ENERGY EFFICIENCY MANUAL

Donald R. Wulfinghoff

for everyone who uses energy,
pays for utilities,
controls energy usage,
designs and builds,
is interested in energy and
environmental preservation

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Energy Efficiency Manual

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The Measure is the unit of information in the *Energy Efficiency Manual*. Each Measure is a self-contained, hands-on guide to one specific method of saving energy and reducing utility costs.

the **Measure number** locates this Measure within the 400 Measures of the *Manual.*

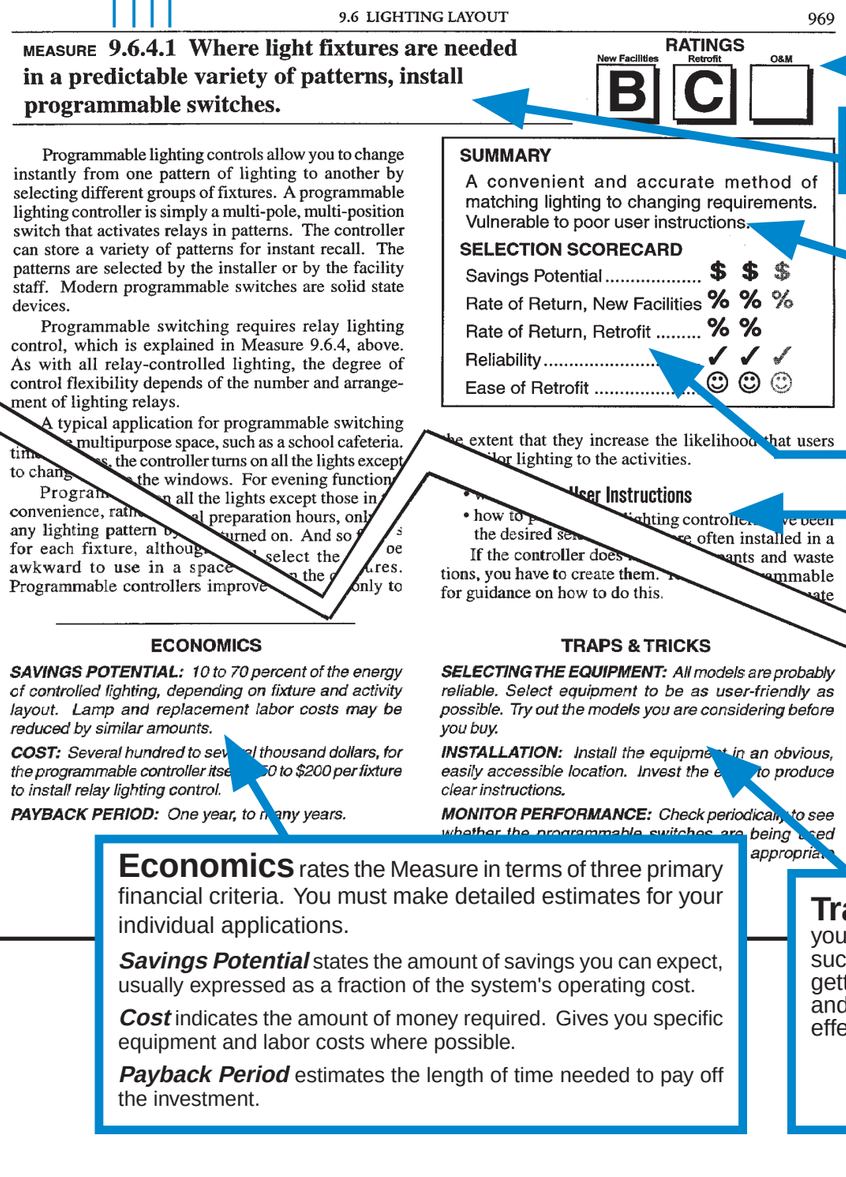
the ***Section*** tells you the major subject area, such as boilers, water systems, or lighting.

the ***Subsection*** tells you the specific type of energy system, such as boiler fuel systems. Or, it tells you a specific area of efficiency, such as reducing solar cooling load.

the ***sequence number*** within the Subsection. The Measures are grouped logically.

the ***subsidiary sequence number***. Only "subsidiary" Measures have this.

NOTE: In the text, **"ff"** after a Measure number means "*the Measure and every Measure that is subsidiary to it.*"



9.6 LIGHTING LAYOUT 969

MEASURE 9.6.4.1 Where light fixtures are needed in a predictable variety of patterns, install programmable switches.

