The Four Pillars of Industrial Energy Efficiency

Alan P. Rossiter, P.E.
Rossiter & Associates

Enhance your facility's energy efficiency through operational improvements, effective maintenance, engineered improvements, and new technologies.

Energy prices can swing dramatically. As this article is being written, West Texas Intermediate is trading at around $50/bbl; less than nine months ago, it traded at around $100/bbl. Other energy sources — including natural gas, the mainstay of the process industries — have also experienced major price fluctuations.

When energy prices fall, energy management efforts in many companies stall. Other organizations, however, take a longer-term view: Energy prices will go up again, and energy efficiency is essential for sustainability. For many, the long-term approach is paying off. For example:

• ExxonMobil instituted its global energy management system (GEMS) in 2000. The company reported that by 2009, the program had identified energy savings opportunities of between 15% and 20% at its manufacturing sites, and had captured more than 60% of these savings *(1)*.

• LyondellBasell committed in 2006 to reduce energy consumption by 10% in five years. Between 2007 and 2009, it achieved a cumulative energy reduction of 7% *(2)*.

• More recently, in 2010, Eastman Chemical Co., which has a long history of energy management successes, announced an aspirational goal to reduce energy intensity by 25% over ten years. Through 2013, its energy intensity improved 8% relative to the baseline year of 2008 *(3)*.

It is not easy to achieve improvements like these, especially in the chemical process industries (CPI), where energy is often a major operating cost. It has therefore received a great deal of attention in the past, and many of the easy opportunities have already been captured.

There is no single method or approach that ensures energy use will be optimized. Real-world energy management must address both the design of new facilities and the operation of existing ones. It requires technical innovation and the use of established methods to develop efficient processes. It also depends on the behavior of individuals and organizations. Management and motivation are critical factors along with engineering skills.

Energy management programs typically include corporate energy policies, reporting systems, benchmarking, corporate and local goals, various types of energy audits and assessments, and integration of energy efficiency elements into engineering procedures and purchasing protocols. All of these activities add value. However, when we distill any program down to its basic elements, there are just four types of changes that lead to improved energy efficiency — the four pillars of industrial energy efficiency.

The four pillars

The four pillars (Figure 1) represent the types of opportunities that can boost plant performance and achieve excellence in energy efficiency across the CPI. The pillars are: operational improvements, effective maintenance, engineered improvements, and new technologies. In each area, robust energy management programs and technical insights can support the behavioral and process changes needed to capture and maintain savings and efficiency improvements.

Pillar 1. Operational improvements

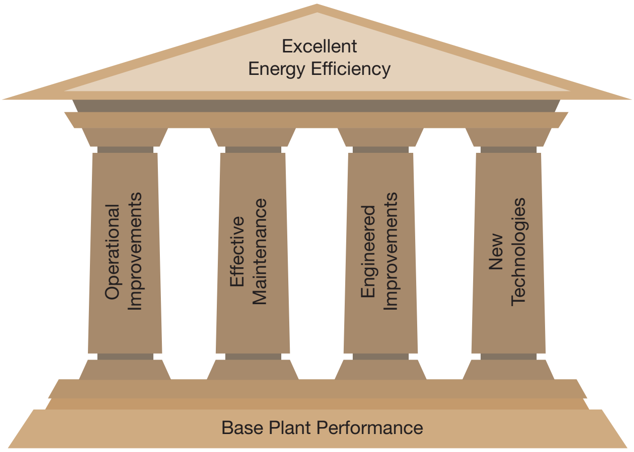
Many operational improvements can be captured at little or no cost. This makes them particularly attractive when energy prices are low and it is difficult to justify investment in energy-efficiency projects. Before committing to projects that require capital expenditure, it is prudent to ensure that existing equipment is being used to its full advantage — to pick the low-hanging fruit — and to change operating practices to ensure the fruit does not grow back.

Operating practices tend to become entrenched over time. Operators may dutifully follow procedures that were developed when their plant was commissioned, even though throughput, feedstocks, product slates, and a host of other factors have changed. And sometimes, established operating practices are simply unnecessarily conservative. The following example, which relates to a fractionating unit at an oil refinery *(4),* illustrates this.

