged. For example, they have learned that most actions taken by people occur to satisfy physical needs, such as the need for food, or emotional needs, such as the need for acceptance, recognition or achievement.

Research has also shown that many efforts to motivate employees deal almost exclusively with trying to satisfy physical needs, such as raises, bonuses or fringe benefits. These methods are effective only for the short term, so we must look beyond these to other needs that may also be motivational.

A study by Heresy and Blanchard in 1977 asked workers to rank job related factors listed below [1]. The results were as follows:

1. Full appreciation for work done
2. Feeling "in" on things
3. Understanding of personal problems
4. Job security
5. Good wages
6. Interesting work
7. Promoting and growth in the company
8. Management loyalty to workers
9. Good working conditions
10. Tactful discipline of workers

This priority list understandably changes with time and individual companies, yet the rankings of what supervisors believed employees wanted were almost diametrically opposed. Supervisors ranked good wages as the first priority.

It becomes obvious that job enrichment is a key to motivation. Knowing this, energy managers can plan programs with greater employee involvement and provide job enrichment with simple and inexpensive recognitions.

Things to consider in employee motivation are:

- There appears to be a positive relationship between fear arousal and persuasion, if the fear appeals deal with topics primarily of significance to the individual (e.g., personal well being).

- The success of persuasive communication is directly related to the credibility of the source of communication, and it may be reduced if recommended changes deviate too far from existing beliefs and practices.

- When directing attention to energy conservation, display the reminder at the point of action at the appropriate time for action, and specify who is responsible for taking the action and when it should occur. Generic posters located in work areas are ineffective.

- Conservation is a conservative form of behavior. Studies have shown that pro-conservation attitudes and actions will be enhanced through associations with others with similar attitudes, such as being part of an energy committee.

- Positive effects are achieved with financial incentives, if the reward is in proportion to the savings and represents respectable increments of spendable income.

- Consumers place considerable importance on the potential of personal discomfort in reducing their consumption of energy. Changing thermostat settings from the comfort zone in occupied areas is not an effective energy management technique.

- Social recognition and approval is important. It can occur by awarding certificates or medals, designating employee(s) of the month, or selecting employees for membership in elite sub-groups. The cost of such recognitions is minimal.

- The potentially most powerful source of social incentives for conservation behavior—but the least used—is the commitment to others that occurs in the course of group decisions.

Before entering into a program involving employees, be prepared to provide a large commitment of time and resources. In particular, have resources available to respond quickly to their suggestions.

2.4 ENERGY POLICY

A well-written energy policy that has been authorized by management is important for program development and implementation. It provides energy managers with the authority to be involved in business planning, new facility location and planning, selection of production equipment, purchase of measuring equipment, energy reporting, and training—activities that are sometimes difficult to accomplish.

If you already have an established energy policy, it is likely too lengthy and cumbersome. To be effective, the policy should be short—a few pages at most. Many people confuse the energy policy statements with a procedures manual. It should be concise yet contain the following items:

- Objectives—This can contain standard statements about energy, but most importantly the organization must incorporate energy efficiency into *all* facilities and new equipment, with emphasis on life cycle cost analysis rather than lowest initial cost.

- Accountability—This should establish the organizational structure and the authority for the energy manager, coordinators, and any committees or task groups.

- Reporting—Without authority from top management, it is often difficult for an energy manager to require others within the organization to comply with reporting requirements necessary to properly manage energy. The policy is the place to establish this. It also provides legitimate reasons for requesting funds for instrumentation to measure energy usage.

- Training—If training requirements are established in the policy, it is easier to include funding in departmental budgets. It should include training at all levels within the organization.

Many companies, rather than adopting a comprehensive policy encompassing all the features described above, choose to develop a simpler policy statement.

Appendices A and B provide two sample energy policies. Appendix A is generic and covers the items discussed above. Appendix B is a policy statement of a multinational corporation.

2.5 PLANNING

Planning is one of the most important parts of the energy management program. There are two major functions in the program. First, a good plan can be a shield from disruptions. Second, by scheduling events throughout the year, continuous emphasis can be applied to the energy management program. This keeps the program active.

Almost everyone from top management to the custodians will be happy to offer opinions on what can be done to save energy. Many suggestions are worthless. It is not always wise from a job security standpoint to say this to top management. However, if you inform people—especially top management—that you will evaluate their suggestions, and then assign them priorities in your plan, not only will you not be disrupted, but you may also be considered effective because you have a plan.

Many programs were started when the fear of energy shortages was greater but have since been abandoned. By planning to have events periodically throughout the year, a continued emphasis will be placed on energy management. Such events might include training programs, workshops, audits, planning sessions, demonstrations, research projects and presentations.

The secret to a workable plan is to have people who are required to implement the plan involved in the planning process. People feel a commitment to making things work if they participated in the design. This is fundamental to any management planning, but is often overlooked. However, in order to prevent the most outspoken members of a committee from dominating with their ideas and rejecting ideas from less outspoken members, a technique for managing committees must be used. A favorite of the author is the nominal group technique developed at the University of Wisconsin in the late 1980s by Andre Delbecq and Andrea Van de Ven [2]. This technique consists of the following basic steps:

1. Problem definition—The problem is clearly defined to members of the group.
2. Grouping—Divide large groups into smaller groups of seven to ten, then have each group elect a recording secretary.
3. Silent generation of ideas—Each person silently and independently writes as many answers to the problem as can be generated within a specified time.
4. Round-robin listing—the secretary lists each idea individually on an easel until all have been recorded.
5. Discussion—Ideas are discussed for clarification, elaboration, evaluation and combining.
6. Ranking—Each person ranks the five most important items. The largest total number of points received for each idea determines the group's first choice.

2.6 ENERGY AUDIT PLANNING

The details of conducting energy audits are discussed comprehensively in Chapter 4, yet planning should be conducted prior to the actual audits. The planning should include types of audits to be performed, team makeup and dates.

By making the energy audits specific rather than general in nature, much more energy can be saved. Examples of some types of audits that might be considered are:

- Tuning-Operation-Maintenance (TOM)
- Compressed air
- Motors
- Lighting
- Steam system
- Water
- Controls
- HVAC
- Employee suggestions

By defining individual energy audits in this manner, it is easy to identify the proper team for the audit. Be sure to invite outside people such as electric utility and natural gas representatives to be team members. Scheduling the audits contributes to the events that will keep the program active.

With the maturing of performance contracting, energy managers have two choices for the energy audit process. They may go through the contracting process to select and define the work of a performance contractor, or they can use their own team to conduct energy audits. In some cases, a corporate energy manager might suggest using a performance contractor for some facilities and performing energy audits for others. Each approach has advantages and disadvantages.

Advantages of performance contracting are:

- No investment is required of the company, other than that involved in the contracting process, which can be very time consuming.
- A minimum of in-house people are involved, namely the energy manager and financial people.

Disadvantages are:

- Technical resources are generally limited to the contracting organization.
- Many firms underestimate the work required.
- The contractor may not have the full spectrum of skills needed.
- The contractor may not have an interest in low/cost no/cost projects.
- High project markups are likely.

Advantages of setting up an audit team are:

- The team can be selected to match the equipment to be audited, and it can include in-house personnel, outside specialists, or best, a combination of both.
- The team can identify all potential energy conservation projects, both low-cost/no-cost and large capital investments.
- The energy audit can be an excellent training tool by involving others in the process, and by including training components as a part of the audit.