RATINGS — New Facilities: B; Retrofit: C; O&M:

Programmable lighting controls allow you to change instantly from one pattern of lighting to another by selecting different groups of fixtures. A programmable lighting controller is simply a multi-pole, multi-position switch that activates relays in patterns. The controller can store a variety of patterns for instant recall. The patterns are selected by the installer or by the facility staff. Modern programmable switches are solid state devices.

Programmable switching requires relay lighting control, which is explained in Measure 9.6.4, above. As with all relay-controlled lighting, the degree of control flexibility depends of the number and arrangement of lighting relays.

A typical application for programmable switching is a multipurpose space, such as a school cafeteria. ... the controller turns on all the lights except ... to chang... the windows. For evening function... Progra... all the lights except those in ... convenience, rat... al preparation hours, onl... any lighting pattern b... urned on. And so ... for each fixture, althoug... select the ... awkward to use in a space ... the ... ures. Programmable controllers improve ... only to ...

SUMMARY

A convenient and accurate method of matching lighting to changing requirements. Vulnerable to poor user instructions.

SELECTION SCORECARD

Savings Potential	$ $ $
Rate of Return, New Facilities	% % %
Rate of Return, Retrofit	% %
Reliability	✓ ✓ ✓
Ease of Retrofit	☺ ☺ ☺

...he extent that they increase the likelihood that users ...lor lighting to the activities.

...User Instructions

- ... how to p... lighting controller... ve been the desired sen... re often installed in a

If the controller does ... ants and waste tions, you have to create them. ... mmable for guidance on how to do this. ...ate

ECONOMICS

SAVINGS POTENTIAL: *10 to 70 percent of the energy of controlled lighting, depending on fixture and activity layout. Lamp and replacement labor costs may be reduced by similar amounts.*

COST: *Several hundred to sev... thousand dollars, for the programmable controller itse... 50 to $200 per fixture to install relay lighting control.*

PAYBACK PERIOD: *One year, to m... any years.*

TRAPS & TRICKS

SELECTING THE EQUIPMENT: *All models are probably reliable. Select equipment to be as user-friendly as possible. Try out the models you are considering before you buy.*

INSTALLATION: *Install the equipment in an obvious, easily accessible location. Invest the e... to produce clear instructions.*

MONITOR PERFORMANCE: *Check periodically to see whether the programmable switches are being used appropria...*

the **Measure title** says what to do.

the **Summary** highlights aspects of the Measure that place it in perspective within your overall efficiency program.

the **text** of the Measure explains ***who, what, where, when, how,*** and ***why***. It focuses on issues that are directly related to accomplishing the Measure. (Important background information for the Measures is in the **Reference Notes**, Section 11.)

Economics rates the Measure in terms of three primary financial criteria. You must make detailed estimates for your individual applications.

Savings Potential states the amount of savings you can expect, usually expressed as a fraction of the system's operating cost.

Cost indicates the amount of money required. Gives you specific equipment and labor costs where possible.

Payback Period estimates the length of time needed to pay off the investment.

Traps & Tricks alert you to factors that threaten success. Gives you hints for getting it right the first time and for keeping the Measure effective in the long term.

the **Ratings** suggest the priority that this Measure deserves in your overall energy conservation program, in typical situations.

*for **New Facilities**:*

- **A** Do it wherever it applies. It costs little, and it has no significant disadvantages.
- **B** Do it in most cases. Modest cost. Pays back quickly. Does not need special skill or increased staffing.
- **C** It is very expensive. Or, the payback period is relatively long. Or, operation may require substantial effort, special skill, or continuing management attention.
- **D** It provides only a small benefit in relation to its cost. Or, it may have high risk because it is novel, unreliable, difficult to install, or difficult to maintain.

*for **Retrofit**:*

- **A** Do it wherever it applies. Simple and quick. Costs little in comparison with its benefits. The risks can be managed easily by the present staff.
- **B** Do it in most facilities where it applies. Pays back quickly. Easy to accomplish. Requires a modest amount of money, effort, and/or training. May have pitfalls that require special attention.
- **C** Expensive or difficult. Or, the saving is small in relation to the money, effort, skill, or management attention required. The risks are clear and manageable.
- **D** Expensive, and provides only little benefit. Or, exceptionally risky because it is difficult to accomplish correctly, or difficult to maintain, or unproven, or unpredictable.

