2. Energy Management

2.1 Overview

While many chemical companies have tried to manage energy expenses by seeking cost-effective fuel sources, few have investigated the substantial savings inherent in energy management. Why? In simple terms, most manufacturing facilities lack organizational support for energy management despite the fact that it improves production, performance and profits.

The term "energy efficiency" refers to practices and standards set forth in an energy management plan. Energy efficiency initiatives should be selected for their ability to reduce expenses, build revenue, and contain operating risk.

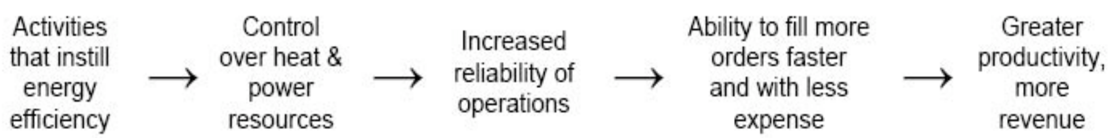

Figure 2.1 Flow Chart of Energy Efficiency Activities[8]

As illustrated by Figure 2.1, unchecked energy expenditures impact every area of production and can actually decrease overall productivity. Facilities of all sizes, shapes, and functions use energy, so the potential for energy-based productivity gains is pervasive. Energy management is an ideal way to secure a competitive market advantage.[8]

2.2 Questions Concerning Current Management Plans

Companies that use management plans like Lean, Total Quality (TQ), Six Sigma, ISO 9000, and Theory of Constraints to achieve world-class performance may wonder whether an energy management (EM) program will work within their current initiatives and constraints. The answer, in *all* cases, is a resounding *yes*! EM will complement any initiative, regardless of a company's state in the process. Whether a company's just beginning TQ or is well into ISO 9000, it will still benefit from a strategic energy management program.

2.2.1 Lean

According to the principles of Lean manufacturing, there are seven forms of waste: overproduction, unnecessary inventory, excessive transportation, inappropriate processing, unnecessary motion, waiting, and defects. At least five and arguably, all seven, involve energy waste. Clearly, efforts to manage energy are consistent with reducing waste.

2.2.2 Total Quality

Parallels exist between Total Quality and energy management as well. Both start with a commitment from the top, are data driven, and involve a cultural change for all of the employees in the organization. TQ provides many tools to make an EM program more effective.

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[8] Russell, C., Alliance to Save Energy, *Energy Management Pathfinding: Understanding Manufacturers' Ability and Desire to Implement Energy Efficiency*, March 2005.

2.2.3 Six Sigma

Six Sigma, which is data driven, focuses on improving the quality of all processes, including energy management plans. Similar to TQ, the tools of Six Sigma can and should be used to enhance the quality of an effective EM program.

2.2.4 ISO 9000 and ISO 14000

ISO 9000 and ISO 14000 are also widely used in the chemical industry. These two standards will work with EM to simultaneously build high quality into the EM program and to improve the program as it develops over time.

2.2.5 Theory of Constraints

Theory of Constraints (TOC) is based on the concept that improving a few capacity constraint resources in a production system will have the greatest impact on the bottom line. In energy intensive industries like chemical processing, energy intensive equipment and operations are frequently the largest bottlenecks in the process. When such equipment is truly a physical constraint, reducing energy consumption per unit by increasing the flow rate at that piece of equipment will significantly improve bottom-line performance.

2.3 Energy Management Strategy Guide

While technology is fundamental to increasing efficiency through energy management, the real key (and often, the real hindrance) is the people charged with energy management duties. The main goal of any company attempting to reduce energy consumption through the use of an energy management plan should be to integrate the strategy into the daily operations and responsibilities of its management and employees.

The following energy management strategy guide may be useful to individual companies interested in developing a plan of action. It is important to note that energy management motives and approaches vary from company to company; there is no “one size fits all” plan. Therefore, prior to implementing a plan, companies must do an internal evaluation to determine the strategies that will work best for them.