Disadvantages of an audit team approach:

- Financing identified projects becomes a separate issue for the energy manager.

- A well-organized energy management structure is needed to take full advantage of the work of the energy audit team.

2.7 EDUCATIONAL PLANNING

A major part of the energy manager's job is to provide energy education for persons within the organization. Despite the fact that we have been concerned with it since the 1970s, there is still ignorance concerning energy.

Raising the energy education level throughout the organization can provide big dividends. The energy program will operate much more effectively if management understands the complexities of energy—and particularly the potential for economic benefit. The coordinators will be more effective if they prioritize energy conservation measures and are aware of the latest technologies. The quality and quantity of employee suggestions improves with training.

Educational training should be considered for three distinct groups—management, the energy team and employees.

2.7.1 Management Training

It is often difficult to obtain much of management's time; more subtle ways must be developed to inform them of the program and its benefits. Holding a periodically scheduled meeting to provide updates on the program is one method. When the program gains momentum, it may be advantageous to have a half- or one-day presentation for management.

A good, concise report periodically can be a tool to educate management. Short articles that are pertinent to your educational goals, taken from magazines and newspapers, can be attached to reports and distributed selectively. Having management be a part of a training program for either the energy team or employees, or both, can provide an educational experience because we learn best when we make presentations.

Ultimately, the energy manager should aspire to be a business planner for the organization. A strategic plan for energy should be a part of every business plan. This places the energy manager in a position with more contact with management people and thus offers the opportunity to inform and teach.

2.7.2 Energy Team Training

Since the energy team is the core group of the energy management program, proper and thorough training for them should have the highest priority. Training is available from many sources and in many forms.

- Self study—This necessitates having a good library of energy related materials from which coordinators can select.

- In-house training—This may be done by a qualified member of the team, usually the energy manager, or someone from outside the organization.

- Short courses—These are offered by associations such as the Association of Energy Engineers [3], by individual consultants, by corporations, and by colleges and universities.

- Comprehensive courses—Such courses of one to four weeks in duration are offered by universities, including Virginia Technical Institute and North Carolina State University among others.

For large decentralized organizations, an annual two- or three-day seminar can provide the basis for the educational program for energy managers. Such programs should be planned carefully. The following suggestions should be incorporated into these programs:

- Select quality speakers from both inside and outside the organization.

- This is an opportunity to obtain top management support. Invite top level executives from within the organization to give opening remarks or make presentations. It may be wise to offer to write the remarks, or at least to provide some material for inclusion.

- Involve the participants in workshop activities so they have opportunities to offer input into the program. Also, provide some practical tips on energy savings that they might implement immediately. One or two good ideas can sometimes pay for their time in the seminar.

- Make the seminar a first class educational event with professional speakers. Consider a banquet with an entertaining—not technical—after dinner speaker and a manual that includes a schedule of events, biosketches of speakers, list of attendees, information on each topic presented, and other relevant information that will help make the seminar successful. Enlist vendors to contribute door prizes.

- You may wish to develop a logo for the program and include it on small favors such as cups, carrying cases, etc.

2.7.3 Employee Training

A systematic approach for involving employees should start with some basic training in energy. This will produce much higher quality ideas from them. Employees place a high value on training, so a benefit is that employee morale increases. Simply teaching the difference between electrical demand and kilowatt hours of energy, and that compressed air is very expensive, is a start. Short training sessions on energy can be incorporated into other ongoing employee training programs. A comprehensive training program might include:

- Energy conservation in the home
- How to eveluate your utility bills
- Fundamentals of electric energy
- Fundamentals of energy systems
- How energy surveys are conducted and what to look for
- Low or no cost energy solutions

2.8 STRATEGIC PLANNING

Developing objectives, strategies, programs, and action items constitutes strategic planning for the energy management program. It is the last but perhaps most important step in the process of developing the program, and unfortunately it is where many stop. The term strategic planning has an ominous sound to those who are more technically inclined. However, by using a simplified approach and involving the energy management team in the process, a plan can be developed using a flow chart that will define the program for the next five years.

If the team is involved in developing each of the components of objectives, strategies, programs, and action items, using the nominal group technique, the result will be a simplified flow chart that can be used for many purposes. First, it is a protective plan that discourages intrusion into the program, once it is approved and established. It provides the basis for resources such as funding and personnel for implementation. It projects strategic planning into overall planning by the organization, and legitimizes the program at top levels of management. By involving the implementers in the planning process, there is a strong commitment to make the program successful.

Appendix C contains flowcharts depicting a strategic plan developed in a workshop conducted by the author for a large defense organization. It is a model plan that considers not only the technical aspects of energy management, but also funding, communications, education and behavior modification.

2.9 REPORTING

There is no generic form that can be used for reporting purposes. There are too many variables, such as the organization's size, types of products, project requirements, and procedures already in place. The ultimate reporting system is one used by a chemical company making a textile product. The Btu/lb. of product is calculated using a computer system that yields instantaneous readings. This is not only a reporting system, but one that detects maintenance problems. Very few companies have these capabilities, but many have some type of energy index for monthly reporting.

When energy prices fluctuate wildly, the best energy index is usually based on units of energy. When energy prices are stable, the best index is dollars. There are many factors that will influence any index, such as weather, production, expansion or contraction of facilities and new technologies.

To be effective, energy reporting systems must be customized to suit the organization's individual circumstances. While reporting may not be the most glamorous part of managing energy, it contributes by providing an accounting of the program's costs and energy effectiveness. It is also a management tool for promoting the program.

The report is probably of greatest value to those who prepare it. It provides a forcing function that requires all information to be identified and compiled in a coherent manner. This requires thought and analysis that might not otherwise take place.

By making reporting a requirement of the energy policy, obtaining the necessary support to implement and continue the program can be easier, since the benefits and costs of the program are presented. In many cases, energy and cost data may already have been collected on a periodic basis and compiled. It may simply require combining production data and energy data to develop an energy index.

Keep the reporting requirements as simple as possible. Monthly reports could be as simple as adding to an ongoing graph that compares present usage to some baseline year. Narratives should be concise, with data kept in a file that can be provided for any supporting in-depth information. Annual reports might be as simple as tabulating the monthly reports.

The best way to report is to compare data against an energy audit that has been performed at the facility. One large corporation has its facilities report prepared in this manner and then has an award for those that complete all energy conservation measures listed on the audit.

2.10 OWNERSHIP

The key to a successful energy management program is ownership which extends to everyone within the organization. Employees who operate a machine own that machine. Attempts to modify their equipment without their participation will not succeed. They have the knowledge to make or break the attempt. Members of the energy team are not going to like seeing one person—the energy manger—get all the fame and glory for their efforts. Management people who invest in energy projects want to share in the recognition for their risk taking. A corporate energy team that performs a division's energy audit must help place a person from the division in the energy management position, then make sure the audit belongs to the division. Below are ideas that have been compiled from observing successful energy management programs.

- Have a plan. A plan dealing with organization, surveys, training, and strategic planning—with scheduled events—has two advantages. It prevents disruptions by non-productive ideas, and helps keep the program active.

- Share ideas for saving energy and reducing costs. One way to kill a project is to be possessive. If others have a vested interest they will help make it successful.

- Be aggressive. The energy team will be the most energy knowledgeable group within the organization. Too many management decisions are made with a meager knowledge of the effects on energy use.