*for **Operation & Maintenance**:*

- **A** Simple, quick, and foolproof. Or, it must be done to prevent damage or major efficiency loss.
- **B** Will be done in a well-managed facility. Pays back quickly. Fairly easy to accomplish. Not too risky. Requires a modest amount of money, effort, and/or training. Or, it is a less critical maintenance activity.
- **C** Requires substantial money, effort, special skill, and/or management attention. Or, the benefit is small.
- **D** The benefit is small in relation to cost. Or, it is exceptionally difficult to accomplish. Or, it has potential for serious adverse side effects.

the **Selection Scorecard** rates the financial and human factors that are most important for deciding whether to exploit the Measure in your application. The scores are for typical commercial applications. *Shaded symbols indicate a range of scores.*

Savings Potential is expressed as a percentage of the facility's total utility cost.

$ $ $ $	over 5%
$ $ $	0.5% to 5%
$ $	0.1% to 0.5%
$	less than 0.1%

Rate of Return estimates the percent of the initial cost that is saved each year.

% % % %	over 100%
% % %	30% to 100%
% %	10% to 30%
%	less than 10%

Reliability indicates the likelihood that the Measure will remain effective throughout its promised service life.

- ✓ ✓ ✓ ✓ **FOOLPROOF**. Equipment or materials will last as long as the facility. Maintenance requirements will not cause the Measure to be abandoned. If a procedure, it is easy to administer. Or, it is a simple, one-time effort.
- ✓ ✓ ✓ **RELIABLE**. Equipment has long service life, is not very vulnerable to damage, negligence, or poor operating practice. May fail visibly at long intervals. If a procedure, it is fairly easy to maintain and requires only modest skill.
- ✓ ✓ **FAILURE PRONE**. Equipment needs skilled maintenance, or it is vulnerable to damage or poor operating practice. Fails invisibly. If a procedure, it is easily forgotten or requires continuing supervision.
- ✓ **VERY RISKY**. Equipment has poor or unknown reliability. Or, it needs frequent maintenance. If a procedure, it is difficult to learn or it may easily cause damage.

Ease of Retrofit or ***Ease of Initiation*** indicates how easy it is for the people involved to accomplish the Measure properly.

- ☺ ☺ ☺ ☺ **EASY**. Only minimal effort and no extra skill are required. No tricky factors.
- ☺ ☺ ☺ **ROUTINE**. Not much effort or skill required. May need to learn a new procedure.
- ☺ ☺ **DIFFICULT**. Needs major staff effort. Or, hard to find reliable contractors. May be tricky.
- ☺ **VERY CHALLENGING.** Can be unpleasant, likely to be resisted. Or, installation is difficult and expensive. Or, requires major experimentation.

How to Use the *Energy Efficiency Manual*

The *Energy Efficiency Manual* is your primary tool for improving energy efficiency and reducing your utility costs. It is a comprehensive, step-by-step guide that is designed to help you manage your activities effectively and with confidence.

The core of the *Energy Efficiency Manual* is 400 energy efficiency "Measures." The Measures have a standard format that makes it easy to organize them into an optimum efficiency program for your facility. Refer to the inside of the front cover to learn how to exploit the Measures.

The Measures are grouped into Sections and Subsections. These correspond to ***types of energy systems*** (for example, boilers, chillers, or lighting) or to ***energy waste in specific components*** (for example, air leakage through doors, or solar heat gain through windows). This arrangement lets you quickly identify whole groups of Measures that may or may not apply to your facility. For example, if your boilers are fueled by natural gas, you can bypass the Subsection that deals with fuel oil systems. Use the Table of Contents to find the Sections and Subsections that apply to your situation.

The Reference Notes, the last Section of the book, serve you in two important ways. They support the Measures with additional explanation, which may be more basic or more advanced than the "working" information in the Measures. Also, you can read each Reference Note by itself for a concise overview of an important energy conservation topic.

Use the Index to find specific topics that interest you, or to find definitions of terms.

❑ **If you are involved in new construction** — if you are an architect, an engineer, a construction manager, a contractor, or a code official — use the *Energy Efficiency Manual* as a design review guide. As you develop your design, continually check the *Manual* for efficiency features that you can exploit. Use it to find where the design wastes energy, and to find better ways of saving energy.

❑ **If you own, manage, or operate facilities** — anything from a private house to an office complex or hospital or paper mill — use the *Energy Efficiency Manual* to find all your opportunities for savings. Then, use it to prioritize your activities. Finally, let it guide you in accomplishing and preserving your improvements.

❑ **If you are a specialist in energy efficiency**, use the *Energy Efficiency Manual* as a designer or facility manager would, depending on whether you deal with new or existing facilities. It will improve the quality of your work and reduce the time you need to provide the best service to your clients.