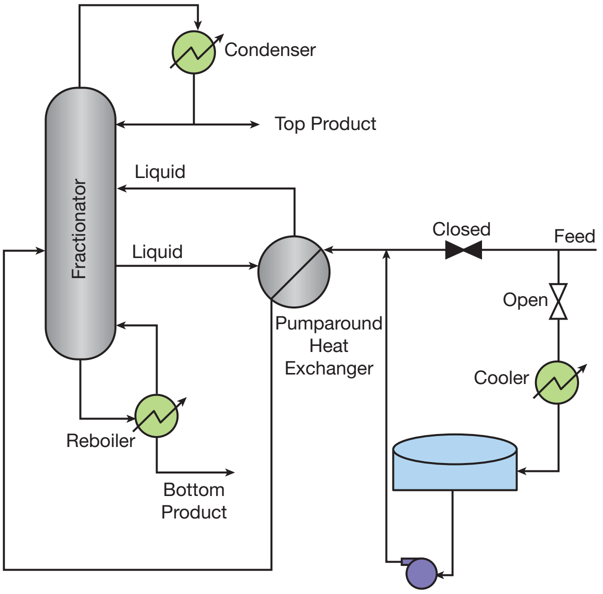
The feed to the fractionator is used to remove heat from a pumparound circuit on the tower, and there needs to be an adequate temperature difference between the pumparound stream and the feed stream to remove the pumparound heat. To ensure that the temperature difference was large enough to meet the pumparound duty, the feed was routinely routed through a cooler and tank and supplied as cold feed (Figure 2).

As part of an energy efficiency study, the pumparound-to-feed heat exchanger came under scrutiny. A review of design specifications showed that it should be possible to achieve the required pumparound duty with the existing heat exchanger even if the feed was supplied hot direct — *i.e.,* without passing through the cooler and tank (Figure 3). Plant trials confirmed this conclusion. As a result, the operating procedures were changed, and hot direct routing is now considered the normal operating procedure. This change increases the temperature of the feed as it enters the fractionator, which in turn reduces the reboiler duty, saving about $600,000/yr, and no investment was required.

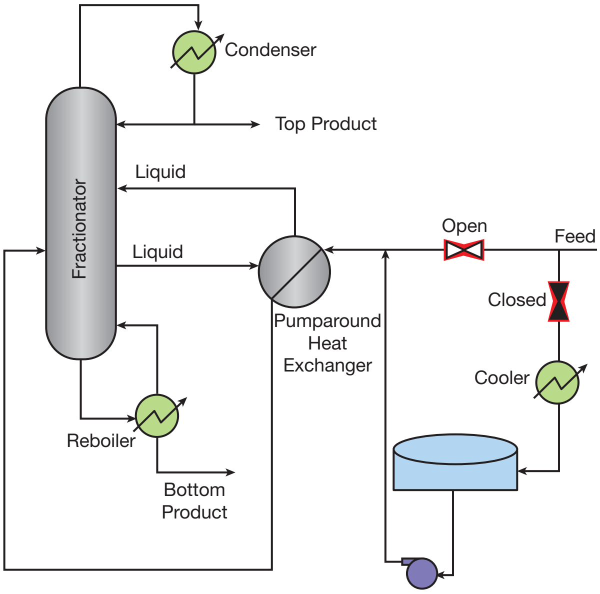
Sometimes, operating decisions are made based on commercial considerations. For example, a boiler may be capable of burning several different fuels. The operating strategy should ensure that the least-cost fuel mix is being



▲ **Figure 1.** Consider the four pillars of industrial energy efficiency when seeking opportunities to improve plant performance.



▲ **Figure 2.** Originally, the refinery cooled a feed stream before it was fed to the fractionator.



▲ **Figure 3.** The refinery reduced its reboiler heating costs by routing the feed hot direct into the pumparound heat exchanger.

used at all times. Similarly, many electricity tariffs include time-of-use pricing, peak demand charges, and other cost components that can be minimized by appropriate management of operations. Alternatively, it may be possible to negotiate electricity rate structures to suit the needs of existing plant operations.

When we become aware of inappropriate operating choices, our first response is to adjust the process (*e.g.,* switch to the hot direct feed alignment in the fractionator example). However, this is only a short-term fix. Additional energy management steps are needed to ensure that the improvement becomes permanent. These might include:

- carry out additional operator training
- modify operating procedures and update documentation
- add control valves and automation
- implement real-time optimization systems
- install monitoring systems to track key performance indicators (KPIs).