- Use proven technology. Many programs get bogged down trying to make a new technology work and lose sight of the easy projects with good paybacks. Don't buy serial number one. In spite of price breaks and promises of vendor support, it can be too consuming to make a new system work.

- Go with the winners. Not every department within a company will be enthused about your energy program. Find those who will be champions of your cause. Make them look good to top management, support their efforts, and all will follow.

- If you are in a production facility, ask the machine operators what is needed to reduce energy. Then make sure they are properly recognized for their ideas.

2.11 SUMMARY

Let's summarize by assuming you have just been appointed energy manager of a fairly large company. What are the steps you might consider in setting up an energy management program? Here is a quick start guide with suggested procedures.

2.11.1 Situation Analysis

Determine what has been done before. Was there a previous attempt to establish an energy management program? What were the results of these efforts? Next, plot the energy usage for all fuels for the past two or more years. Then estimate the future usages and costs for the next five years, at the present rates of change. This will help you sell your program and identify areas of concentration for reducing energy usage.

2.11.2 Policy

Develop some type of acceptable policy that gives authority to the program. This will help in the future with reporting requirements and the need for measurement and verification instrumentation.

2.11.3 Organization

Establish an energy committee with energy coordinators.

2.11.4 Training

With the committee's involvement, develop a training plan for the first year.

2.11.5 Energy Audits

With the committee's involvement, develop an energy auditing plan for the first year.

2.11.6 Reporting

Develop an energy reporting system and provide periodic reports.

2.11.7 Schedule

Using the above information, develop a schedule of events for the following year, timing the events to enable periodic energy program actions, which will help keep the program active and visible.

2.11.8 Implement the program

2.12 CONCLUSION

Energy management has matured to the point that it offers outstanding opportunities for those willing to invest time and effort to learn its fundamentals. It requires technical and management skills that broadens educational needs for both technical and management people desiring to enter this field. Because of the economic return of energy management, it is attractive to top management. Exposure of the energy manager to top management provides opportunities for recognition and advancement. Managing energy will be a continuously needed skill in the future, so persons with energy management skills will have personal job security and fulfilling careers.

References

1. Hersey, P. and Kenneth H. Blanchard, 1970. *Management of Organizational Behavior: Utilizing Human Resources*, Harper and Row.
2. Delbecq, A., Van de Ven, A., and Gustafson, D. (1986). *Group Techniques for Program Planning*, Green Briar Press.
3. Mashburn, W. (1992). *Managing Energy Resources in Times of Dynamic Change*, The Fairmont Press, Inc.
4. Turner, W. (1993). *Energy Management Handbook*, 2nd edition, Chapter 2, The Fairmont Press, Inc.

Appendix A

ENERGY POLICY

Acme Manufacturing Company

Policy and Procedures Manual

Subject: Energy Management Program

I. Policy

Energy management shall be practiced in all areas of the company's operation.

II. Energy Management Program Objectives

It is the company's objective to use energy efficiently and to provide energy security for the organization, both in the immediate and long range, by:

- Utilizing energy efficiently throughout the company's operations.
- Incorporating energy efficiency into existing equipment and facilities, as well as in the selection and purchase of new equipment.
- Complying with federal, state and local government regulations.
- Establishing an energy management program to accomplish the above objectives.

III. Implementation

A. Organization

The company's energy management program shall be administered through the facilities department.

1. *Energy Manager*

The energy manager shall report directly to the vice president of facilities and shall have overall responsibility for implementing the energy management program.

2. *Energy Committee*

The energy manager may appoint an energy committee, to be comprised of representatives from various departments. Members will serve for a specified period of time. The purpose of the energy committee is to advise the energy manager on the operation of the energy management program and to provide assistance on specific tasks when needed.

3. *Energy Coordinators*

Energy coordinators shall be appointed to represent a specific department or division. The energy manager shall establish minimum qualification standards for coordinators and shall have joint approval authority for each coordinator appointed.

Energy coordinators shall be responsible for maintaining an ongoing awareness of energy consumption and expenditures in their assigned areas. They shall recommend and implement energy conservation projects and energy management practices.

Energy coordinators shall provide necessary information for reporting from their specific areas of authority.

They may be assigned on a full-time or part-time basis, as required to implement programs in their areas.

B. Reporting

The energy coordinator shall advise the energy office of all efforts to increase energy efficiency in their areas of authority. A summary of energy cost savings shall be submitted quarterly to the energy office.

The energy manager shall be responsible for consolidating these reports to submit to top management.

C. Training

The energy manager shall provide energy training at all levels of the company.

IV. Policy Updating

The energy manager and the energy advisory committee shall review this policy annually and make recommendations for updating or changes.

Appendix B

POLICY STATEMENT

Acme International Corporation is committed to the efficient, cost effective, and environmentally responsible use of energy throughout its worldwide operations. Acme will promote energy efficiency by implementing cost-effective programs that will maintain or improve the quality of the work environment, optimize service reliability, increase productivity, and enhance the safety of our workplace.

Appendix C

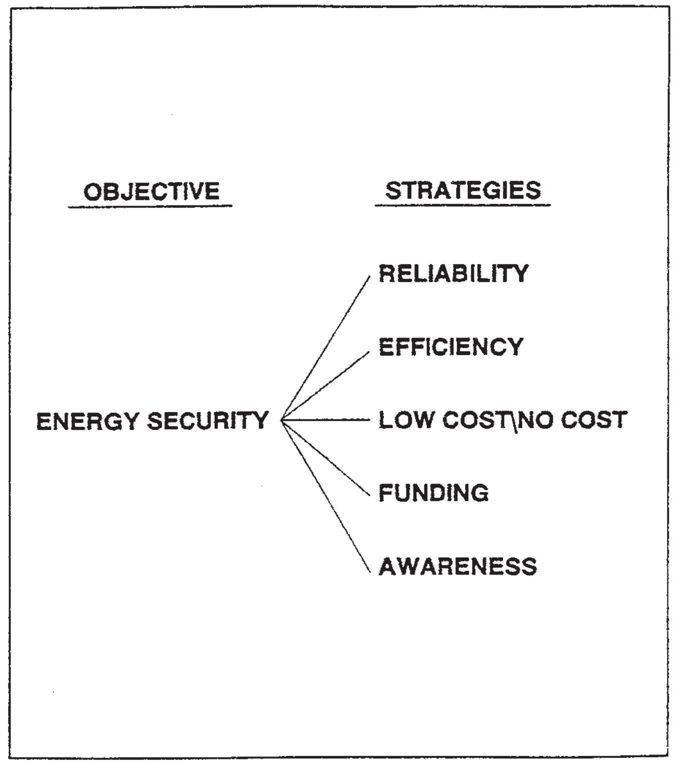

Figure 2-2. Strategies supporting the objective of energy security.