❑ **If you are a student or teacher**, start with the Reference Notes to learn fundamental principles. With each Reference Note, use the related Measures as examples of practical applications.

❑ **If you are an advocate for efficiency or the environment**, use the *Energy Efficiency Manual* to learn the real-world aspects of the conservation activities that interest you. The *Manual* will help you to promote resource conservation that produces credible results.

Now, please read "A Personal Note: the Right Way to Do Energy Conservation."

A PERSONAL NOTE: THE RIGHT WAY TO DO ENERGY CONSERVATION

Improving energy efficiency may be the most profitable thing that you can do in the short term. How much you will actually benefit from this opportunity depends on how you approach it. Please take a few minutes to read the following suggestions about using the *Energy Efficiency Manual* and about your role in energy conservation. Invest a little time in learning how to use the *Manual*, and it will reward you with years of savings and achievement.

If you are involved in new construction — if you are an architect, an engineer, a construction manager, a contractor, or a code official — use the *Energy Efficiency Manual* as a design review guide. As you develop your design, continually check the *Manual* for efficiency features that you can exploit. Use it to find where the design wastes energy, and to find new ways of saving energy.

If you own, manage, or operate facilities — anything from a private house to an office complex or hospital or steel mill — use the *Energy Efficiency Manual* first to find all your opportunities for savings. Then, use it to prioritize your activities. Finally, let it guide you in accomplishing and preserving your improvements.

If you are a specialist in energy efficiency — if you are an energy consultant, a utility energy specialist, or an energy services provider — use the *Energy Efficiency Manual* in the same way, depending on whether you deal with new or existing facilities. You will find that it greatly improves the quality of your work and reduces the time you need to provide service of top quality to your clients.

If you are a student preparing to enter any of these important fields, or if you are a teacher, you will use the *Energy Efficiency Manual* in a different way. Start with the Reference Notes to learn fundamental principles. With each Reference Note, use the related Measures as examples of practical applications.

If your job or your vocation is to advocate efficiency — for example, if you are a government energy official or an environmental advocate — use the *Energy Efficiency Manual* to learn the real-world aspects of the conservation activities that interest you. Both governments and advocacy groups have played an invaluable role in promoting efficiency. At the same time, naive enthusiasm sets the stage for failures, which undermine public confidence in energy conservation and actually waste energy. The *Energy Efficiency Manual* will help you to promote resource conservation that produces credible results.

How to Use the Energy Efficiency Manual

The *Energy Efficiency Manual* is designed to be your primary tool for improving energy efficiency and reducing your utility costs. It is a comprehensive, step-by-step technical guide, and it also helps you manage your activities efficiently. Learning to use this tool proficiently will take only a few moments.

The core of the *Energy Efficiency Manual* consists of four hundred energy efficiency "Measures." Each Measure is a specific energy efficiency improvement or cost saving activity. Each Measure gives you the information you need to plan the activity efficiently and accomplish it successfully.

All the Measures have a standard format. This includes special features, Ratings and a Selection Scorecard, that help you to quickly judge the value of each Measure for your applications. Other features, the Summary, Economics, and Traps & Tricks, give you the main features of each Measure. To become familiar with these features, refer to the key to the Measures, inside the front cover, as you browse through the Measures.

The Measures are grouped into Sections and Subsections. These correspond to *types of energy systems* (e.g., boilers, chillers, lighting) or to *energy waste in specific components* (e.g., air leakage through doors, solar heat gain through windows). This lets you quickly identify whole groups of Measures that may or may not apply to your facility. For example, if your boilers are fueled by natural gas, you can bypass the Subsection that deals with fuel oil systems. Use the Table of Contents to select the Sections and Subsections that apply to your facility.

First, find all your opportunities.

Resist the temptation to rush into energy conservation projects without considering all your opportunities first. You may be eager to get started after attending a seminar, or reading an article, or getting a sales pitch. Those are good ways to get an introduction to new concepts, but they are no substitute for knowing all your opportunities.

If you grab at opportunities randomly, you will miss many good ones and waste money. In a facility of any size, there will be many things that you can do to reduce your utility costs. Every building and plant wastes energy in hundreds or thousands of places. Find them all.

There is no way to find the best opportunities first. It is like an Easter egg hunt. You can't tell how big the prizes are until you have searched everywhere and found all the eggs. By the same token, don't expect to find a "short list" of improvements that are best for your facility. Each building and plant wastes energy in different ways.

Your search for efficiency improvements will be time-consuming. (In existing facilities, this search is often called an "energy audit.") Typically, it requires weeks or months. In a large, diverse facility, it may require more than a year. Demand the time to do it right.