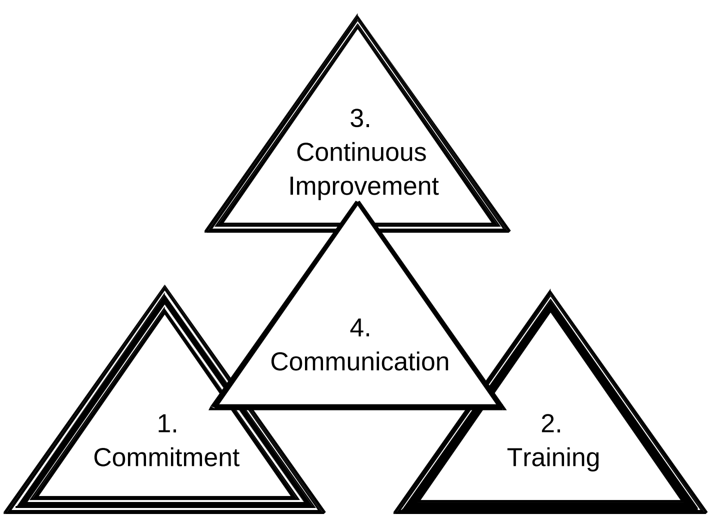

Figure 2.2 Energy Management Guide

A strategic approach to energy management can result in significant energy savings and improved productivity for all types of chemical producers. A general guide for an energy management model is depicted in Figure 2.2. The model requires the coordination of four main issues:

1. Commitment from leadership.
2. Continuous training of personnel at all levels.
3. Continuous improvement through strategic goals and action plans.
4. Communication of all involved in the energy management concept.

This model draws on ideas from several existing programs, including the "Energy Star" program developed jointly by the U.S. Department of Energy and the Environmental Protection Agency.

2.3.1 Make the Commitment

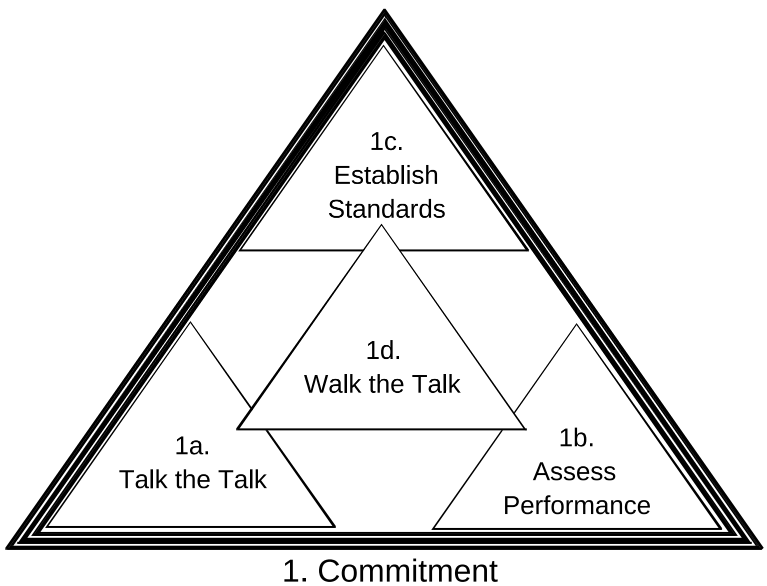

Figure 2.3 Making the Commitment Guide

Dr. W. Edwards Deming, an Iowa native whom many consider to be the founder of the Total Quality (TQ or TQM) movement, refused to work with an organization unless its top leaders were involved in the improvement process. Commitment starts at the top, he believed. So it is with energy management—an effective EM program starts with the support and participation of company leaders. So, what constitutes real participation?

Talk the Talk (1a Figure 2.3)
Company leaders must be strong advocates for an EM program. In addition to supporting a corporate energy policy, they should make EM part of the corporate strategic plan, tying it to financial and environmental goals.

Assess Performance (1b Figure 2.3)
Once energy management is truly on the corporate radar screen, an initial assessment of energy performance is necessary. It should include an understanding of the energy cost structure as well as an understanding of current energy use and trends. A more detailed discussion of these concepts follows.