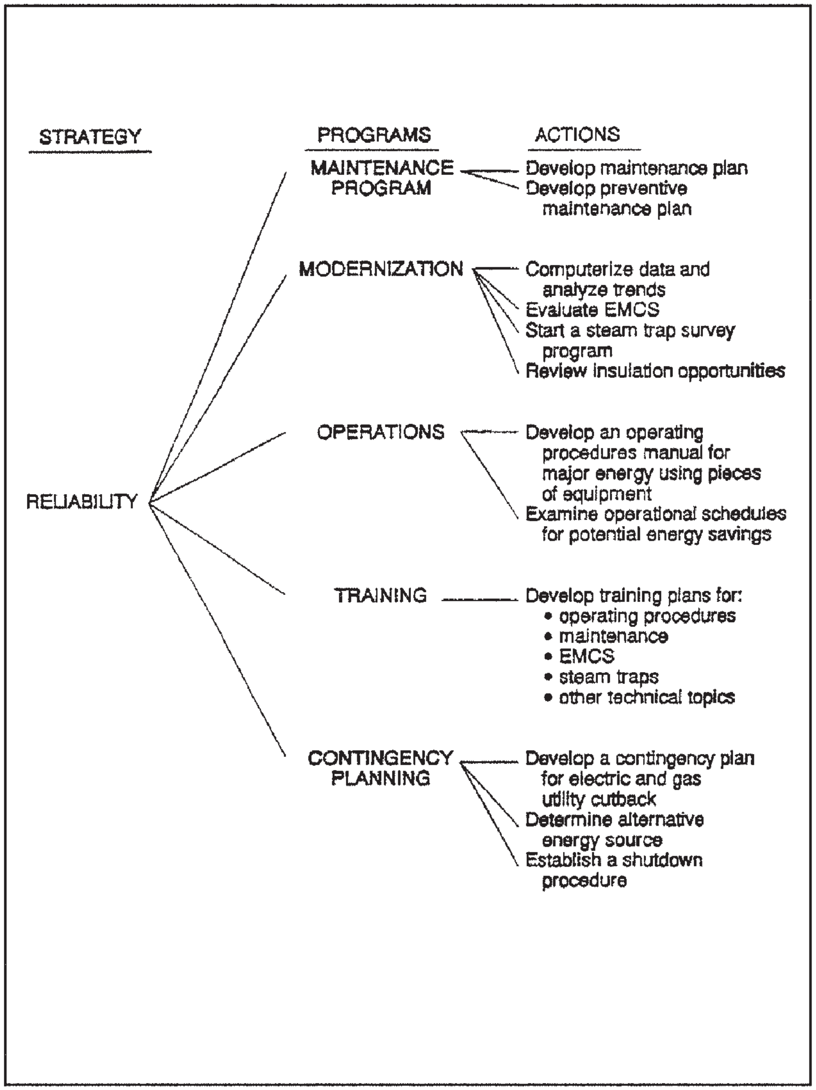

Figure 2-3. Programs that support reliability.

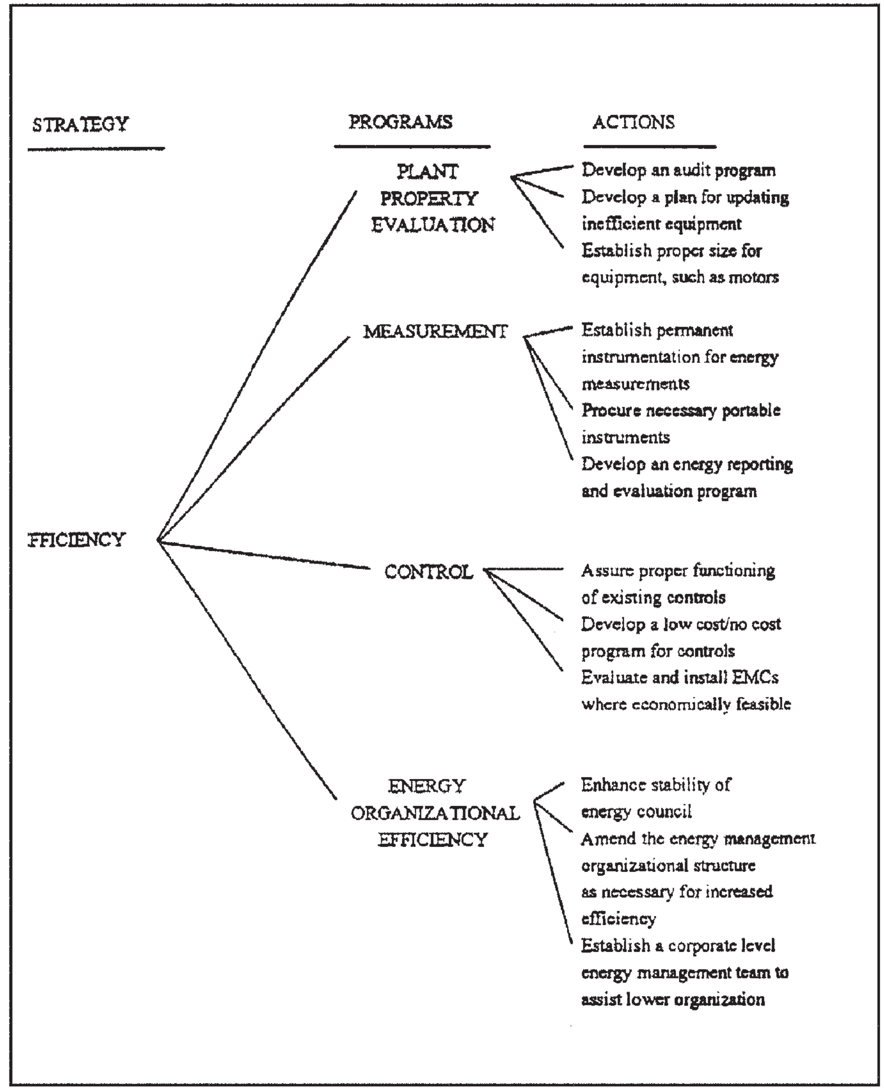

Figure 2-4. Programs that support efficiency.

