SECTION 1

ENERGY MANAGEMENT PROGRAMS

1

ENERGY MANAGEMENT IN PRACTICE

Beth P. Jones

LyondellBasell (Retired), Guildford, Surrey, UK

Attention to energy efficiency seems to rise and fall in corporate priority with both the rise and fall of energy prices and the rise and fall in manufacturing margins. The life of the corporate energy manager is much the same. If energy costs are high and margins are slim, you are the man or woman of the hour, and if times are good and natural gas supplies are booming, no one will return your calls. Resources are allocated similarly. Bad times and poor prospects for capital spending free up lots of people to look for opportunities for more efficient operations. When times are better, those human resources are reallocated to opportunities with higher expected returns. A well thought-out energy management program identifies opportunities, sets the bar for ongoing performance, and maintains improvements with a minimum of resources. Otherwise, over time and with reduced scrutiny, efficiencies decline and relative costs go up. A few years later, the cycle repeats itself and a new team relearns all the lessons from the last cycle.

Several years ago, a technician received the company's highest "attaboy" award from its then president. His achievement included tuning up all the company's huge olefin furnaces and saving millions of dollars per year in energy costs. To quote the president's comment in this regard, "Great job rediscovering what we already knew! Next time maybe we'll just punish the people who stopped doing it." The technician took

Energy Management and Efficiency for the Process Industries, First Edition. Edited by Alan P. Rossiter and Beth P. Jones.

the comment to heart and wrote a "Furnace Manifesto" to preserve and institutionalize the knowledge.

This book is intended to provide an overview of industrial energy management, particularly for the process industries. Section 1 is focused on management issues—how to start and maintain an effective program, identify the components of a successful program, benchmark, and create management systems—and case studies that provide practical insights from successful and experienced energy managers. The rest of the book provides expert technical help in what to do to save energy, with particular focus on the energy users most significant to the process industries.

This chapter describes a practical overall approach to starting an energy management program and identifying and implementing energy efficiency improvements in a sustainable way. The chapter is particularly focused on helping new energy managers get started: What do they need to know to be effective in their role? Since most of these issues are also relevant to experienced managers and engineers with energy management responsibilities, we hope it will also be useful to all readers.

ASSESSING THE VALUE OF AN ENERGY MANAGEMENT PROGRAM

In most process industries, energy costs are second only to raw material costs. Entire departments are devoted to optimizing raw material choices and product slates, using planning models, supply strategies, and online optimization. Apart from buying energy at the lowest possible cost, most companies also consider energy to be an inevitable cost of doing business. However, energy use is not just a concern for the utilities department, and you, as an energy manager, must separate the cost of doing business from the cost of doing business well. Other benefits flow from focusing on energy, such as a reduced environmental impact and a cultural change toward reducing waste, but the scope of any energy management program is determined by its economic value.

Determine your company's energy use and energy cost, beginning with large sections of the organization and drilling down as far as it is practical. Use the data that are available now and are already understood by the organization. Energy information can come from site utility bills, internal cost accounting, and/or the utilities procurement group. Often the search for the data is as enlightening as the actual data. Was the information easy or difficult to collect? What does it tell you about each site? Are total company or division costs combined and analyzed already?

Draw a material balance box around each unit, site, or division, based on the details that are available (Figure 1.1). Include all external sources of energy that cross the boundary, such as purchased electric power, fuel gas, solid or liquid fuel, purchased steam, or whatever else is consumed within the box. If feed or product streams are burned or consumed to produce energy, include those as well. Collect both the nameplate capacity of each unit and its average operating rate.

Now that you have an initial fix on the company's energy profile, you can proceed toward estimating the value of potential energy savings with a combination of data and engineering judgment. From industry publications or data searches, determine the benchmark-specific energy use for the technologies in each box, and scale the specific

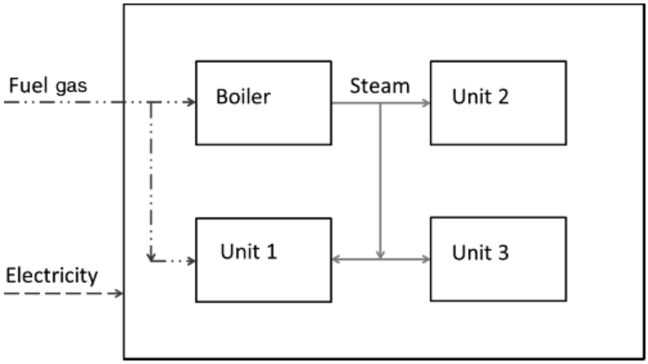

Figure 1.1. A simple material balance provides great insights into overall energy usage.

Site energy use = fuel gas rate × heating value + electricity rate
Site energy cost = fuel gas rate × price + electricity rate × electricity price
Site-specific energy use = site energy use/average feed(or major product)rate

energy to the nameplate capacity of each process. Chapter 5 gives a more detailed look at benchmarking.

Subtract the actual energy use from the benchmark use for each box and add up the potential savings. If no benchmark is available or the available data are not detailed enough to apply a benchmark, choose a reasonable percentage of current use. If no energy improvement program was active in the last 5–10 years, a 10% saving is feasible. Even relatively new and efficient units generally have a bit of refinement available (1–2%) through active energy management.

Compare your estimate of potential savings with the current total energy bill.

Can you afford to focus some resources on energy? Can you afford not to?

LAUNCHING THE PROGRAM

Like most corporate objectives, energy efficiency goals need support from above and heavy lifting from below. Managers will not generally support a new initiative unless they think that the issue is important enough to displace other priorities, and benefits cannot be achieved unless people are motivated to work toward them. An energy management program is a circular process of identifying opportunities, scoping solutions, and implementing improvements, and by doing so, refining the view for another pass (Figure 1.2). Getting started is the important thing. Significant energy improvements can be achieved without the final polishing of the process, so do not lose the good enough in pursuit of the perfect. Early successes prove that focusing on energy is worthwhile and inspire people to go out and look for opportunities in their areas.