Understanding the Energy Cost Structure
Utility companies generally determine the energy cost structure. Most utilities have multiple rate plans, which can complicate attempts to understand them. Customer service representatives work with businesses to ensure that the most favorable plan has been assigned. An onsite visit from the energy provider is one way to facilitate a discussion on energy needs and cost structures.

Understanding Current Energy Usage and Trends
Understanding current energy usage and trends goes hand-in-hand with understanding energy cost structures. Usage dictates the choice of rate plan, and the rate plan greatly influences cost-savings strategies. As much as feasible, energy usage should be tracked by both end use and fuel type.

End Use
An important step in energy management is determining the exact sources of energy consumption. The Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) recommends establishing Energy Accountable Centers (EAC)[9] to facilitate this step of the process. These are production areas that are neither too small nor too large, in which energy consumption can be independently measured and reported. (It may be necessary to install meters for this purpose.) For example, it may be revealing to monitor the energy consumption of a separate building, a central boiler house, or a specific production line.

Many of the details of the end-use patterns can be defined by a technical assessment or energy audit. There are many sources for these audits. Larger companies may want to participate in the DOE's Plant Wide Assessment (PWA) program. "Plant-wide energy assessments investigate overall energy use in industrial facilities, and highlight opportunities for best practices in energy management, including the adoption of new, energy-efficient technologies and process and equipment improvements."[10] These projects, which require matching funds from the company, bring world-class experts into the facility. A very successful plant-wide assessment was done in Iowa at North Star Steel; details are available on the DOE website listed in the footnote below.[11] PWAs are competitive grants and most medium- and smaller-sized companies will not be able to participate in this large-scale project.

Another valuable resource for energy assessments is the DOE-funded Industrial Assessment Center (IAC). The IAC provides free energy audits to small- and medium-sized facilities. The

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[9] *Energy Management in Industry, Analyses Series 17*, Centre for the Analysis and Dissemination of Demonstrated Energy Technologies, CADDET 1995.
[10] *DOE: Plant Wide Assessment*, http://www.oit.doe.gov/bestpractices/plant_wide_assessments.shtml
[11] *North Star Steel Company: Iowa Mini-Mill Conducts Plant-Wide Energy Assessment Using a Total Assessment Audit,* http://www.oit.doe.gov/bestpractices/factsheets/steel_cs_northstar.pdf

center that serves Iowa (and some of the area in surrounding states) is located on the Iowa State University campus. For more information about the program and complete eligibility requirements (less than 500 employees, $100K to $2.5M in energy costs, etc.) check out the website listed in the footnote below.[12]

A third resource for identifying potential energy efficiency assistance is CIRAS or the Iowa Manufacturing Extension Partnership (IMEP). CIRAS/IMEP can conduct onsite assessments and connect manufacturers with the appropriate programs or resources to help them with their energy needs.

Fuel Type

Businesses that use multiple sources of fuel (e.g., electricity, natural gas, oil, and/or steam) are encouraged to keep records of the amount of each fuel type consumed. It can be useful to measure the distribution of major energy forms such as steam in order to know the total amount of steam used by any one piece of equipment.

Establish Standards (1c Figure 2.3)

A system of energy accounting is needed to collect and track useful data. This involves defining the data to be collected and the measures to be generated. Each company should develop a customized prime measure to calculate whether the energy purchased is being productively utilized.

Energy Productivity Index

The energy productivity index is a ratio of energy consumed, usually stated in British Thermal Units (Btu), to a chosen base unit. This performance measure is very important, so the base unit must be carefully chosen. Possible base units include:

- per square foot of space
- per piece manufactured or shipped
- per pound, gallon, or some other measure of output
- per dollar of sales
- per dollar of “value added”

Each of these possible base units has advantages and limitations. For example, using square footage makes more sense when HVAC is the primary energy consumer but less sense when process energy consumption is significant. The shortcoming to using dollars of sales is that, over time, the figure is distorted by inflation. Using pounds, gallons, or some other appropriate measure of output/volume that has a logical relationship to energy consumed is often a good approach. It may be advisable to use a monetary unit that’s directly related to business performance, like dollars of value added. Using both of these measures will give company leaders two important views: how energy management reduces energy cost when measured by cost per unit volume of output, and how energy costs compare to the prices that customers are willing to pay for value-added products.

