PART 1

BASIC CONCEPTS AND THEORY

1

OVERVIEW OF THIS BOOK

1.1 INTRODUCTION

Energy management is a buzzword nowadays. What is the objective of energy management in the process industry? It is not simply energy minimization. The ultimate goal of energy management is to control energy usage in the most efficient manner to make production more economical and efficient. To achieve this goal, energy use must be optimized with the same rigor as how product yields and process safety are managed.

The time of "let the plant engineers do their technical work" is long gone. The reduction of the technical workforce due to automation and technology advances has also increased the level of responsibility on business management of plant operations, often resulting in fewer workers taking on more tasks. Furthermore, it is often the case that plant managers and engineers are ill-prepared to take on widespread responsibilities, particularly when working under time pressures. This in turn results in their devoting less time on plant operation and equipment reliability and maintenance. Therefore, the current challenge for energy optimization is: How can we develop effective enablers to support engineers and management?

In addition, plant management and engineers are presented with modern management concepts and techniques. Not all these methods are easily translatable or applicable to any given company. Even if implemented, some of these methods require tailor-made revisions to fit into specific applications. The challenge here becomes: Which methods should be selected and how to implement them for specific circumstances?

Energy and Process Optimization for the Process Industries, First Edition. Frank (Xin X.) Zhu.

This reminds me of a project I led a few years into the new millennium. My company took on a project to provide technical support to a large oil refining plant and I was tasked with leading a team of engineers to spearhead this effort. When I met with the general manager of the refinery plant, his words were brief. “My plant spends huge amounts of money on operating costs, in the order of hundreds of million dollars per year.” The general manager started after a quick introduction. “I know someone out there can help my plant to cut down the energy cost by more than 10%. I hope it is you.” These simple words from the general manager became a strong motivation like a heavy weight on my shoulder. I took the challenge and worked with the team and the plant staff to achieve the goal. By the end of the fifth year, a survey team from corporate management came on site. After reviewing the data and various utility costs, the team issued the statement that the plant had achieved the corporate goal of saving 10% energy costs. Our efforts were successful and the results were recognized by the plant and corporate management.

Over time, I applied the methods and tools I had developed over the course of my career to other projects I was staffed on in the past 10 years. The theory and practice of these methods and experience has become the foundation of this book. The book will present the core of a systematic approach covering energy optimization strategy, solution methodology, supporting structure, and assessment methods. In short, it will describe what it takes to make sizable reductions in energy operating costs for process plants and how to sustain energy-saving benefits. The benefits of this effective approach include identification of large energy-saving projects via applying assessment methods, capturing hidden opportunities in process operation via use of key energy indicators, closing of various loose ends in steam system and off-site utilities via good steam balances, optimizing utility system operation via setting up appropriate steam prices, and maintaining continuous improvement via regular review and performance matrices.

The concepts, methods, and tools presented in this book provide a glimpse of recent advances in energy utilization techniques based on simultaneous optimization of process and energy considerations. The case studies show that very substantial improvements in energy utilization can be made by applying these methods and tools not only in new investment projects but also in existing plants.

1.2 WHO IS THIS BOOK WRITTEN FOR?

This book is written with the following people in mind: managers, engineers, and operators working in the process industries who face challenges and wish to find opportunities for improved processing energy efficiency and are searching for tools for better energy management.

It is my hope that readers are able to take away methods and techniques for analysis, optimization, engineering design, and monitoring, which are required to identify, assess, implement, and sustain energy improvement opportunities. The analysis methods are used for energy benchmarking and gap assessment, while optimization methods are used for operation improvement, heat integration, process changes, and utility system optimization. Engineering methods are applied for developing energy revamp projects, while monitoring methods are used for establishing energy management systems. More importantly, I would like to help readers to build mental models for critical equipment and processes in terms of key parameters and their limits and interactions. You can then revisit these models whenever you need them.