Starting a program can be easier if you begin at the top. Presumably, upper management has both the vision to see the benefits of energy efficiency and command

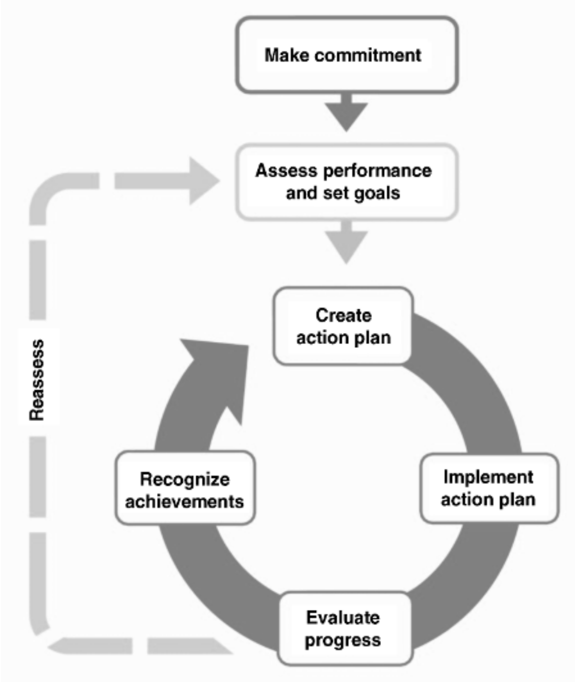

Figure 1.2. The “circular process” of energy management. (*Source:* www.energystar.gov/guidelines)

of the resources needed to do the work. Management commitment is key to the success of the effort. An energy policy statement from the executives demonstrates that commitment and provides the justification to get every site involved in the energy management process.

Some groundwork is necessary before you present your request for support. It is not enough just to estimate potential savings. You will need a rough action plan and an idea of the resources needed to achieve the savings in a given time. Data, plans, and resource requirements will improve with time and study, but first you must get the program off the ground.

Your credibility will also be enhanced by some judicious energy information gathering. You may encounter people within your company who do not believe that significant improvements in energy use are possible. Show them what your competitors are doing. Most large corporations discuss their energy improvements, and the resulting environmental improvements, on their websites. Case studies of successful programs from three companies in very different businesses and with very different energy usage profiles are discussed in Chapters 2–4. Energy policy statements are also displayed on corporate websites. Public organizations, such as ENERGY STAR from the U.S. Environmental Protection Agency (Chapter 7), also showcase companies that have made significant improvements. It is important to point out to management that spending resources on energy always provides some return. Energy prices fluctuate, but the risk associated with that spending is low compared to many other types of spending.

Involving the people you need to actually work on the energy efficiency issue will help ensure that your plans are feasible. Each company is different, but process or production engineers are usually the best points of contact for an energy-saving initiative. Each functional group has a role to play in the program, but the leaders of the energy-saving initiative need to understand the process flow and how energy consumption is affected by process variables. A senior process engineer makes a terrific site leader for the energy program. Site leaders must also have access to energy use data and the skills to develop and justify projects to improve energy efficiency. They also need the support of their managers. Choose a site with potential and spend some time talking to both the engineers and the operations managers. Share the site energy costs and any benchmarking data and brainstorm ways to identify saving opportunities and implement improvements. The exercise should both test your assumptions about achievable benefits and help you to determine the resources needed to realize the savings. Extrapolate these discussions to the entire company, and you will have a good start on an action plan.

Test the plan against the opportunities the group identified during the brainstorming at your "pilot" site. Will the plan be successful in implementing the opportunities? Is the site willing to follow the plan and try to capture those opportunities? Encourage them to start right away. Early successes increase buy-in at all levels and help to sell, and fund, the program.

Another potential selling point is the environmental benefit of an energy-saving program. The U.S. EPA provides some conversion factors for the greenhouse gas impact of different types of energy use [1]. You can use these factors to estimate the environmental impact associated with the energy-saving path you expect. Table 1.1 shows a few handy factors.

The next stage of planning adds timing and targeting, which leads to initial goals. Take a first pass at prioritizing your company's energy opportunities and determining what could be achieved in the first year or two by applying the resources you have just identified. Start with the sites with both significant energy use and a significant gap between benchmark and actual energy use, and work outward from there.

Initial goals should be achievable but not necessarily easy. The organization should have to act, even to stretch itself, to achieve the goal. As the energy program ramps up, the resource–return relationship will become clearer, but setting a target will get people moving in the right direction. Your management will not hesitate to weigh in on how much can be accomplished in a given time.

TABLE 1.1. Greenhouse Gas Impacts for Various Common Fuels [1]

Natural gas	53.02 kg CO_2/MBtu
Propane	61.46 kg CO_2/MBtu
No. 2 fuel oil	73.96 kg CO_2/MBtu
Bituminous coal	93.4 kg CO_2/MBtu

1 kg/MBtu = 1 kilogram per million Btu.