[12] *Industrial Assessment Center*, http://www.me.iastate.edu/iac/

Energy cost index

One additional useful index is the energy cost index. It compares the cost of energy to some base unit (as opposed to the number of Btus consumed). The base unit should be the same unit used for the energy utilization index.

Productivity Standards

Most chemical processors have standards for judging the performance of their production system over time. Similarly, it is recommended that standards be established for energy usage so that the performance of the EM system can be judged over time. Two basic approaches to establishing standards are discussed in the following paragraphs.

Engineering data can be used to calculate energy and mass balances, and the amount of energy theoretically required when equipment in the plant is performing optimally. However, while this calculation is useful, the result is often not considered “realistic” or achievable “in the real world.” For this reason, some will reject using this as a standard.

A second method is to compile data on past energy consumption. This data should be segmented by EACs whenever possible. An average consumption over some period of time can be calculated and used as a standard. To be “realistic,” it may be necessary to consider factors such as time of year; the “standard” amount of required energy can vary greatly depending on outside temperature and humidity.

While average past energy consumption might accurately predict probable future energy consumption, it does not give any indication of how efficiently energy is being used in each EAC. For this purpose, a combination of the two methods may be useful. The calculations based on the engineering data that show theoretical optimal efficiency can be compared with the average (or seasonal average). This will give an idea of the “money on the table,” or theoretical potential savings from improving efficiency.

Companies may choose to set the standard at the statistical average or at a different point based on the theoretical optimum. In either case, performance can be monitored against the standard and variation can be managed appropriately according to each company’s chosen management approach.

Another possible source for setting a standard is benchmarking. This technique has strong supporters and opponents. To be effective, benchmarking requires enough demographic and quality information about another company to determine whether or not a comparison is appropriate. In other words, the comparison should be apples to apples, not apples to oranges.

It may be safer to benchmark against “best practices.” For example, DOE has developed computer-based tools that allow one company that uses steam to compare itself to another company that also uses steam. These tools are available at no cost at the website in the footnote below.[13]

[13] *DOE Industrial Technologies Program,* http://www.oit.doe.gov/bestpractices/software_tools.shtml

One of the basic tenets of Lean Manufacturing, a method for reducing waste, is "perfection." Rather than being satisfied with meeting some benchmark, companies are urged to relentlessly pursue perfection or zero waste. Zero waste in energy consumption may be hard to define, unless the calculated theoretical energy balance point mentioned earlier is used. Opponents argue that perfection is not a realistic goal because it is impossible to achieve. On the other hand, advocates stress that it is the pursuit of perfection that forces managers to look for the breakthrough ideas that bring into reach that which was previously thought to be impossible.

Assigning Causes for Variation

Once energy accounting is established and standards are set, management should begin to compare actual performance to the standards. However, these comparisons alone do not give a complete picture of what is happening. In order to understand whether a variation is a "normal" statistical fluctuation or something more significant, there must be a thorough understanding of the complete set of measures.

For example, tracking the energy cost index helps management isolate one possible source of variation in the energy productivity index. If energy productivity has deteriorated in the most recent analysis period, some—or all—of the drop may be attributable to an increase in energy costs.

Additional information may be gained by tracking the trend of energy cost per Btu. This will help determine whether an increase in the energy cost index is attributable primarily to an increase in the base cost of energy/Btu or an increase in Btus per chosen unit of output.

Following are other common, identifiable sources of variation in energy costs. The time period for all such assignable factors should be noted on the data records.