A false concept that came out of the popular energy conservation movement of the 1970's is the "walk-through" or "one-day" energy audit. According to this notion, whizzing through a facility reveals energy conservation opportunities by a mystical kind of inspiration. Reject this ouija board approach, even as a starting point. Quickie surveys fool you into believing that you know your options when you really don't.

Budget your time as wisely as your money.

When you complete your list of potential efficiency improvements, your next job is to decide the most effective sequence for accomplishing them. You want to produce the greatest payoff in the shortest time. Be shrewd about managing your program's two most important resources, money and personal capabilities.

The *Energy Efficiency Manual* helps you make the best use of both these resources. The Ratings in each Measure suggest its overall priority, taking into account the economics of the Measure, the difficulty of accomplishing it, and the degree of risk. To refine your ranking, the Selection Scorecard, just below the title, rates these factors individually. At the end of each Measure, the Economics gives you general estimates of the potential savings, the cost, and the rate of return.

Recognize that your time is a more precious resource than the money needed to make the improvements. Energy efficiency is a profit maker. So, you could borrow money to fund any project that you know will pay off. The skills and effort of the people involved are the real limiting factors. Traps & Tricks, located right after Economics, alert you to aspects of the Measure that will challenge the people involved.

Give priority to the Measures, or groups of Measures, that will produce the largest savings, even though they may not pay off most quickly. Don't divert your time to minor activities while there are more important things to be done. On the other hand, if you see that you can accomplish a Measure quickly and reliably, go ahead and do it. Don't waste time analyzing small improvements in detail.

Try to accomplish groups of related Measures together. For example, make all the control improvements to your air handling systems as a single activity. This avoids duplication of effort, saves money in contracting, and produces a better overall system. The *Energy Efficiency Manual* is organized to make this easy for you.

Most important, don't get in over your head at the beginning with a large project that demands all your attention. If a Measure seems overwhelming, defer it until you have more time to study it. Don't start any Measure until you are ready to complete it *successfully*.

Don't expect instant gratification.

The desire for quick and effortless results has ruined more energy conservation projects than any other cause. Rushing into a project blindly is unprofessional. You would not want your surgeon to rush through your operation just to prove how quickly he can do it.

You have heard expressions like "no-cost energy conservation measure," "pick the low fruit," and so forth, to describe retrofit projects that are supposed to be "easy" or "simple." These notions are illusions that lure you into being too hasty. Every opportunity for saving energy requires significant effort, if it is going to work and to endure.

Your willingness to invest the needed effort and time is what guarantees the success of your projects. The *Energy Efficiency Manual* will show you how to make your improvements as quickly and easily as possible.

Rely on proven equipment and methods.

Energy conservation is not a license to use the owner as a guinea pig. In most cases, rely on conventional equipment and methods. Contrary to popular opinion, energy efficiency does not require exotic technology. That's good news. The bad news is that fads in energy conservation have strong appeal, distracting people from proven profit makers. The only good reason to do energy conservation is to produce predictable, certain savings.

Everyone is fascinated by innovation. Innovation drives progress. But, the price of innovation is a big chance of failure. Most owners can't afford that risk. Leave unproven equipment and methods to those who develop new products and have a laboratory budget.

On the other hand, if you are in a position to work at the frontiers of energy efficiency, the *Energy Efficiency Manual* will help you survive as a pioneer. You will find many Measures at the leading edge of energy efficiency (and a few that are just on the outer fringe). These too can be profitable if you give them the attention they need. Riskier Measures have a Rating of "C" or "D", and their Traps & Tricks warn you of the dangers of unexplored territory.

Why is there so much stress on reliability?

The *Energy Efficiency Manual* devotes a lot of attention to the details that make the difference between a reliable system and one that is riddled with problems. This emphasis on avoiding pitfalls and dealing with tricky factors is intended to alert you, not to frighten you. Energy conservation is still a new subject. The blunt truth is that many energy conservation projects have failed, almost always because people ignored vital issues at the outset. These issues are often simple. For example, a common cause of energy waste is failing to mark controls so that people know how to use them.

Only successful projects pay off. We want you to contribute to the successes, not to the failures. The Measures spell out the issues that you need to consider. It's like driving around potholes. Keep your eyes open and don't rush.

Why all the explanations?

A large part of the *Energy Efficiency Manual* is devoted to explaining how things work. There are several important reasons for this. If you understand the principles, you are much less likely to make mistakes. Knowing the principles also enables you to keep up with changes in technology. And, knowing what you are doing at a basic level turns the work into fun.