Now set up that management meeting and state your case:

> We believe that as a company we could save A% of our total energy use over the next B years. At today's prices, the savings are worth $C million per year by the end of that period. Other companies in our industry have achieved similar results—and have advertised the savings and the environmental benefits on their websites. The energy savings bring with them about D tons per year in CO_2 reductions.
>
> Your commitment to a policy of tracking and saving energy, and setting an energy-saving goal, is critical. Setting both a short-term reduction goal and a corporate energy policy that explains how we view energy will kick-start the program. Your continuing attention will ensure that the program is sustained. Here are some suggestions for a goal and a policy statement.
>
> (For example: WeCo pledges itself to monitoring our energy consumption, instituting an energy reduction program, and reporting our progress to employees and shareholders. Our initial goal is to reduce energy consumption by 10% over the next 6 years, based on last year's energy consumption and throughput.)
>
> And here are some ideas on how we could structure a program here at WeCo.
>
> (For example: We could begin with a small central energy resource group to identify initial opportunities through site visits and surveys. To help to implement those opportunities and find others, we could name an energy leader at each site. At most sites, that role would take about 25% of an engineer's time, and at larger sites, 50% of an engineering resource.)

And now, armed with management approval and input, and start-up resources, you can begin an energy program for real. Let us start with resources.

ENERGY RESOURCES: ROLES AND RESPONSIBILITIES

A well thought-out energy management program identifies opportunities, sets the bar for ongoing performance, and maintains improvements with a minimum of resources. Resources are necessary, however. First, we will discuss the people resources. It takes the right resources to understand energy data, identify opportunities, act, and track the consequences of acting on the opportunities. It also takes people to design and implement policies and procedures to maintain efficiency improvements.

Energy Manager and Energy Staff

Your job as an energy manager is to help identify, facilitate, and reward energy improvements, using whatever means you have at your disposal. The energy management role generally provides an opportunity to influence others to take action. A good energy management program provides tools and requirements that identify opportunities. Rarely does an energy manager have the authority and budget to actually realize those opportunities. Instead, the energy manager gets to persuade and assist other people in completing the actions or projects needed.

The energy manager has access to all the company's energy information and is responsible for communicating progress toward goals. Formal communications keep management informed about the value of their investment in energy resources and also keep the participants in the energy-saving process informed and, sometimes, rewarded. Informal communications are more important in getting people engaged in the process and producing useful activity. How you do your job is as important as what you do. Here are a few bits of personal advice, from both the "this worked for me" and the "do what I say, not what I did" columns:

- Remember that you are there to help, not to judge.
- Reward successes before you chide failures.
- Be respectful of competing priorities, but be persistent. Give people every opportunity to do the right thing.
- Give credit generously and enthusiastically. Having the idea is not as important as completing the work to deliver the savings. Be a cheerleader.
- Ensure that savings are "owned" by the site where they are generated. You are a helper, not a pirate who swoops in to claim the treasure.
- Look for links between energy and other functions and resources. You can recruit other groups to consider energy in their normal activities, and you can also help out other groups with what you know and the data you keep.

The next section goes into energy accounting more deeply, but a few more bits of advice are useful while discussing the energy management function:

- Create metrics that fairly measure performance and ensure that the metrics are publicized.
- Account for savings clearly and fairly. Energy calculations should be easy to understand and should be based on the same prices or forecasts as are used for any other project or opportunity. There should be no easy opportunity for hand waving or fogging the results. It is better to underestimate (and over deliver) than to inflate expectations and lose credibility.
- Weave energy efficiency into existing processes and systems—both for tracking savings and for maintaining the savings. It is better to make a pretty good addition to a system people understand than to create a perfect but new and unfamiliar system—especially if it takes time away from looking for savings.
- Likewise, consider related process and maintenance benefits as you consider energy projects. For example, improving the efficiency of a major and limiting piece of equipment reduces energy use at the current throughput, but the change could also be used to increase throughput—and still achieve a lower specific energy.
- Bring the energy message to the people and do your best to set their minds on conservation. Remind employees of simple things such as reporting steam leaks,

turning off lights when they leave their offices, and turning off outside lights in the daytime. Posters, publications, and "toys" are useful tools.
- Automate what you can and think ahead for sustainability.

It is very helpful to amass a small group of energy specialists with specialized skills to get the process off the ground. Experience in energy assessment, database construction and management, accounting, process engineering, and best practice gathering is useful. Depending on the types of energy opportunities you find, specific technical skills could be a tremendous asset. In any of the process industries, solid furnace and boiler skills are helpful—both a good understanding of process- and firebox-side efficiency and good furnace maintenance knowledge. Enthusiasm for the tasks ahead, persuasive capabilities, and a desire to help are important personal qualities.

The energy manager and the energy group also represent the company in external associations and forums. Associating with peers brings in new ideas and proven methods for starting and maintaining energy management programs. Public energy meetings also bring out a wide range of service and equipment providers, and create opportunities to discuss the usefulness of the providers and products with their customers. The energy group can also take the lead in seeking public recognition for the company's energy achievements: for example, by certification through the ENERGY STAR program (Chapter 7) or ISO50001/SEP (Chapter 6) or by applying for energy-saving awards. Public recognition also goes a long way toward improving the internal focus on energy efficiency.

Site Energy Leads

It is important for each site to name a local leader for the energy reduction effort. Ideally, the site energy lead will report directly to the site manager, and energy efficiency will be a topic of discussion at each management staff meeting. The fraction of a person's time required at each site will depend on the size and complexity of the site and on the time line set in the energy goal.

An energy lead's duties include collecting and reporting energy data; identifying, justifying, and supporting energy project implementation; and acting as the advocate for energy efficiency at the site. The energy advocate role requires belief in the value of the activity and active engagement with other functions at the site.

If your company has multiple units or sites, bringing the energy leaders together into a team (a best practice team, a center of excellence, or a business improvement team—whatever your corporate culture supports) is an effective way to leverage improvements between sites. Team meetings are helpful, but organizers should be respectful of time and ensure that each meeting provides value to the participants. Statistics can be handled in reports. Regular virtual meetings keep both the team focused and engaged and the team members up to date on issues and plans. For example, the background behind changes in energy statistics or the reasons for a new initiative can be discussed. If Plant A has a highly successful compressed air audit, the Plant A representative can share justification, process, and results with the rest of the team.