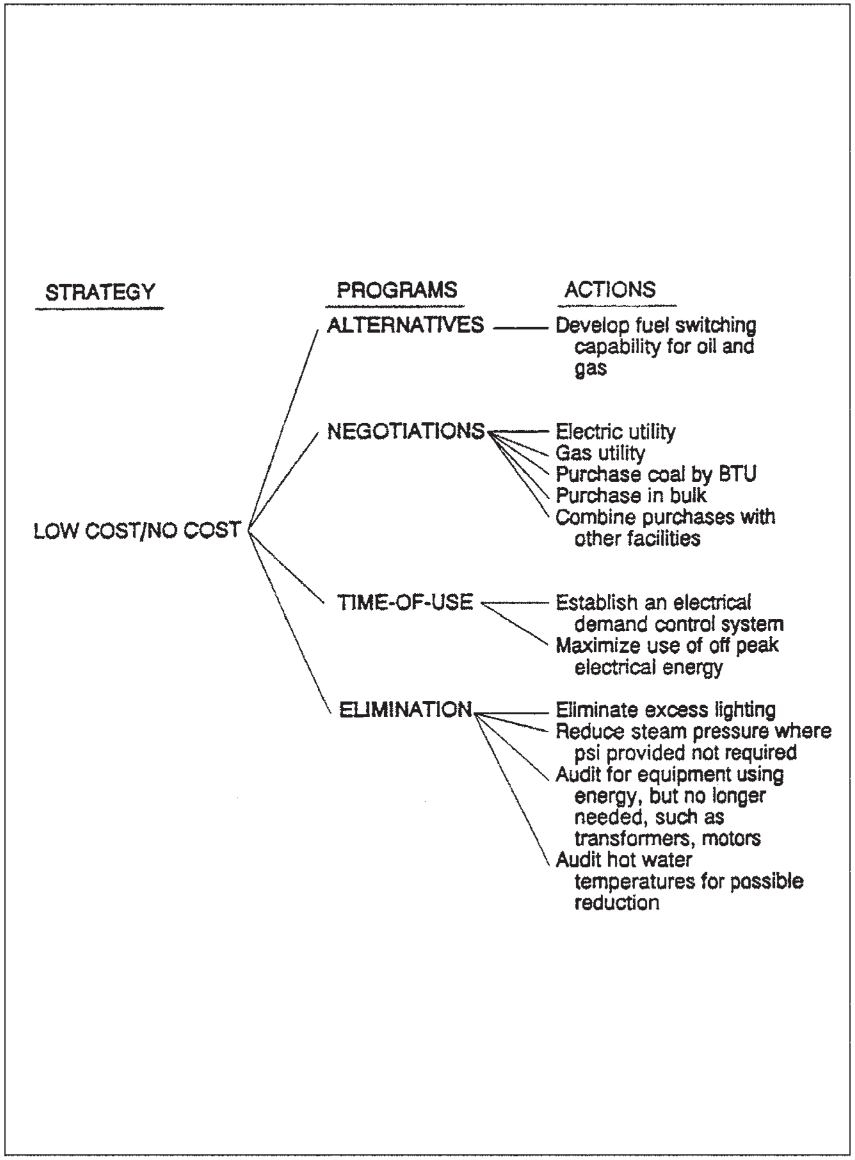

Figure 2-5. Programs that support low cost/no cost strategies.

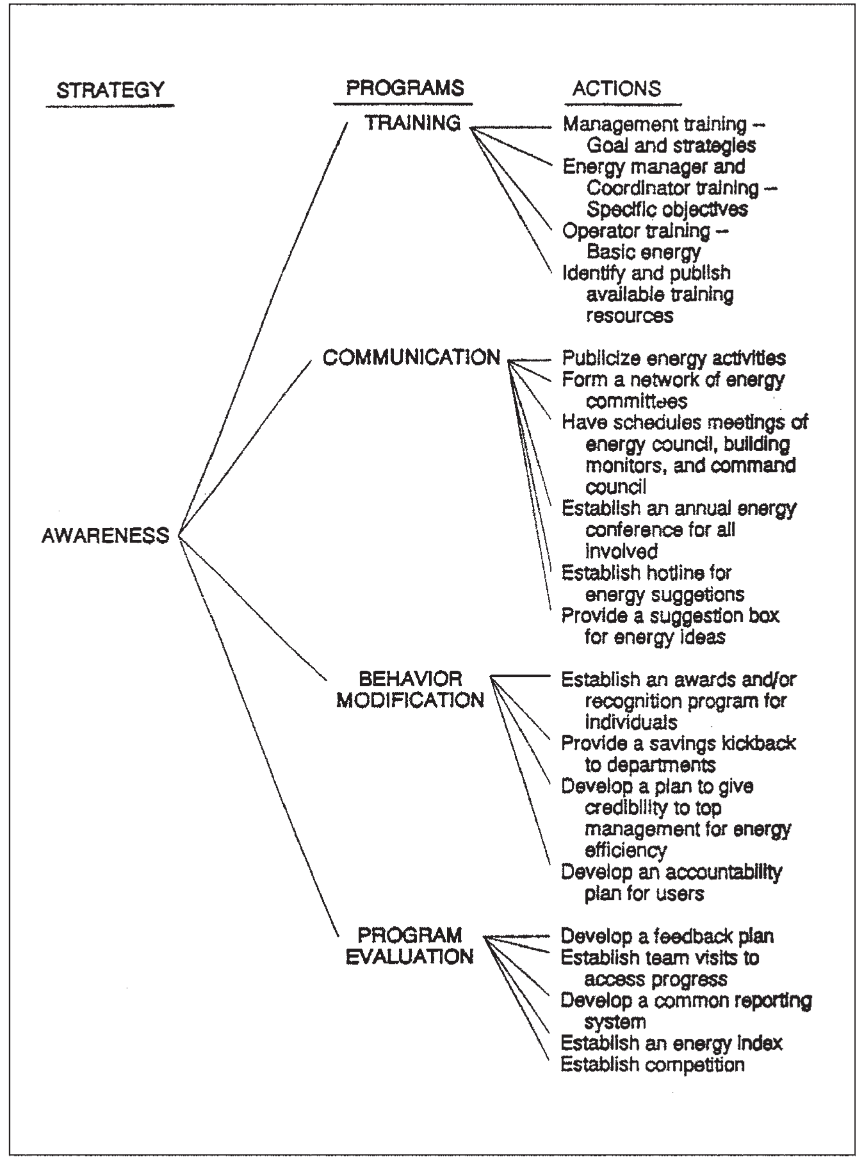

Figure 2-6. Programs that support awareness.