The "theory" is located in two places. Each Measure offers the basic information that you need, and if necessary, it suggests where to get more information. Often, a Measure will refer you to one or more Reference Notes. Each Reference Note is a self-contained explanation of a specific topic.

Don't let mere words get in your way.

Each area of design, construction, and facility operation has a separate vocabulary. Architects have one set of jargon, mechanical engineers have another, electrical contractors still another, and so forth. Don't let this deter you from making efficiency improvements in each of these areas. The principles are important, not knowing particular words.

The *Energy Efficiency Manual* keeps the language as simple as possible. For example, we say "lamp" or "light fixture" instead of "luminaire." We say "window" or "skylight" instead of "fenestration." To help you communicate with specialists who may be fussy about language, the *Manual* explains specialized terms in the places where you need to know them.

Fortunately, each area has only a few specialized terms that are important. If you find a word that is unfamiliar, the Index will steer you to a concise, practical explanation.

You don't need much math, but be comfortable with numbers.

You will probably be happy to see that the *Energy Efficiency Manual* uses little mathematics. There are only a few simple formulas, and you need only arithmetic to use them.

Even so, energy efficiency is all about numbers. In most cases, you are not doing something that is fundamentally new. Instead, you are doing something *better*. To judge whether the improvement is worth the cost, you have to be able estimate the benefit in terms of numbers. If you are not comfortable doing the math, of if you need a calculation that requires specialized knowledge, get a specialist to make the calculations for you.

Recognize that energy savings are uncertain to some extent. They are subject to conditions that you cannot predict, including future energy costs,

operating schedules, weather, and human behavior. Make your estimates of savings for a reasonable range of conditions.

Keep your facility efficient for its entire life.

When energy conservation became a public issue during the 1970's, it was promoted by many well-intentioned people who lacked experience in keeping things working. Energy conservation was treated as a magic pill that would cure the disease of energy waste once and for all. In reality, energy waste is a degenerative condition that keeps trying to return.

Maintaining efficiency is like maintaining your physical fitness. You have to keep it up. Design your efficiency improvements to survive as long as the facility. Each Measure that requires maintenance tells you how to keep it profitable.

Let all your information sources work for you.

Capable professionals depend primarily on a few well-worn references. But, they also know how to get information from other sources quickly. Whether you are a professional or not, the *Energy Efficiency Manual* is your primary reference for energy efficiency. However, no single book can tell you everything you need to know. To do battle with energy waste, assemble an armory of information that is appropriate for the level of improvements that you plan to make.

You will see that the *Energy Efficiency Manual* is not cluttered with formulas and tables. When you need detailed engineering data, get it from the appropriate reference books. Fortunately, you need only a few of these. If you are involved at a professional level with heating, air conditioning, refrigeration, or designing a building's skin, you should have the four-volume *ASHRAE Handbook* on your shelf. For electric lighting, the prime reference source is the *IESNA Handbook*.

Many books are available on specialized aspects of energy conservation, such as solar energy, cogeneration, and residential insulation. Don't hesitate to get another book to expand your knowledge about a subject. There is no better bargain. A good book costs almost nothing in comparison with your utility expenses, and it protects your most valuable assets, which are your time and your professional reputation.

Once you decide to use a particular type of equipment, study the catalogs and equipment manuals of different manufacturers. These are a treasure of important details, and they are your most current source of information. But, beware. The big weakness of manufacturers' literature is a selective rendition of the truth. Knowing potential problems beforehand is critical to success, but manufacturers tend to omit or minimize this vital information.

Talk to others.

Two heads are better than one. Seek other people's opinions before you get involved with unfamiliar equipment or procedures. You can get practical advice from books, trade magazines, professional organizations, consultants, colleagues, and vendors. Talk to facility operators for their opinions about how well something really works.

As you do this, take everything with a grain of salt. People's perceptions are distorted by wishful thinking, embarrassment about disappointing outcomes, and inability to measure actual performance. I have listened to experienced plant operators brag about big efficiency improvements that they were convinced they had achieved with gadgets that were purely bogus.

Don't try to do everything yourself.

If you have a big facility, you will not live long enough to make it efficient by yourself. If you try, energy and money will bleed away while valuable efficiency improvements wait to be made.

Spread the work effectively. In a big facility, your main job is to decide which Measures to accomplish, and to make sure that they get done correctly. Use engineers, architects, contractors, specialized consultants, along with the facility staff. As your program gains momentum, you will have your hands full making sure that others do their work correctly.