Occasional face-to-face meetings provide more space for team members to share ideas and results, ask questions, and help each other with issues. Face-to-face meetings also provide an opportunity to bring in subject matter experts to build technical proficiency, upper management to demonstrate support and value for the program, or colleagues who can discuss the impact of the energy program on their area of business.

The energy manager should provide each team member or site energy lead with a "job description" and a set of ground rules for energy accounting and energy goals. The description and rules should cover reporting requirements (energy use, actions taken to reduce energy, savings, etc.) and frequency of reporting, guidelines accounting for usage and savings, and team input requirements. Providing a resource guide with the available internal and external energy tools and services is important. It is also useful, over time, to check to see if each energy lead has taken advantage of all the energy resources (audits, tools, etc.) available. And most importantly, you as the energy manager should check in with each team member on a regular basis and see what you and your team can do to help.

Operations Management

Operations managers "own" both the energy-using equipment and the people and systems that can control a large part of energy use. In a perfect world, the operations staff provides enthusiastic support and interweaves energy awareness into processes and procedures. Operations managers have approval authority for operating changes and oversight of the operating technicians. Technicians often have excellent energy-saving ideas, and their vigilance maintains energy improvements. Managers' interest ensures the technicians remain interested, and profitability from improved energy performance accrues visibly to their site's economics. It is important to have the operations staff's active buy-in, and in order to achieve that, they must have a say in how the energy program is implemented in their area. This does not mean allowing a handcrafted "I will do this, but not that" approach; rather, it is a collaboration on "how can we best achieve these corporate objectives in your area." Work together, and share your vision and agreement with the entire operations staff.

Maintenance

The maintenance department has the power to control a surprisingly large amount of site energy waste. Active, enthusiastic management of antiwaste programs like steam trap testing, repair, and replacement, steam leak repair, and insulation maintenance have a huge impact. Chapters 9–16 contain a number of energy-critical maintenance suggestions. Maintenance groups are often given a fixed annual budget, and unexpected repairs can whittle away at the discretionary portion of the budget. Waste minimization programs are often the first choice for "saving" maintenance funds. It is important to ensure both that the maintenance group understands the value these programs provide and that the group gets credit for their savings. Often the maintenance group sees no consequence for cutting these programs and no credit for saving them. The energy manager can provide both. Chapters 13 and 14 discuss steam traps and leaks in more detail.

In the longer term, maintenance standards can also have a large impact on ongoing energy costs. Ensure that standards reflect the current economics of equipment replacement and refitting. For example, it is frequently more cost-effective to replace old electric motors with newer, more efficient motors than to continue to rewind older motors. Ensure that insulation standards include appropriate services and thicknesses based on the marginal costs of the heat—or refrigeration—that could be lost. Insulation is discussed in more detail in Chapter 16.

Measurement is also important in energy management. Many plants have meters only at the utility system level, rather than providing meters and measurements for all energy sources at the unit or subunit level. Even when sufficient meters are available to close a unit energy balance, maintaining utility meters is generally given a lower priority than maintaining feed or product meters. Regular attention and good preventive maintenance standards can improve the situation.

Process Control

It is worth the time and effort to ensure that reasonable marginal costs of energy are included in process-side advanced process control (APC) and optimization calculations. Advanced control of boilers, furnaces, and utility systems can also bring substantial benefits. Real-time optimization of complex utility systems can also be worthwhile, as discussed in Chapter 19.

Collaboration between the energy manager, site energy leads, unit operators, and process control engineers can highlight opportunities to use APC methods to balance energy needs and energy generators. Better control of utility systems can even allow the shutdown of individual utility generators or plants for increased savings.

COMPONENTS AND SYSTEMS

We have identified the key people; now we will discuss the systems necessary to success for the energy management program. The following are key components of an energy management program:

- Data collection and analysis
- Goal setting
- Identification of opportunities
- Implementation of opportunities
- Reporting and recognizing achievements
- Re-evaluation and renewal

While each component is important, some components will evolve faster than others in a new energy management program. It is more important to get started than to have each step fully planned out and methodically executed. Set a basic plan and get going, and refine the plan as you go along. Early savings provide motivation and secure resources, as well as provide learning that can be applied to the evolving program. Even mature and successful programs continue to evolve to adapt to changing situations.

Data Collection and Analysis

Data collection and analysis depends on measurement, accounting, and benchmarking. Handling the data also requires an understanding of the program's ground rules for accounting.

Ground Rules: Basis and Calculation Methods. Savings in pursuit of a goal must be clear and calculable, from an easily understood baseline. The full year before the program starts makes a useful baseline. If that year's operating rate was unusual for a plant, such as the effect of a major turnaround, an average of 3 years' data may be more appropriate.

Progress against goals should be measured in terms controllable and understood by the participants. For example, a change in energy consumption (Btu) is a better goal than a change in spending on energy ($) because of fluctuations in market prices. Sites can control processes, however, and can be accountable for the way the processes run. For some processes, specific energy use per pound or ton of product is an easily understood goal. For other processes, optimum feedstock choices or reaction severities are more valuable than specific energy, and the optimum energy use will change as situations change. Is there a way to easily measure the gap between the optimum and actual energy use? Discuss this with the process control or production planning group and incorporate their input into the energy goal.

If the savings goal is expressed as a percentage of base year energy use, the annual goal becomes harder to achieve as energy use declines. Should the basis be reset at some point? Should each year's goal be relative to the year before?