Pillar 2. Effective maintenance

To get the most out of existing facilities, we must ensure that the plant is properly maintained. The primary focus is the equipment and systems that have the largest impact on energy use, such as heat exchangers (especially those in preheat services), furnaces and boilers, steam traps, and insulation, as well as compressors, pumps, and turbines. Another important system to consider is steam piping, and especially the management of steam leaks, as the following example illustrates.

Rohm & Haas achieved significant savings at its Deer Park, TX, chemical plant *(5, 6)*. The plant had been in existence for a considerable time, and some of the piping was more than 50 years old. An audit of steam traps and steam leaks in March 1999 identified combined steam losses of 90,000 lb/hr, of which just over 40,000 lb/hr was from steam leaks and a little less than 50,000 lb/hr was from failed steam traps. This prompted a $500,000 capital project and a program of repairs in partnership with local service providers.

Follow-up audits in September 2000 and July 2002 found that the combined losses had been reduced to 44,000 lb/hr and 28,000 lb/hr, respectively. The program continued to evolve, with the adoption of software tools to aid in auditing and recordkeeping.

Steam trap management programs have been described in detail elsewhere *(7)*, so this discussion focuses on steam leaks. At the start of the program, the losses from steam leaks alone amounted to over 40,000 lb/hr. At a cost of $5.00 per 1,000 lb (typical for many chemical plants and refineries in 2014), this translates to around $1,750,000/yr. After just three years, the repair program reduced steam leak losses to around 10,000 lb/hr — a reduction of roughly 75%.

Even though the steam losses due to leaks were greatly reduced, survey results indicated that new leaks appeared at a rate of more than one every three days. Most of the leaks were fairly small; only about 10% were estimated at more than 100 lb/hr. The rate of leak formation did not change appreciably over the three-year period for which information was provided. This point is significant, and it is consistent with findings for other steam systems.

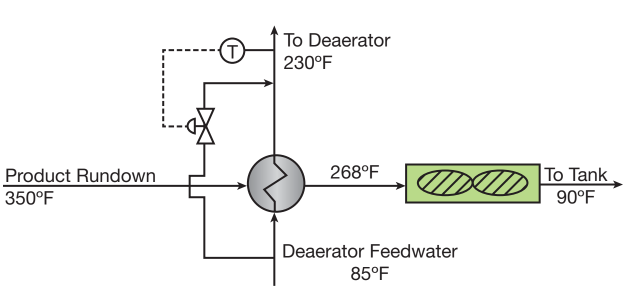
Many facilities have reported that even though their steam leak programs do lead to a significant reduction in steam losses, new leaks continue to form at an undiminished rate. In many cases, these leaks are in the same places as the ones that have been repaired. One option is to continue to repeat the repairs. A better approach is to explore root causes *(8)*. The underlying issue is frequently poor piping design or inadequate drainage — often because of insufficient or poorly located drop legs or because a steam trap fails to drain condensate *(9)*. Correcting the root cause (*e.g.,* rerouting steam lines, adding drop legs, replacing failed steam traps) can eliminate — or at least minimize — the occurrence of future steam leaks, and the cost and inconvenience of future steam leak repairs.

Pillar 3. Engineered improvements

Engineered improvements — additions and upgrades to existing plant facilities, and modifications to new plant designs — can lead to significant improvements in energy efficiency. Examples include:

- resequencing equipment (*e.g.,* heat exchangers in a preheat train)
- replacing or upgrading electric driver systems (*e.g.,* installing variable-frequency drives)
- adding heat exchangers, steam turbines, distillation columns, etc.
- installing new control schemes.

This example (Figure 4) illustrates how important control schemes can be in energy efficiency projects. An energy management project at a petrochemicals complex *(4)*



▲ **Figure 4.** A new heat exchanger used a product rundown stream as the heat source to preheat deaerator feedwater. In this configuration, the temperature control was unstable, and vapor locking in the new heat exchanger raised the pressure drop in the deaerator feed line.

included a new heat exchanger that uses a product rundown stream as the heat source to preheat deaerator feedwater. A temperature controller limits the feedwater preheat temperature to 230°F. Steam is injected into the deaerator, which operates at 10 psig (240°F saturation temperature). The rundown stream is at 350°F; before the project, it went directly to an air cooler that cooled it to 90°F. The project was intended to reduce the heat load in the air cooler, and at the same time reduce the steam demand in the deaerator.