- seasonal weather changes
- increases in total output
- product mix variations
- physical changes to the system such as the installation of pollution control devices
- use of an alternative fuel
- pilot programs
- specific conservation efforts

Walk the Talk (1d Figure 2.3)

The central component in Figure 2.3 is "Walk the Talk." Company leaders must commit resources including time, talent, and money on an ongoing basis. Attention at the outset followed in a few months by a total disregard for EM will doom energy management efforts to mediocrity at best, and failure at worst.

Indications that senior leadership has an ongoing commitment to energy management include the following:

- A corporate champion is named, and, in larger companies, a team is identified.
- Accountability is clearly established.
- EM is an agenda item at all regular leadership meetings.

- The energy policy is evaluated regularly and updated as needed.
- Adequate budget is provided annually for effective EM.

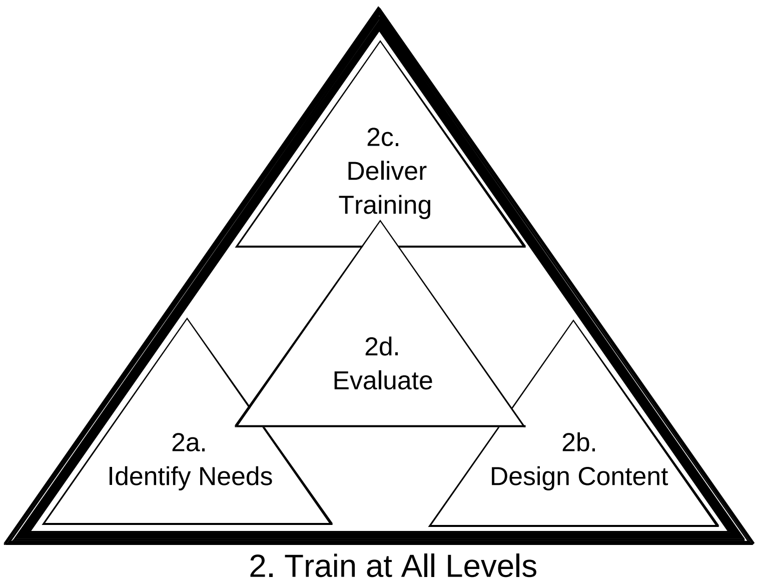

Figure 2.4 Continuous Training of Personnel Guide

After company leaders have made the commitment to an EM program and after current energy performance has been assessed and standards set, it is time to provide training for all company personnel. Sharing information and increasing the knowledge level of employees is a prerequisite to the successful implementation of an EM plan. The opportunity to express personal opinions, ask questions, and get answers generally increases the level of engagement for individuals. Employees are more likely to be motivated to save energy if they feel engaged in the process. Steps for engaging workers follow.

Identify Training Needs (2a Figure 2.4)
Initially, every employee will need training on topics such as awareness of the corporate energy policy, current energy usage and trends, basic EM terminology, and energy measures. More specific topics such as boiler management or assessing return on investment in energy projects will be delegated to smaller groups. Be sure to take the time to identify the general and specific needs of the entire staff.

Design Content (2b Figure 2.4)
To create training content, begin by identifying the specific learning objectives for the targeted individuals. The delivery methods and materials should be chosen to maximize the likelihood of reaching the learning objectives. Training that is specific to a company program will probably have to be developed in-house. Training on more universal topics such as boiler management is commercially available from professional sources.

Deliver Training (2c Figure 2.4)
Planning and good intentions don't move an EM program forward. A training calendar should be established and all staff should be scheduled for training based on their needs and duties.

Follow-through is critical in establishing in the minds of employees that energy management is truly important to the organization. Training is best delivered during the staff's paid time in a facility that is conducive to learning and that is free of work interruptions.

Evaluate (2d Figure 2.4)
It is important to determine the effectiveness of the training. Evaluate each learning objective in each session. In addition, it is usually beneficial to ask participants about the following:

- effectiveness of the instructor(s)
- effectiveness of the delivery methods (videos, etc.)
- value of any handout materials
- quality of the training facility

Of course, feedback is good, but it is worthless unless it's used! Use the feedback to make changes to subsequent training sessions. Re-evaluate and compare scores to determine the impact of the changes.