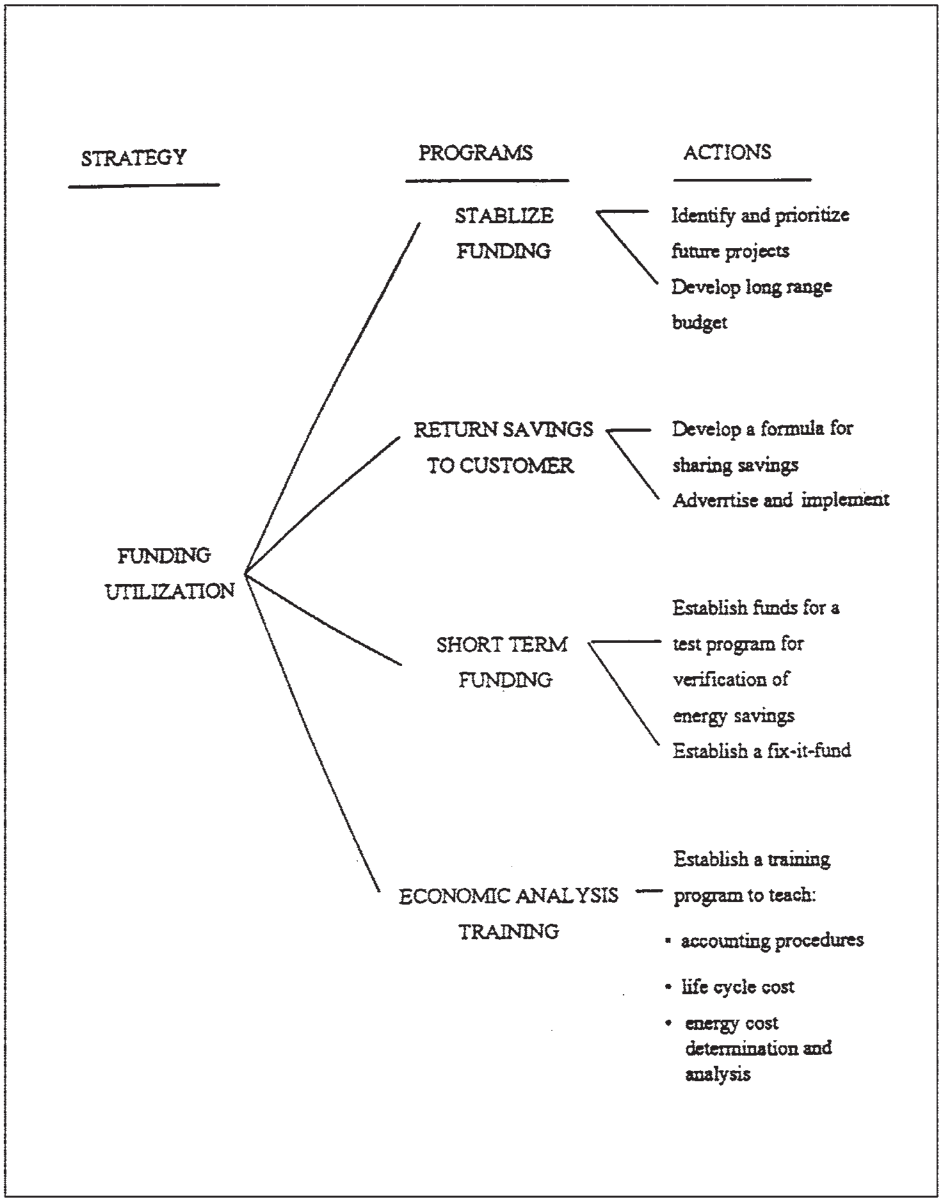

Figure 2-7. Programs that support funding utilization.

Chapter 3
Energy Auditing

BARNEY L. CAPEHART Professor Emeritus
University of Florida
Gainesville, Florida

MARK B. SPILLER
Spiller Consulting
Gainesville, Florida

SCOTT FRAZIER
Oklahoma State University
Stillwater, Oklahoma

3.1 INTRODUCTION

Saving money on energy is attractive to businesses, industries and individuals. Customers whose energy bills are a large part of their total income, and especially those businesses whose energy bills represent a substantial fraction of their company's operating costs, have strong motivations to initiate and continue an on-going energy cost-control program. No-cost or very low-cost operational changes can often save a customer or an industry 10% to 20% of their utility bills; capital cost programs with payback periods of two years or less can often save an additional 20% to 30%. In many cases, energy cost control programs result in both reduced energy consumption and reduced emissions of environmental pollutants.

Energy audits are one of the first tasks to be performed in the accomplishment of an effective energy cost control program. Energy audits are detailed examinations of how facilities use energy, what the facilities pay for that energy, plus a recommended program for changes in operating practices or energy-consuming equipment that will cost-effectively save dollars on energy bills. The energy audits are sometimes called energy surveys, or energy assessments, so that they are not identified with the negative connotations of an Internal Revenue Services (IRS) audit. The energy audit is intended to be a positive experience with significant benefits to the individual or business, and the term audit should be avoided if it clearly produces a negative image.

3.2 ENERGY AUDITING SERVICES

Energy audits are performed by several different groups. Electric and gas utilities throughout the country offer free residential energy audits. A utility's residential energy auditors analyze the monthly bills, inspect the construction of the dwelling unit, and inspect all of the energy-consuming appliances in an apartment or house. Ceiling and wall insulation is measured, ducts are inspected, appliances such as heaters, air conditioners, water heaters, refrigerators, and freezers are examined, and the lighting system is checked.

Many utilities perform audits for their industrial and commercial customers. They often have professional engineers on their staffs who perform the detailed audits needed by companies with complex process equipment and operations. When utilities offer free or low-cost energy audits for commercial customers, they usually only provide walk-through audits rather than detailed audits. Even so, they generally consider lighting, heating, ventilating and air conditioning (HVAC) equipment, water heating, insulation and electric motors.

Large commercial or industrial customers may hire an engineering consulting firm to perform a complete energy audit. Other companies may elect to hire an energy manager or establish an internal energy management team whose job is to conduct periodic audits and to stay abreast of currently available energy efficiency technologies.

The U.S. Department of Energy (U.S. DOE) funds a program for universities in the U.S. enabling them to operate industrial assessment centers (IACs) and to perform free energy audits for small and medium sized manufacturing companies. There are currently 26 IACs funded by the industrial division of the U.S. DOE.

State energy programs provide energy audit services funded by the U.S. Department of Energy. They are usually administered by state energy offices. This program pays for energy audits for schools, hospitals, and other institutions, and it has some funding assistance for energy conservation improvements.

3.3 COMPONENTS OF AN ENERGY AUDIT

An initial summary of the basic steps involved in conducting a successful energy audit is provided here, and these steps are explained more fully in the sections that follow. This audit description primarily addresses the steps in an industrial or large-scale commercial audit; not all of the procedures described in this section are required for every type of audit.

The energy audit process starts by collecting information about a facility's operation and past record of utility consumption and costs. These data are then analyzed to determine how the facility uses—and possibly wastes—energy, and to help the auditor learn what areas to examine to reduce energy costs. Specific changes—called energy conservation opportunities (ECOs)—are identified and evaluated to determine their benefits and their cost-effectiveness. These ECOs are assessed in terms of their costs and benefits, and an economic comparison is made to rank the various ECOs. Finally, an action plan is created where certain ECOs are selected for implementation, and the actual process of saving energy and saving money begins.

3.3.1 The Energy Auditor's Toolbox

To obtain the best information for a successful energy cost control program, the energy auditor must take some measurements during the audit visit. The amount of equipment needed depends on the type of energy-consuming equipment used at the facility and on the range of potential ECOs that might be considered. For example, if waste heat recovery is being considered, then the auditor must take substantial temperature measurement data from potential heat sources. Tools commonly needed for energy audits are listed below:

Tape Measures

The most basic measuring device needed is the tape measure. A 25-foot tape measure (1" wide) and a 100-foot tape measure are used to check the dimensions of walls, ceilings, windows, and distances between pieces of equipment for purposes such as determining the length of a pipe for transferring waste heat from one piece of equipment to the other. Infrared dimensioning devices are also available to measure larger distances.

Lightmeter

One simple and useful instrument is the light meter, which is used to measure illumination levels in facilities. A light meter that reads in footcandles allows direct analysis of lighting systems and comparison with recommended light levels specified by the Illuminating Engineering Society (IES). A digital light meter that is portable and can be hand carried is the most useful. Many areas in buildings and plants are still significantly over-lighted, and measuring this excess illumination then allows the auditor to recommend a reduction in lighting levels through lamp removal programs, or by replacing inefficient lamps with high efficiency lamps that may not supply the same amount of illumination as the old inefficient lamps.

Thermometers

Several thermometers are generally needed to measure temperatures in offices and other work areas, and to measure the temperature of operating equipment. Knowing process temperatures allows the auditor to determine process equipment efficiencies and to also identify waste heat sources for potential heat recovery programs. Inexpensive electronic thermometers with interchangeable probes are now available to measure temperatures in both these areas. Some common types include an immersion probe, a surface temperature probe, and a radiation shielded probe for measuring true air temperature. Other types of infrared thermometers and thermographic equipment are also available. An infrared laser thermometer is valuable for measuring temperatures of surfaces or steam lines that are not readily reached without a ladder.

Humidity sensors are useful to measure indoor humidity levels. Excessive humidification or dehumidification is expensive and is easily spotted in this way. It is useful to verify the performance of some economizer control operations that make control choices based on dew point, wet bulb, or enthalpy of air, and for cooling tower optimization from wet bulb temperature.