Savings must also be calculated in a defensible fashion. While reduced usage is a good thing, a site or unit should be able to show that it took action in order to achieve the savings. Reducing waste by changing an operating condition is as valid an action as installing a new heat exchanger. In most cases, the savings are best represented at average conditions—average operations and average reactor conditions—rather than at design or actual operating conditions. To be completely accurate would require the database savings to be a calculated function of operating rate and reactor severity, but to track those fluctuations would generally take more time and effort than the value the accuracy could provide. If a project is so material to the company's energy use that it is worth the effort, by all means you should be more accurate—preferably by performing the calculations in the plant data historian.

Justifications for energy-saving projects should reflect the company's official economic outlook, meaning that energy projects should be justified using the same pricing assumptions as every other project. It is necessary, however, to represent relative risk appropriately. Energy projects often have a much lower risk than new products or expansions, where product price or demand changes can eliminate returns. If the energy price drops, project returns can drop, but rarely do the energy savings drop to zero.

This lower risk can be expressed through sensitivity calculations or in the manner your company normally treats risk.

Measurement. The measurement of energy use and energy savings must be balanced between data accuracy and the effort and expense required to provide the data. Survey the energy metering and the details that are available to you now at each site. Do the data from various sections of the plant add up to the site total? Are the data detailed enough to provide a clear picture of the energy use of significant portions of the plant, and of the significant users? Can you create a history of energy use that is meaningful to the site? Accurate-enough measurement of energy use provides a clear-enough picture of the performance of the unit or portion. It can also identify opportunities for improvement, and it allows savings to be measured. In an ideal world, the energy consumption of individual pieces of high-energy-use equipment, individual units, and meaningful sections of units and plants would be measured. In reality, there may be one electricity meter for the whole plant, and one steam flow meter on the main boiler. It can be difficult to justify new utility metering, but you should be able to make a case for clarity when the usage is material and variable. Utility meters are generally low on plant preventive maintenance priorities as well. Meters are useless if they are not maintained to a reasonable degree of accuracy. Ensure that key energy measurements are treated appropriately in the preventive maintenance schedule.

Accounting. In order to maintain and evaluate the effectiveness of an energy management program, energy data must be collected and analyzed. Collecting credible utility data in the plant data historian provides tracking capability at a low "people" cost. Ultimately, all energy use and energy-saving projects and actions should be collected in a database of some sort. Careful forethought will minimize the time required, rework, and irritation. It is certainly possible to start with a spreadsheet, but designing an energy database and thinking ahead about its contents and dimensions are worth the time. Again, it is more important to get started than to create the perfect database, so by all means go ahead and build the spreadsheet while you think about the database.

That said, an ideal energy database would pull historian data into a central repository for all sites. In many cases, however, that level of communication through various firewalls is difficult and human intervention is necessary. A benefit of intervention is that the energy lead can "smell test" the data and catch metering errors or even a significant issue in the plant. The downside is that it takes time for the energy lead to enter the data into a separate database, and data entry is not the best use of an engineer's time. Ideally, the site lead would initiate an automated data collection, give it a quick look, and then upload it into a combined company database. Discussing the functions needed in the database with the IT department should lead to a solution that achieves your needs in a way that is time efficient, easy to learn, and robust.

It is also useful to track what type of energy is being used. Again, complexity and accuracy must be in balance, but it is reasonable to separate electricity, fuels, and different levels of steam. These histories can also be used to optimize utility systems.

Chapters 17–19 discuss steam balances, steam pricing, and steam system optimization. Tracking the utility type can also allow the environmental benefits of energy savings to be tracked accurately.

Benefits are the more exciting—and the more complex—side of energy data collection. How will you track improvements? Again, thinking ahead will give you credible data that you can use to support longer term programs as well as report the results of your early efforts. Reporting is a balance between useful details and the time and complexity required from the reporters.

Experience provides some useful details to collect about each energy-saving action:

- Type of project
  - Operations change
    - Immediate or relatively quick
    - No or little spending required
    - May require a change in operating procedures or targets
    - Generally provides ongoing savings for a given operating mode
  - Maintenance spending (e.g., steam leak or steam trap programs)
    - Generally requires ongoing spending
    - Generates savings that exceed costs and are ongoing or have a sawtooth decay/repair pattern
  - Capital project
    - Requires justification and budgeting
    - Has a timing profile associated with both savings and spending
    - Generally provides ongoing savings
- Savings profile
  - Savings rate and timing
  - Savings duration (ongoing or one time)
- Spending profile
  - Spending rate and timing
- Source of savings
  - Steam and pressure level
  - Fuel
  - Electricity
- Environmental benefit of savings (dependent on energy source and site)
- Project status
  - Completed
  - In progress
  - Not currently active (useful to collect ideas or maintain “almost” projects)

The following are some hard-won insights into useful features to build into a database, should you decide to build one:

- Plan for easy uploading of data collected from plant historians.
- Design input forms that are as intuitively obvious as possible.
- Insist that each number in the database has an associated set of units. Energy could be entered in kWh or in Btu or in kJ, but the unit is a part of the value and the value is useless without the unit. This is obvious to engineers, but experience suggests it is not so obvious to programmers.
- Facilitate unit conversions so that people can enter data in the units most familiar to them.
- Provide reporting tools so that common reports can be generated easily.
- Consider the time increments for data gathering and for reporting. Should data be collected daily? Monthly? Quarterly? What roll-up increments are necessary, and how will you handle increments of varying length?
- Provide common analysis tools, but also allow the data to be dumped into a spreadsheet for a more personalized analysis. Pivot tables are very powerful.
- Finally, think about how to track actual energy costs. Costs are often markedly different from site to site and from utility to utility. An energy management program should focus on saving energy, which is controllable, rather than on money, which fluctuates with prices, but the program must be able to explain its worth. Consider the effort–accuracy balance for site and overall energy prices. Whether prices are internal to the energy database or tracked externally is your call.