2.3.3 Continuous Improvement Cycle

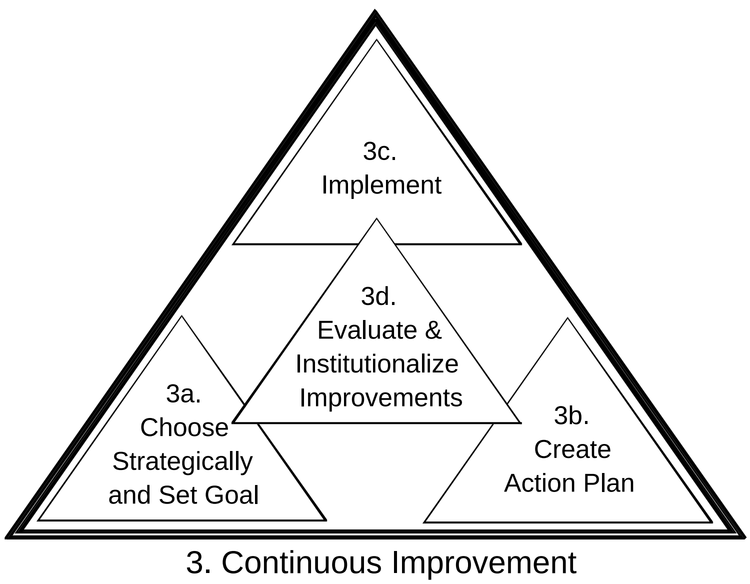

Figure 2.5 Continuous Improvement Cycle Guide

Figures 2.3 and 2.4 illustrated the steps required to implement an Energy Management initiative. Depicted in Figure 2.5 are the steps of a continuous improvement cycle. These steps should be followed for each project in an EM initiative. As soon as one project is completed, the next opportunity is identified and strategies to meet it are undertaken.

Choose Energy Projects Strategically (3a Figure 2.5)
The corporate strategic plan should include a section on energy management that, among other things, establishes a relationship between EM projects and non-energy issues in the strategic plan. This is not as difficult as it sounds. Energy costs are an unavoidable part of doing business and any money spent on energy cannot be spent on other activities such as marketing, training,

personnel, etc. Reducing energy costs frees up resources for the non-energy related components of the corporate strategic plan.

Specific energy management projects must be strategically chosen. This requires comparing two important factors: 1) the potential impact of a successful project to company finances, and, 2) the investment required for implementation.

A good strategy is to start with low investment projects that have moderate or high potential for savings. A significant portion of the savings generated by these projects should then be budgeted to finance the investment for more costly ventures. When identifying projects with the potential to save energy, be sure to solicit input from all employees. They frequently have ideas that are easy to implement and provide excellent results.

Assessing Financial Impact

Although challenging, this is an important component because it is the key to strategic choice. The merits of a project may seem clear to those who work in a particular area, however, it may be difficult to get buy-in from the boss or the financial officer. These challenges can be minimized if the case is presented in financial terms. Three common types of financial analyses are:

- payback period
- rate of return
- total lifecycle cost

The *payback-period* analysis is commonly used, in part, because it is simple. To make the calculation, divide the cost of doing the project by the annual savings or return from a successful project. For example, if it would cost $25,000 to implement changes and the annual savings are projected to be $15,000, then the payback period would be 1.67 years (25,000/15,000). Most companies set a maximum that is acceptable for a payback period and reject projects that do not meet the test.

The *rate of return* method involves other factors and more complex concepts such as net present value, interest rates, and depreciation. A detailed explanation of these factors is beyond the scope of this publication. There are resources available to explain these terms and even help to make the calculations. For example, DOE offers several software packages that will take information and calculate projected savings. These tools are available at the website in the footnote below.[14]

Although the *total lifecycle costing* method is a more complex way of evaluating projects, it is gaining support as a more accurate method of determining long-term impact. Depending on the complexity of the model, total lifecycle will consider owning and operating costs as well as such factors as environmental impact and costs, disposal/recycling costs, etc. For projects that may not meet the required investment threshold using other methods, this long-term look at costs may show that energy management practices are indeed a wise investment.