Digital Camera

Digital cameras that provide high quality images have become commonplace. These are used extensively in the field by energy auditing professionals to document exterior and interior facility conditions. The high resolution they provide enables equipment such as lighting, controls, HVAC, motors, etc. to be documented. Most can record images of equipment manufacturer nameplates. It is not uncommon for energy auditors to use the camera functions on cellphones to capture images of existing site conditions. Aerial, drone-mounted digital cameras are also useful.

Infrared Cameras

Infrared cameras have substantially dropped in price, but they are still rather expensive pieces of equipment. An investment of at least $10,000 to $15,000 is needed to have a good quality infrared camera. However, these are very versatile pieces of equipment and can be used to find overheated electrical wires, connections, neutrals, circuit breakers, transformers, motors and other pieces of electrical equipment. They can also be used to find wet insulation, missing insulation, roof leaks and cold spots. Thus, infrared cameras are excellent tools for both safety related diagnostics and energy savings diagnostics. A good rule of thumb is that if one safety hazard is found during an infrared scan of a facility, then that has paid for the cost of the scan for the entire facility. Many insurers require infrared scans of buildings for facilities annually.

Voltmeter

An inexpensive digital voltmeter is useful for determining operating voltages of electrical equipment, especially when the nameplate has worn off of a piece of equipment or is otherwise unreadable or missing. The most versatile instrument is a digital combined volt-ohm-ammeter with a clamp-on feature for measuring currents in conductors that are easily accessible. This type of multi-meter is convenient and relatively inexpensive. Any newly purchased voltmeter or multimeter should be a true remote sensing (RMS) meter, for greatest accuracy where harmonics might be involved.

Clamp-on Ammeter

These are very useful instruments for measuring current in a wire without having to make any live electrical connections. The clamp is opened and placed around one insulated conductor, and the meter reads the current in that conductor. New clamp-on ammeters can be purchased rather inexpensively that read true RMS values. This is important because of the level of harmonics in many of our facilities. An idea of the level of harmonics in a load can be estimated by using a non-RMS ammeter and then using a true RMS ammeter to measure the current. If there is more than a 5% to 10% difference between the two readings, there is a significant harmonic content to that load.

Wattmeter/Power Factor Meter

A portable hand-held wattmeter and power factor meter is handy for determining the power consumption and power factor of individual motors and other inductive devices. This meter typically has a clamp-on feature that allows an easy connection to the current-carrying conductor, as well as probes for voltage connections. Any newly purchased wattmeter or power factor meter should be a true RMS meter for greatest accuracy where harmonics might be involved.

Combustion Analyzer

Combustion analyzers are portable devices capable of estimating the combustion efficiency of furnaces, boilers, or other fossil fuel burning machines. Electronic digital combustion meters perform the measurements and display the readout in percent of combustion efficiency. Today these instruments are hand-held devices that are very accurate, and they are also quite inexpensive costing $800 to $1,000 for most heaters and boilers.

Airflow Measurement Devices

Measuring air flow from heating, air conditioning, or ventilating ducts, or from other sources of air flow, is one of the energy auditor's tasks. Airflow measurement devices can be used to identify problems with air flows, such as whether the combustion air flow into a gas heater is correct. Typical airflow measuring devices include a velometer, an anemometer, or an airflow hood. See section 3.4.3 for more detail on airflow measurement devices.

Blower Door Attachment

Building or structure tightness can be measured with a blower door attachment. This device is frequently used in residences and in small office buildings to determine the air leakage rate or the number of air changes per hour in the facility. This often helps determine whether the facility has substantial structural or duct leaks that need to be found and sealed. See section 3.4.2 for additional information on blower doors.

Smoke Generator

A simple smoke generator can also be used in residences, offices, and other buildings to find air infiltration and leakage around doors, windows, ducts, and other structural features. Care must be taken in using this device since the chemical smoke produced may be hazardous, and breathing protection masks may be needed. See section 3.4.1 for additional information on the smoke generation process and the use of smoke generators.

Safety Equipment

The use of safety equipment is a vital precaution for any energy auditor. A good pair of safety glasses is an absolute necessity for almost any manufacturing facility audit visit. Hearing protectors may also be required on audit visits to noisy plants or areas with high horsepower motors driving fans and pumps. Electrical insulated gloves should be used if electrical measurements will be taken, and thermally insulated gloves should be used for working around boilers and heaters. Breathing masks may also be needed when hazardous fumes are present from processes or materials used. Steel-toe and steel-shank safety shoes may be needed on audits of plants where heavy materials, hot or sharp materials, or hazardous materials are being used. In areas where construction is taking place, hard hats may be needed. See section 3.3.3 for an additional discussion of safety procedures.

Miniature Data Loggers

Miniature data loggers have appeared in low cost models in the last five years. These are often devices that can be held in the palm of the hand and are electronic instruments that record measurements of temperature, relative humidity, light intensity, light on/off, and motor on/off. If they have an external sensor input jack, these little boxes are actually general purpose data loggers. With external sensors, they can record measurements of current, voltage, apparent power (kVA), pressure and CO_2.

These data loggers have a microcomputer control chip and a memory chip, so they can be initialized and then record data for periods of time from days to weeks. They can record data on a continuous 24-hour-a-day basis, without any attention or intervention on the part of the energy auditor. Most of these data loggers interface with a digital personal computer and can transfer data into a spreadsheet of the user's choice, or they can use the software provided by the suppliers of the loggers.

Collecting audit data with these small data loggers gives a more complete and accurate picture of an energy system's overall performance, because some conditions may change over long periods of time or when no one is physically present to observe the changes.

Vibration Analysis Gear

Relatively new in the energy manager's tool box is vibration analysis equipment. The correlation between machine condition (bearings, pulley alignment, etc.) and energy consumption is related, and this equipment monitors such machine health. This equipment comes in various levels of sophistication and price. At the lower end of the spectrum are vibration pens (or probes) that simply provide real-time amplitude readings of vibrating equipment in inches/seconds or mm/seconds. This type of equipment can cost under $1,000. The engineer compares the measured vibration amplitude to a list of vibration levels (ISO2372) and is able to determine if the vibration is excessive for that particular piece of equipment.

The more typical type of vibration equipment will measure and log the vibration into a database (on-board and downloadable). In addition to simply measuring vibration amplitude, the machine vibration can be displayed in time or frequency domains. The graphs of vibration in the frequency domain will normally exhibit spikes at certain frequencies. These spikes can be interpreted by a trained individual to determine the relative health of the machine monitored.

The more sophisticated machines are capable of trend analysis so that facility equipment can be monitored on a schedule and changes in vibration (amplitudes and frequencies) can be noted. Such trending can be used to schedule maintenance based on observations of change. This type of equipment starts at about $3,000, increasing in cost depending on features desired.

3.3.2 Preparing for the Audit Visit

Some preliminary work must be done before the auditor makes the actual energy audit visit to a facility. Data should be collected on the facility's use of energy through examination of utility bills, and some preliminary information should be compiled on the physical description and operation of the facility. These data should then be analyzed so that the auditor can do the most complete job of identifying energy conservation opportunities during the actual site visit to the facility.

Energy Use Data

The energy auditor should start by collecting data on energy use, power demand, and utility costs for at least the previous 12 months. Twenty-four months of data might be necessary to adequately understand some types of billing methods. Invoices for natural or propane gas, oil, coal, electricity, etc. should be compiled and examined to determine both the amount of energy used and the cost of that energy. These data should then be put into tabular and graphic form to see what kind of patterns or problems appear from the tables or graphs. Any anomalies in the patterns of energy use raise the possibility for energy or cost savings by identifying and controlling that anomalous behavior. Sometimes an anomaly on the graph or in the table reflects an error in billing, but generally the deviation shows that some activity is happening that has not been noticed or is not completely understood by the customer.