Benchmarking. It is useful to compare each unit and site with its own past performance to determine energy savings, but the internal view is not very useful in determining how the process compares with its competitors. Several companies provide confidential benchmarking services, and benchmarking is discussed at greater length in Chapter 5. An understanding of benchmark energy use and any structural differences between your processes and competitors' processes is necessary to set realistic goals for each site and for the organization.

Another valuable source of "benchmarking" information is the original design data for each process, or the updated design after major revisions. Does the process operate at or near the specific energy inherent in its design?

Goal Setting

An energy goal focuses attention on improvement, and the goal can reflect a number of corporate concerns. If competitive position is important, the goal can be stated in terms of closing any gap between the company's performance and the benchmark energy performance of competitors. The company may have the capability and desire to be a pacesetter in energy performance, and the goal can reflect a commitment to change the energy profile of the company. Some companies spur employees into action with a "big, hairy, audacious goal," believing that a big vision produces big results. Different processes or sites will have different opportunities and different opportunity costs. Goals can be tailored to fit those different opportunities, but in that case they must be communicated very carefully so as not to create the belief that energy conservation is the responsibility of only some sites and not others. It may be better to set the same goal for all sites and excuse poorer performance in sites with fewer opportunities.

Whatever the chosen goal, it should include the expected change in performance and the time allowed to make the change.

Identification of Opportunities

The right people resources have been identified. Many will already have the skills and good ideas necessary to capture energy improvements, but they will be even more effective with a more specialized set of energy tools and methods. The second half of the book contains more detailed discussions of technologies and tools for saving energy. A very brief overview is given herein, with an emphasis on bringing resources together to use the tools and identify the opportunities.

Site Energy Reviews. Often the most effective way to find and begin implementing energy improvements is to get all the interested parties into one room for a structured discussion of their plant. Careful preparation and actively involved stakeholders are critical to success. A good energy review leaves a site with its own plan, developed by its own people and supported by its management.

Work with the plant energy lead to gather site energy data, benchmarking data, process flow diagrams (PFDs), and major equipment specifications. The U.S. Department of Energy (DOE) plant energy profiler (ePEP) tool's questions help gather all the relevant energy and equipment information for the plant and the profiler identifies many potential opportunity areas. The energy group and the site energy lead can work through the Profiler in preparation for the site energy review. At the time of this writing, the Plant Profiler is available for free download at https://ecenter.ee.doe.gov/EM/tools/Pages/ePEP.aspx.

The actual review can be led by knowledgeable internal resources (e.g., energy group members) or by an external consultant, and should include representatives from engineering, operations, and maintenance functions. The team should "walk" through the unit via the PFDs, taking note of changes in operation or in performance compared to design. Are major energy users operating at or near their design efficiencies? Is all the heat recovery equipment clean and in service? Have any short-term operating changes been overlooked and become long-term energy drains? The team can discuss any opportunities identified by the Plant Energy Profiler as well. Chapter 25 also discusses process reviews and improvements.

The team should also physically walk through the unit looking for opportunities such as steam leaks, failed steam traps, missing or damaged insulation in hot or cold areas, or compressed air leaks, and noting their findings.

The team, or a portion of the team, should then consolidate the notes and estimate the energy savings available from each opportunity identified, and the costs, time, and resources required to capture each opportunity. The estimates do not have to be perfect, but they should be reasonable and defensible. Group the opportunities into categories—things to do immediately with available resources, capital projects, turnaround projects, and maintenance programs—and put together a rough action plan for the site. Each review should end with a report out to the plant management, including value, costs, timing, and comparison of expected results with the energy goal.

Energy Tools Overview. A wealth of energy tools is available through both public sources and commercial vendors. Some are easy to use and others require training or even certification. We cannot begin to list the commercial tools for process simulation, furnace simulation, steam or cooling water network evaluation, or even energy management practice evaluation. Many vendors of equipment and services would be happy to survey your plants' version of their systems, either in anticipation of sales or for a fee. Steam trap surveys are a good example (Chapter 13).

We will highlight some offerings from a free, public source: The US Department of Energy's suite of tools is available for free either for on-line use or as downloads, and their entire tool suite is outlined at https://ecenter.ee.doe.gov/Pages/default.aspx.

The tools offered have changed over time in response to changing needs. Some of the tools available at the time of this writing are discussed below, with the DOE's descriptions:

1. *Steam System Modeler Tool* (*SSMT*)*:* This new on-line tool allows you to create up to a 3-pressure-header basic model of your current steam system. It includes a series of adjustable characteristics simulating technical or input changes, thereby demonstrating how each component impacts the others and what changes may best promote overall efficiency and stability of the system. SSMT replaces an earlier spreadsheet-based modeling tool, *Steam System Assessment Tool (SSAT).*
2. *Process Heating Assessment and Survey Tool (PHAST)* introduces methods to improve the thermal efficiency of heating equipment. This tool helps industrial users survey process heating equipment that consumes fuel, steam, or electricity, and identifies the most energy-intensive equipment. The tool can be used to perform a heat balance that identifies major areas of energy use under various operating conditions and test "what-if" scenarios for various options to reduce energy use.
3. *Pumping System Assessment Tool (PSAT)* is a free online software tool to help industrial users assess the efficiency of pumping system operations. PSAT uses achievable pump performance data from Hydraulic Institute standards and motor performance data from the MotorMaster+ database to calculate potential energy and associated cost savings. The tool also enables users to save and retrieve log files, default values, and system curves for sharing analyses with other users.