Many Measures straddle the boundaries of the established design and construction disciplines. For example, successful daylighting requires close coordination between the architect, the lighting designer, the electrical engineer, and the mechanical engineer. You have to bring all these people together and require them to address all the issues that are critical for success. This is not always easy. Select your people for their willingness to listen and learn.

Seize the opportunity!

The most important point is to get started. At every moment, motors and fans are running, lights are turned on, boilers are burning fuel, and other equipment is consuming energy. Some of this energy is being wasted, and it is probably more expensive than you realize. Remember that cost savings are pure profit. You would have to sell a lot more of your product or service to make as much profit as you can from energy efficiency. Start tapping this resource.

On an industry-wide basis, the efficiency of your facilities will increasingly determine whether your organization can continue to survive and compete. On a global scale, improving efficiency is the most satisfactory way for civilization to adapt to declining energy resources and to minimize harm to the environment.

Enjoy yourself.

At this point, you may feel that you got into more than you bargained for. Don't worry. Energy conservation is a bigger challenge than most people expect, but the *Energy Efficiency Manual* breaks it down into easy steps. Set a comfortable pace, and stick with it. Your energy savings will soon show up on your utility bills, and those saving will continue to grow and accumulate.

Your energy efficiency program can be the most interesting and rewarding part of your career. It will give you an opportunity to become involved in every aspect of your industry. There is probably no other way that you can have as much fun while doing something of fundamental importance.

Donald Wulfinghoff
Wheaton, Maryland, USA

Expression of Gratitude

This book aspires to bring order and understanding to the vast field of energy efficiency. It organizes what I have learned about the subject during a career that has spanned the most exciting years of energy conservation in the United States and the world. Almost everything that I know was learned from others in one way or another. I would like to begin the book by recognizing those who contributed generously and specifically to the book, and also to recognize several persons and organizations who contributed more generally to my education in energy efficiency. This book is largely their achievement. The following brief acknowledgments cannot adequately recognize the individuals who made important contributions. However, I hope that these mentions will be accepted as a token of my deep gratitude.

Clinton W. Phillips, a figure revered in the air conditioning industry for his limitless contributions, erudition, and charm, meticulously reviewed two separate drafts of the material that deals with cooling systems. In addition to checking the text, he made important comments on both the theory of refrigeration and the lore of practical applications.

Henry Borger, a leader in construction research as well as a talented writer on diverse subjects, reviewed the entire book, suggesting improvements in structure and content.

Charles Wood reviewed the text that deals with boiler systems, providing valuable comments on this technical area and on the editorial approach.

Jim Crawford of the Trane Company contributed extensive and detailed information about the fast-changing world of refrigerants. Dave Molin of the Trane Company reviewed the Reference Note on energy analysis computer programs.

Richard Ertinger and Edward Huenniger of Carrier Corporation provided valuable information about the most recent advances in cooling technology.

Ken Fonstad, of the Graham Division of Danfoss, Inc., wrote lucid explanations of the electrical subtleties of variable-frequency motor drives, accompanied by extensive oscilloscope traces that he made. He also contributed a number of illustrations.

Sean Gallagher shared his experience with the practical aspects of lighting retrofits and with utility purchasing in this era of rapid change in the utility industry.

Don Warfield of Solarex provided information about the current state of photovoltaic technology, and made several illustrations available.

Many others contributed information during the twenty years of the book's preparation. It is impossible now to recall all the valuable discussions and presentations. I hope that the individuals will approve of the way that the book reflects their expertise.

Many organizations contributed illustrations that help to achieve the book's goal of bringing to life many unfamiliar and subtle concepts. These organizations are listed in the back of the book. The individuals who were especially helpful in providing the illustrations include Pat McDermott and Claudia Urmoneit of Osram Sylvania; Eric Johnson, Dave McDevitt, and Pat Barbagallo of Carrier Corporation; Jake Delwiche and Dick Figgie of the Trane Company; Thomas Henry and Pam Blasius of Armstrong International; Andrew Olson and Jim Baker of Rite-Hite Corporation; Tania Davero of Advance Transformer Company; Leight Murray and Diane Iaderosa of the Airolite Company; Doby Byers of American Mill Sales; Peter DeMarco of American Standard; John Figan of Bacharach; William McCloskey of Baltimore Aircoil Company; Steve Hill of Blender Products; Roy Nathan of Calmac Manufacturing Corporation; Bob Agnew of Celotex Corporation; Sharon Quint and Bill Garratt of Cleaver-Brooks; Paul Moulton of Construction Specialties, Inc.; Dewey Boggs of Coyote Electronics; Sherri Snow of Danfoss Automatic Controls; Lynn Hamrick of Donlee Technologies; Trish Steele of Dow Chemical Company; Linda Byam of Duo-Gard Industries; Herman Knapp and Keith Knapp of Fuel Efficiency, Inc.; Chris Van Name of Goodway

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The archives of Wulfinghoff Energy Services, Inc. yielded many of the figures, found among thousands of photographs that were originally taken as field notes in energy efficiency projects, and among illustrations made for courses and seminars.