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[14] *DOE Industrial Technologies Program,* http://www.oit.doe.gov/bestpractices/software_tools.shtml

No matter what method of financial analysis is used, it is *critical* to carefully account for not only the savings that come directly from a project, but also any measurable “returns” that are caused by the project or made possible because of it. These increases in revenues, for example, represent funds that were not available before, which further increases the value of the venture.

Set the Goal (3a Figure 2.5)
Goal-setting can be controversial subject. Dr. Deming argued vehemently against what he called arbitrary numerical targets. However, others feel that setting an arbitrary goal can force an organization to commit to action and the setting of non-arbitrary goals. Many times the setting of an arbitrary goal generates dialogue that addresses the root problems that can affect the success of an energy management program. They can act as a catalyst for management to invest in performing assessments and initiating improvements.

Benchmarking can help avoid arbitrariness. By using benchmarking to compare your operation and its energy usage to other similar plants or industries, you can see how your organization stacks up to the competition or related industries. This information can then be used to set goals that are based on data, providing a goal that is both realistic and achievable.

Also needed is a systematic approach to continuous improvement. To give people a goal that requires improving the underlying system but not giving them the means to change/improve the system would be viewed by Dr. Deming as both arbitrary and de-motivating. The means to improving the system requires the authority that comes from management’s commitment to support the goals and the continuous improvement process.

Create an Action Plan (3b Figure 2.5)
The steps needed to achieve improvement should be carefully planned and, at a minimum, should include the following:

- clear statement of desired outcomes and measures of success
- list of resources that are and are not available
- sequential list of steps involved
- list of key milestones or intermediate indicators of success
- expected completion date
- clear explanation of reporting requirements (frequency and scope)
- rewards for successfully achieving goals (if applicable)

Using a systems approach to balance the supply side against the demand side is a good way to create an action plan because it compares the inputs of an energy system to the outputs.

Be sure to consider the potential negative impacts on product flow and peak energy demand. It is usually advisable to pilot proposed changes, before full implementation, if possible. For example, if an action plan suggests adjusting four air compressors for a desired affect, change one unit and measure the impact before continuing with the other three.

Implement the Plan (3c Figure 2.5)

Follow-through is the key to success. Execute the plan step-by-step. Monitor progress regularly and implement subsequent steps accordingly. Or, if the evaluation indicates a problem, make adjustments to the action plan.

Evaluate and Institutionalize Improvements (3d Figure 2.5)
Evaluate the success of implementation against the goal established at the outset. If a pilot project is successfully implemented, changes should be phased in across the larger system. Challenges unique to the larger system can be evaluated during this transitional phase from the pilot project to the larger system. Data collected during the pilot project should make the computation of financial return easier and justify the additional investment in expanding the changes across the larger system.

Continue the Cycle
As soon as a project is completed, begin the process anew by selecting the next project and setting goals for it. You should be prepared to repeat this cycle continuously, always striving to reduce energy consumption and increase productivity while contemplating cost and other impacts, until the return does not justify repeating the cycle again.

2.3.4 Communication

Figure 2.6 Communication Guide

The centerpiece of any successful EM model is ongoing communication. Knowledge must be shared in formats that are easily understood, readily accessible and appropriate for the audience. For example, senior management will probably require a format and content that differs from what is needed by engineers in the steam room. In addition, company leaders must regularly address the topic of EM and communicate the importance throughout the workforce. If energy management is not a regular topic of discussion throughout the company, it will soon be viewed as a meaningless gesture without any real priority. Ongoing training must be provided throughout all levels of the organization where information on energy performance should be shared with trainers to help them identify the needs of employees. Milestones must be recognized and celebrated. Employees need to see that their efforts are appreciated and that they make a difference.