4. *Other:* The DOE also offers tools for assessing fans and compressed air systems, motors, and solar power, as well as guides for energy management.

Another very useful tool available for free download is *3E Plus*®, which comes from the North American Insulation Manufacturers Association (NAIMA). The program calculates the most economical thickness of industrial insulation for user input operating conditions. The user can carry out calculations using the built-in thermal performance relationships of generic insulation materials or supply conductivity data for other materials.

Good Engineering Practices. Designing energy efficiency into new processes is the best way to ensure that they operate efficiently. Process engineers routinely optimize operating pressure, recoveries, and costs in distillation. They can utilize pinch analysis (Chapter 26) to optimize heat recovery and its costs and evaluate new exchanger technologies. They can also be aware of energy loss through pressure drop. When a process change is anticipated, process engineers should take the time to look at its energy impact and reoptimize the utility systems if necessary. A major energy efficiency change could also bring new process-side opportunities, particularly if the energy user was a bottleneck for process throughput or reaction conditions.

Likewise, robust mechanical engineering standards and practices should ensure that life cycle costs are considered in equipment choices and should set expectations for motor efficiencies, repair versus replacement decisions, preventive maintenance, and insulation and refractory standards.

Energy Optimization. Just as including energy costs and constraints in process-side advanced process control provides benefits, utility systems can benefit from advanced process control and optimization. A complex steam system can be operated more efficiently if boiler rates, steam rates at each pressure, pump drivers, and variable steam demands are optimized (Chapter 19).

Implementation of Opportunities

This section provides some recommendations for implementing different sorts of energy opportunities to achieve real energy reduction results. The most important recommendation for a new energy reduction program is go for the "low-hanging fruit." Early and free, or inexpensive, savings improve energy program credibility in several ways: They justify the use of people resources to look for savings, they prove that savings are available, they show that even good operations can be made better, and they show that the energy team is and will be good stewards of the resources assigned to the program. Look for waste and for easy operating changes first. Capital requests to capture energy benefits are easier to justify when all the no-capital opportunities have already been captured, and the low-hanging fruit can help fund longer term projects.

In general, energy opportunity projects should be implemented as if they were any other project, using the processes and procedures already in place in the plant. Since energy use is subject to "drift," some extra care should be taken to document and preserve the new equipment, program, or operating scheme in the collective consciousness.

Operating Changes. The site energy lead should engage operations and process engineering to implement changes in set points or procedures. In some cases, an operating change may take a process into an unknown territory. Use the best practice team to see if another plant can provide information on its impact. Ensure that the change is sustainable by recording it into operating orders or procedures.

Maintenance Programs. Once again, the site energy lead should engage the maintenance and operations staff to implement a change. Often several sites have similar maintenance needs and programs, and the energy group should consider advocating for a corporate policy and a set-aside budget for the work.

Capital. Usually energy projects are subject to the same capital limitations and procedures as any other project, and must compete for funding against all other projects. Sometimes energy projects are developed in an "energy silo." Ensure that other groups are informed and involved in the development of the energy project so that any associated improvements or alternative uses are considered in the project's justification, and also that energy impacts are considered in the justification of other projects. It is much easier to justify energy improvements in conjunction with process changes or debottlenecks. Also ensure that the risks associated with project earnings are outlined appropriately. As discussed earlier, energy projects generally have a lower risk of loss than many other types of projects. Project earnings are reduced if energy prices or throughputs fall, but energy costs never go away while the unit is running—therefore, for most energy projects, earnings cannot go to zero.

Reporting and Recognizing Achievements

Communicating energy-saving progress is critical to maintain support for the program and to recognize good work by the sites, as well as to hold each site accountable for its goals. Progress reports can be generated from the energy database or from separate record keeping. It is useful to be able to provide the same report format at a unit, site, division, and corporate level. Some sites may wish to express the same goal differently.

Often the energy-savings goal is expressed as a percentage of a baseline year's use. Tracking savings is relatively simple, and each site is held to the same standard, regardless of its base usage. Figure 1.3 shows an example format for three sites.

While sites cannot be held responsible for energy price fluctuations, costs are something they truly understand. It is inspirational to translate energy savings into cost savings for a time period. One meaningful way of tracking the value of the program is shown herein. If you have chosen to track energy prices (either by site or by average of the company), it is relatively easy to combine cumulative energy savings for any time period and the price for that time period. You can calculate the value of the savings to date for each period. You could also subtract the costs of the program in each period and

Site	Baseline usage Trillion Btu/yr	New 2015 reductions Trillion Btu/yr Q1	Q2	Q3	Q4	New 2016 reductions Trillion Btu/yr Q1	Q2	Q3	Q4
A	20.0	0.1	0.1	0.1	0.1	0.1			
B	60.0	0.8	0.1	0.3	0.1	0.2			
C	27.0	0.1	0.1	0.2	0.1	0.1			

Site	Baseline usage Trillion Btu/yr	New 2015 reductions % of baseline Q1	Q2	Q3	Q4	New 2016 reductions % of baseline Q1	Q2	Q3	Q4
A	20.0	0.3%	0.5%	0.5%	0.4%	0.5%			
B	60.0	1.3%	0.2%	0.5%	0.2%	0.3%			
C	27.0	0.2%	0.2%	0.6%	0.2%	0.2%			

Site	Baseline usage Trillion Btu/yr	New 2015 reductions Cumulative % of baseline 1Q15	2Q15	3Q15	4Q15	New 2016 reductions Cumulative % of baseline 1Q16	2Q16	3Q16	4Q16
A	20.0	0.3%	0.8%	1.3%	1.7%	2.2%			
B	60.0	1.3%	1.4%	1.9%	2.1%	2.4%			
C	27.0	0.2%	0.4%	0.9%	1.1%	1.3%			
Goal		0.5%	1.0%	1.5%	2.0%	2.5%			