1.3 FIVE WAYS TO IMPROVE ENERGY EFFICIENCY

The five ways in which improved energy efficiency can be achieved within plant processes are highlighted below and will be discussed in detail in this book:

- Minimizing wastes and losses
- Optimizing process operation
- Achieving better heat recovery
- Determining process changes
- Optimizing energy supply system

1.3.1 Minimize Waste and Losses

In reality, steam generated in the boiler house is distributed through an extensive network of steam pipelines to end users. The losses in steam distribution can be 10–20% of fuel fired in boilers. Hence, the net boiler efficiency could be 10–20% lower from the user's point of view.

The losses do not necessarily attribute to a single cause but are the result of a combination of various causes. It is common to observe the major steam loss caused by steam trap failure and condensate discharge problems. Steam loss could also occur due to poor insulation of steam pipes, leaks through flanges and valve seals, opened bypass and/or bleeder valves, and so on. Simple measures such as maintenance of steam traps and monitoring of steam distribution to determine if steam generated is in accordance with steam consumed can lead to significant cost-saving benefits.

Apart from distribution losses, other forms of energy losses could occur due to poor insulation, condensate loss to drainage, pressure loss from steam letdown through valves, pump spill backs, and so on. To detect losses, you must know how much energy is generated versus how much is used in individual processes. The benchmarking method in Chapter 3 could be used to determine the overall gap of the energy performance, and individual losses are identified using different methods. Process energy losses can be detected using the energy loss assessment methods discussed in Chapter 8, while identification of steam losses and the ways to overcome the losses in the steam system are discussed in Chapter 18.

1.3.2 Optimizing Process Operation

The most important step in developing an energy management solution to optimize a process is to be able to measure what process performance looks like against a reasonable set of benchmarks. This involves capturing energy data related to the process and organizing it in a way that allows operations to quickly identify where the big energy consumers are and how well they are doing against a consumption target that reflects the current operations. Only then is it possible to do some analysis to determine the cause of deviations from target and take appropriate remedial action. For this purpose, the concept of key energy indicators is introduced in Chapter 4.

The operation performance gaps are mainly caused by operation variability. Two kinds of operation variability are common in the industry. The first is the so-called operation inconsistency, which is mainly caused by different operation policy and practices applied due to different experience from operators. The second operation inefficiency refers to the kind of operation that is consistent but nonoptimal. This occurs when there are no tools available to indicate to the shift operators the optimal method to run the process and equipment when conditions of feeds and product yields vary.

Once operational gaps are identified, assessment methods (Chapters 5–8 for energy operation, Chapters 12 and 13 for process operation, and Chapter 16 for utility system operation) are then applied to identify root causes—potential causes include inefficient process operation, insufficient maintenance, inadequate operating practices, procedures, and control, inefficient energy system design, and outdated technology. Assessment results are translated into specific corrective actions to achieve targets via either manual adjustments, the best practices, or by automatic control systems. Finally, the results are tracked to measure the improvements and benefits achieved.

1.3.3 Achieving Better Heat Recovery

Using monitoring and optimization tools to improve energy efficiency usually results in pushing the process up against multiple physical constraints. To reach the next level of energy efficiency requires capital cost modifications to increase heat recovery within and across process units. One of the key values of implementing operational solutions first is that it can clearly highlight where the physical constraints exist to the process.

Once specific process units have been identified for improved heat integration, pinch technology can be applied to efficiently screen potential modification options, which is explained in Chapter 9. Practical assessment (Chapter 10) is required, which considers not only the value and cost of improved heat recovery but also the impact in terms of operating flexibility, especially with respect to start-up, shutdown, maintenance, control, and safety.

1.3.4 Determining Process Changes

Improved heat recovery is the most common type of capital projects implemented to improve energy efficiency. However, the use of advanced process/equipment technology may provide significant opportunities. Many of these areas make use of advanced process technology, such as enhanced heat exchangers, high-capacity fractionator internals, dividing wall columns, new reactor internals, power recovery turbines, improved catalysts, and other design features.

There are a variety of advanced technologies that can be applied, all of which vary in terms of implementation cost and return on investment. Careful evaluation of each of these solutions is required to select only the best opportunities that provide the highest return on the capital employed. Chapter 11 provides directions and principles for making process changes.