Rate Structures

To fully understand the cost of energy, the auditor must determine the rate structure under which that energy use is billed. Energy rate structures may be extremely simple—for example, $2.00 per gallon of Number 2 fuel oil—or very complex ones, such as electricity consumption which may have a customer charge, on- and off-peak charge, energy charge, demand charge, power factor charge, environmental surcharge and other miscellaneous charges that vary from month to month. Few customers or businesses really understand the various rate structures that control the cost of the energy they consume. The energy auditor can help because the customer must know the basis for the costs in order to control them successfully.

- *Energy charges*: For electrical use, this is in terms of kWh and is often different for on- and off-peak use. For fuel, this is in terms of gallons of oil, therms of natural gas, etc. and usually does not differentiate by time of use, although there may be seasonal adjustments (e.g., higher in winter).

- *Electrical demand charges*: The demand charge is based on a reading of the maximum power in kW that a customer demands in one month. Power is the rate at which energy is used, and it varies quite rapidly for many facilities. Electric utilities average the power reading over intervals from 15 minutes to 1 hour, so that very short fluctuations do not adversely affect customers. Thus, a customer might be billed for demand for a month based on a maximum value of a 15-minute integrated average of their power use. Demand charges are often different for on- and off-peak times.

- *Ratchet clauses*: Some utilities have a ratchet clause in their rate structure which stipulates that the minimum power demand charge will be the highest demand recorded in the last billing period or some percentage (i.e., typically 70% to 75%) of the highest power demand recorded in the last year. The ratchet clause can increase utility charges for facilities during periods of low activity or where power demand is influenced by extreme weather conditions.

- *Discounts and penalties*: Utilities generally provide discounts on their energy and power rates for customers who accept power at high voltage and provide transformers on site. They also commonly assess penalties when a customer has a power factor (PF) less than 0.9 to 0.95. Inductive loads (e.g., lightly loaded electric motors, old fluorescent lighting ballasts, etc.) reduce the PF. Improvements in PF can be made by adding capacitance to correct for lagging PF, and variable capacitor banks are most useful for improving the PF at the service drop. Capacitance added near the loads can effectively increase the electrical system capacity. Turning off idling or lightly loaded motors can also help.

- *Water and wastewater charges*: The energy auditor also looks at water and wastewater use and costs as part of the audit visit. These costs are often related to the energy costs at a facility. Wastewater charges are usually based on some proportion of the metered water use since the solids are difficult to meter. This can needlessly result in substantial increases in the utility bill for processes which do not contribute to the wastewater stream (e.g., makeup water for cooling towers and other evaporative devices, irrigation, etc.). For many customers, utility companies allow water submeters to be installed on branch lines that supply the loads not returning water to the sewage system. This can reduce the sewer charges for these branch water flows by up to 75%.

  Note: Understanding the relationship between the cost of energy compared to water and wastewater is important for effective audit recommendations. For example, in areas where electricity cost is low and water cost is high, suggested HVAC measures that convert air-cooled equipment to evaporatively cooled may find most of the energy savings negated by water and wastewater charges, even with the sewer consumptive use credit.

Energy bills should be broken down into the components that can be controlled by the facility. These cost components can be listed individually in tables and then plotted. For example, electricity bills should be broken down into power demand costs per kW per month, and energy costs per kWh. The following example illustrates the parts of a rate structure for an industrial electrical user in Florida.

Example 3-1: A company that fabricates metal products gets electricity from its electric utility at the following general service demand rate structure.

Rate structure:

Customer cost	=	$21.00 per month
Energy cost	=	$0.051 per kWh
Demand cost	=	$6.50 per kW per month
Taxes	=	Total of 8%
Fuel adjustment	=	A variable amount per kWh each month

The energy use and costs for that company for a year are summarized below.

The auditor must be sure to account for all the taxes, the fuel adjustment costs, the fixed charges, and any other costs so that the true cost of the controllable energy cost components can be determined. In the electric rate structure described above, the quoted costs for a kW of demand and a kWh of energy are not complete until all these additional costs are added. Although the rate structure indicates that there is a basic charge of $6.50 per kW per month, the actual cost including all taxes is $7.02 per kW per month. The average cost per kWh is most easily obtained by taking the data for the 12-month period and calculating the cost over this period of time. Using the numbers from the table, one can see that this company has an average energy cost of $0.075 per kWh.

Figure 3-1. Sample summary of energy usage and costs.

Month	*kWh Used (kWh)*	*kWh Cost ($)*	*Demand (kW)*	*Demand Cost ($)*	*Total Cost ($)*
Mar	44,960	1,581	213	1,495	3,076
Apr	47,920	1,859	213	1,495	3,354
May	56,000	2,318	231	1,621	3,939
Jun	56,320	2,423	222	1,558	3,981
Jul	45,120	1,908	222	1,558	3,466
Aug	54,240	2,410	231	1,621	4,032
Sept	50,720	2,260	222	1,558	3,819
Oct	52,080	2,312	231	1,621	3,933
Nov	44,480	1,954	213	1,495	3,449
Dec	38,640	1,715	213	1,495	3,210
Jan	36,000	1,591	204	1,432	3,023
Feb	42,880	1,908	204	1,432	3,340
Totals	569,360	24,243	2,619	18,385	42,628
Monthly Averages	47,447	2,020	218	1,532	3,552

This example is simplified for the sake of illustration. Most rate structures that include demand charges also include time of use charges for on/off peak, and power factor charges.

These data are used initially to analyze potential ECOs and will ultimately influence which ECOs are recommended. For example, an ECO that reduces peak demand during a month would save $7.02 per kW per month. Therefore, the auditor should consider ECOs that would involve using certain equipment during the night shift, when the peak load is much less than the first shift peak load. ECOs that save both energy and demand on the first shift would save costs at a rate of $0.075 per kWh. Finally, ECOs that save electrical energy during the off-peak shift should be examined as well, but they may not be as advantageous; they would only save at the electricity rate of $0.043 per kWh because they are already used during off-peak periods and there would not be any additional demand cost savings.

Physical and Operational Data for the Facility

The auditor must gather information on factors likely to affect energy use in the facility. Geographic location, weather data, facility layout and construction, operating hours, and equipment can all influence energy use.

- *Geographic location and weather data*: The geographic location of the facility should be noted, together with the weather data for that location. Contact the local weather station, the local utility, or the state energy office to obtain the average monthly degree days for the heating and cooling seasons for that location for the past year. These degree-day data are useful in analyzing the energy required for heating or cooling the facility. Bin weather data are also useful if a thermal envelope simulation of the facility is being performed as part of the audit.

- *Facility layout*: The facility architectural plans should be obtained and reviewed to determine the facility size, floor plans, and construction features such as wall and roof material and insulation levels, as well as door and window sizes and types of construction. A set of building plans could supply this information in sufficient detail. It is important to make sure the plans reflect the as-built features of the facility since many original building plans are not updated after building alterations. A review of the lighting, HVAC and equipment plans and schedules is also helpful.

- *Operating hours*: Operating hours for the facil-