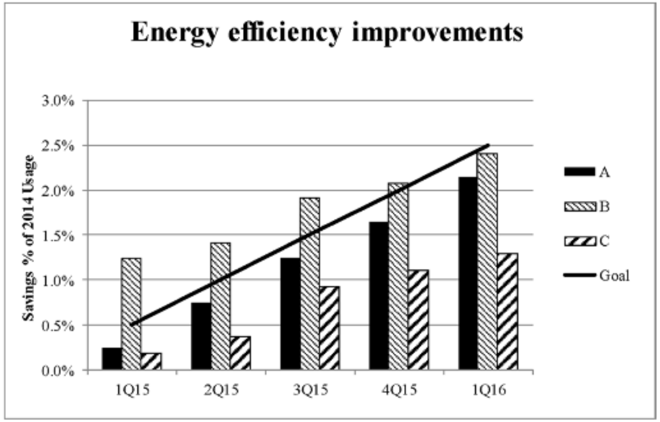

Figure 1.3. Tracking energy savings for three sites.

show net savings, or simply report the total cost along with the accumulated savings (Figure 1.4).

Re-evaluation and Renewal

Just as data become clearer with analysis, the potential for energy savings at each site becomes clearer as it is explored, and the efficacy of each energy program component becomes clearer as it is put into use. In the spirit of continuous improvement, you should pause periodically to adjust methods and expectations and refocus the energy effort. Chapters 2 and 3 have good discussions of how this works even in mature and successful programs.

The following are some of the points to ponder:

How is the company performing versus its goals? Is the performance a function of the goal or of the actions in response to the goal? If most sites are exceeding the goal, maybe the goal was set too low. How much work has been done? Perhaps the company should be celebrating an exceptional effort, or perhaps it should set its sights higher. On the other hand, if most sites are not reaching the goal, there are other questions to ask. Is the goal unrealistic, or has the response been less than exceptional? Are the sites availing themselves of the services and tools available to them? Has the company supported the goal with both people and economic resources? Consider all these factors in continuing or adjusting the goal, and follow through with the discussions necessary to reward good efforts, align the resource support with the opportunities available, and refocus the laggards on expectations.

What is the potential for energy improvement going forward? Have justifiable projects and actions been proposed? What is the balance between potential savings at low cost and potential savings that will require more expensive changes to the process? Are the resources available to execute the projects and actions? Is it worthwhile to develop an energy plan for each unit or site that includes cost and ultimate energy benefit, both in savings value and in competitive position, and a realistic timeline for execution?

How is the best practice team performing? Are true best practices recorded, shared, and adopted? Are the team members engaged? Talk to the team to see what elements are working for the members and what they feel could be de-emphasized. What are their greatest needs to help them do a better job?

Are the right resources employed in finding and implementing energy savings? Do you have the right members on the energy team? Are there technical or managerial gaps, or new resources that could be applied to the effort? Are the capital and maintenance budgets sufficient to meet the goals?

ONWARD AND UPWARD!

Now that we have discussed the "hows" of starting and sustaining a successful energy management program, we will spend the rest of Section 1 examining successful corporate energy management programs, benchmarking techniques, and general energy

Total ongoing energy savings, trillion Btu/yr (using half-period convention)

Site	1Q15	2Q15	3Q15	4Q15	1Q16	2Q16	3Q16	4Q16
Site A	0.03	0.10	0.20	0.29	0.38			
Site B	0.38	0.80	1.00	1.20	1.35			
Site C	0.03	0.08	0.18	0.28	0.33			

Site average energy price, $/MBtu

Site	1Q15	2Q15	3Q15	4Q15	1Q16	2Q16	3Q16	4Q16
Site A	2.13	2.45	2.31	2.76	2.61			
Site B	1.85	1.95	2.00	2.25	1.85			
Site C	2.00	1.87	2.10	2.20	2.40			

Achieved value of savings activity, M$

Site	1Q15	2Q15	3Q15	4Q15	1Q16	2Q16	3Q16	4Q16
Site A	0.05	0.30	0.76	1.56	2.55			
Site B	0.69	2.25	4.25	6.95	9.45			
Site C	0.05	0.19	0.56	1.16	1.94			
Total	0.80	2.74	5.57	9.68	13.95			

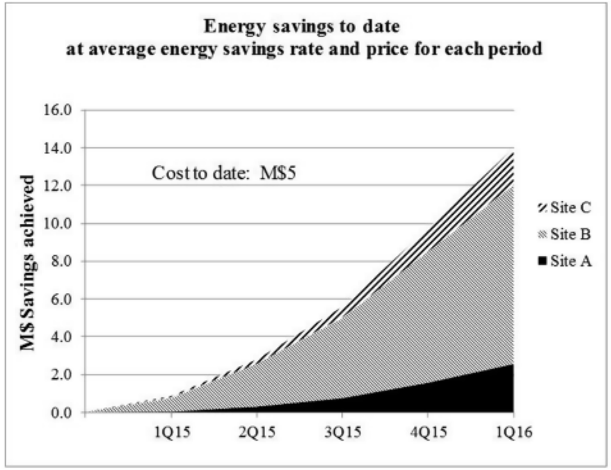

Figure 1.4. Tracking accumulated cost savings for three sites.

management systems. In Section 2 we will concentrate on the “whats”: expert technical help in techniques and process insight toward saving energy, with particular focus on the energy users most significant to the process industries.

REFERENCE

1. U.S. EPA (2004) Unit Conversions, Emissions Factors, and Other Reference Data. Available at http://www.epa.gov/appdstar/pdf/brochure.pdf (accessed November 2004).