1.3.5 Optimizing Energy Supply System

In addition to using energy more efficiently in the process, another common strategy is to produce energy more efficiently. Many plants have their own on-site power plants that primarily exist to provide steam and power to the process units, but may also supply electricity to the grid when electricity price is high.

Energy supply optimization is achieved by optimizing the configuration and operating profiles of the boilers and turbines to meet energy demand while taking into account tiered pricing for power and natural gas, power contracts to the grid while meeting environmental limits on NO_x and CO_2 emissions. Energy supply optimization is discussed in Chapter 19.

1.4 FOUR KEY ELEMENTS FOR CONTINUOUS IMPROVEMENT

An effective energy optimization consists of four key elements: target setting, measuring, gap identification, and implementation. Achieving continuous energy improvement occurs only when all these four elements are working in good order as shown in Figure 1.1.

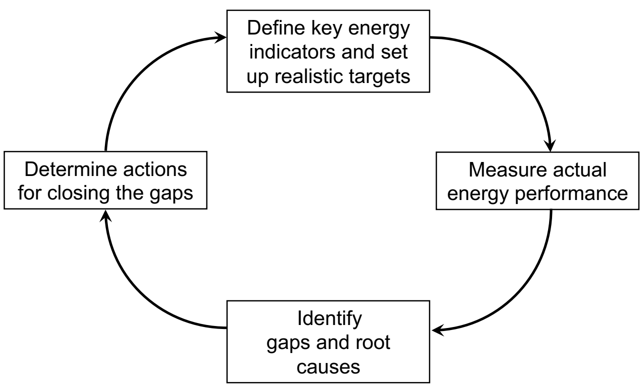

FIGURE 1.1. Four elements of energy management system.

The energy targeting implies setting up a base line energy performance against which actual energy performance can be compared. The base line energy performance should take into account the production rate and processing severity. The ratio of actual performance and base line performance is the energy performance indicator for a process area and an overall plant. The base line energy performance becomes the energy guideline or target for operation. For the energy target to be practical, it must be achievable based on equipment integrity, technology capability, availability of required tools, and skills.

1.5 PROMOTING IMPROVEMENT IDEAS IN THE ORGANIZATION

As a technical manager or process engineer or operator, you may have already acquired some good ideas for improving your plant and process unit. However, it is not an easy feat to persuade the technical committee to consider your ideas and then proceed to accept and eventually implement them. I have observed many good ideas that have died in the infancy stage because they could not pass the evaluation gates. Such failure is commonly due to a lack of techno-economic assessment and communications. Remember, it is always necessary to sell your ideas to key stakeholders.

First, you need to develop technical and economic merits to build a business case. Therefore, it is imperative that you determine the benefit of your ideas, that is, what is the value to the stakeholders, in the very early stages. Next, you should identify, with the help of process specialists, what it takes to implement the idea. You need to do the necessary homework to come up with rough estimates of the capital cost required to deliver the benefit for your ideas.

If the benefit outweighs the cost significantly, it is then necessary to elicit comments and feedback from technical specialists in the areas of operation, engineering, maintenance, and control. Their feedback will provide additional insights for the feasibility of implementing your ideas. Several review meetings may be required during idea development and assessment. Try to limit the scope of these meetings with highly selective attendees because a focused meeting could allow in-depth discussions leading to idea expansion and improvements. In the end, a thorough safety review is essential.

Once you pass reviews based on technical merits, you need to sell your ideas to get buy-in from management. Although management expresses a strong voice for supporting energy efficiency improvement, management will not provide a blank check. You should remember the fact that the business objective of your plant is to produce desirable products and realize targeted economic margins. To successfully convince management, you need to connect your ideas with key business drivers.

In the chapters that follow, all the essential tools will be provided in a clear, step-by-step manner together with application examples. My hope is that by applying the methods in your work—one step at a time, whether you are a manager, an engineer, or an operator—it will enable you to discover improvement ideas, to asses them, and then finally to prioritize them in a good order. Once all these boxes are checked, you will have a good chance to communicate and implement your ideas successfully within your organization.