Like all who are involved with energy efficiency, I owe a great debt to the American Society of Heating, Refrigerating, and Air Conditioning Engineers, known to the world as ASHRAE. This book's many referrals to the *ASHRAE Handbook* attest to its role as the primary reference for the practice of refrigeration and building design. The Society gave me the opportunity to serve with several committees that defined the course of energy conservation in response to energy crises of the 1970's. Among these responsibilities were helping to organize and to serve as a judge of the ASHRAE Energy Awards, which provided exposure to the energy conservation philosophies of the most innovative engineers of that era. ASHRAE also provided the impetus to write *Managing Your Energy*, the tutorial on the management aspects of energy conservation that became the basis of the Energy Management chapter of the *ASHRAE Handbook.* Another committee assignment gave me the opportunity to investigate how the different types of buildings use energy, then and now a topic that is rife with misconceptions.

I am particularly indebted to the National Capital Chapter of ASHRAE. During the years that I have been a member, the Chapter presented several hundred technical presentations, from each of which I learned something new and valuable. Two individuals stand out for their accomplishments in the Chapter. Jim Wolf, the president when I first began to serve in its offices, created the model of disciplined organization that keeps the Chapter effective to this day. Jim also facilitated technical reviews and illustrations from the Trane Company and American Standard. Jose Reig was the mainstay of the Energy Management Committee when I served as its early chairman, and later supported me when I became responsible for ASHRAE's energy conservation programs in the mid-Atlantic States. His intense dedication to everything he undertakes has been rewarded by the success of the engineering firm that he built.

The George Washington University provided my first platform for teaching energy efficiency to professionals, starting during the late 1970's. This gave me the occasion to consolidate the lessons that were being learned in those heady days of intense interest in energy conservation. The notes of those courses became the early structure of the *Energy Efficiency Manual.*

The U.S. Navy Engineer Officers School, San Diego, provided my first serious introduction to the machinery of energy systems. The School was a model of effective instruction that should be copied by all engineering schools.

My education in energy efficiency would have been inadequate for this task without the practical experience gained while working for the clients of my energy efficiency firm. Improving their facilities taught me the lessons of energy efficiency in the real world, including the diversity of ways that energy is wasted, the importance of details at every step, and the need for relentless maintenance and management attention. I always tried to spare our clients from the fads that were rampant during the infancy of the energy conservation movement. Still, those forward looking managers were the experimental subjects who made progress possible. And, they provided the living that financed the long years of writing.

Among our clients who became good friends, Michael Whitcomb deserves special mention as an extraordinary facility energy manager who aggressively and successfully pioneers important areas of energy efficiency. Our discussions about the practical realities of managing energy systems continue to be instructive.

The *Energy Efficiency Manual* benefited immensely from the editorial review of two extraordinary individuals. Nancy Dashiell, the original and veteran writer and technical editor of U.S. Pharmacopeia *Drug Information* (published by Consumers Union under the title *Complete Drug Reference*), edited the crucial final manuscript of the book and made valuable suggestions about earlier versions. Felicity Evans, whose experience includes service as a government energy official, insisted on essential changes to the early structure and style of the book. Among other important improvements, her suggestions led to the creation of the Reference Notes.

Dan Poynter, renowned parachutist and publishing mentor, made penetrating comments on an early draft that led to a complete rewrite to make the book easy to use by a broad audience.

In the production of the book, one individual stands out. Mark Dorbert, the proprietor of Wet Ink Printing & Graphics, shepherded the book from manuscript to press, rendering the interior design, accomplishing the composition and typesetting, and electronically processing the illustrations. An inspired artist, he also designed the end material. He did an enormous amount of work that would normally require a large team of individuals, mastering the range of prepress skills during a period in which the technology of publishing is changing from month to month. Nothing daunts him, he never slackens the pace, and his humor keeps the work enjoyable.

Cindy Fowler, of Graves Fowler Associates, rendered the cover design flawlessly and quickly, patiently dealing with many details.

Steve Dolan, of Scanners LLC, made the electronic renderings of the author's drawings, putting in many hours of work to meet a short deadline.

— Donald Wulfinghoff