Shortly after the project came online, operators started reporting problems. The temperature control was unstable, and vapor locking in the new heat exchanger caused excessive pressure drop in the feedwater line. After numerous attempts to fix the problem by modifying plant operations, the heat exchanger was taken out of service, using existing manual bypasses and isolation valves.

The underlying problem was in the control scheme. Bypassing deaerator feedwater around the heat exchanger was effective at controlling the heat load. However, when the heat load went down, so did the amount of deaerator feedwater passing through the heat exchanger. Consequently, the temperature of the water leaving the heat exchanger rose as the bypass opened, and it could easily reach its boiling point. This accounted for the observed difficulty in controlling temperature and the associated vapor locking.

The simplest interim solution to this problem was to open the existing manual bypass on the product rundown stream, as shown in Figure 5. This reduced the flow of the rundown stream through the heat exchanger while maintaining the water flow, thus ensuring that the water would not overheat. To ensure that the water did not boil in the heat exchanger under any of the anticipated operating conditions, the manual bypass valve had to be about halfway open. This meant that in some situations, the temperature of the water going to the deaerator was much lower than the target value of 230°F. Nevertheless, this simple strategy did allow the plant to obtain a significant percentage of the potential benefits with no additional investment.

A better solution required the temperature control valve to be relocated on the product rundown bypass (Figure 6). With this arrangement, the target deaerator feedwater temperature could be achieved under all operating conditions.

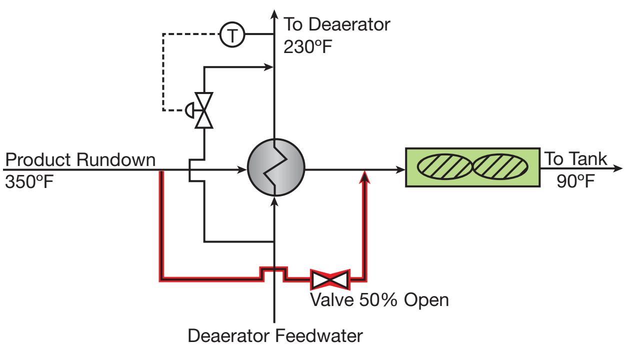
The feedwater temperature control example is a very simple engineered improvement. Typically, engineered improvements require significant input from engineering personnel to identify, evaluate, and design the solution. Furthermore, unlike operating improvements and maintenance programs, upgrades to facilities generally require capital investment, and it can be difficult to justify the investment solely on the basis of energy savings — especially in an environment where energy is inexpensive. However, it is often possible to incorporate energy efficiency improvements cost-effectively into projects that are driven and justified by capacity increases, feed slate changes, or product upgrades. Indeed, in many cases, the economics of these larger projects are improved by including components that enhance energy efficiency *(10)*.

Pillar 4. New technologies

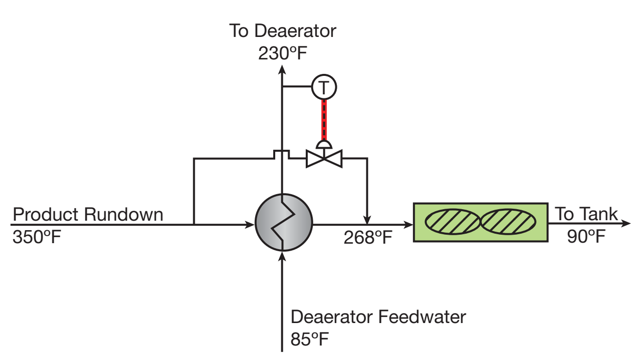
Engineered improvements apply proven solutions to identified problems. In contrast, solutions that incorporate new (or breakthrough) technologies require validation through research and/or development. New technologies therefore require more time to implement, and the technical and financial risks are higher than those of engineered improvements.

Some of the largest energy efficiency improvements in the process industries have come through technological breakthroughs. A well-known example is the development of the low-pressure polyethylene process in the 1950s. This was a major advance over the older high-pressure process, and the new process used much less energy per unit of production.

Article continues on next page



▲ **Figure 5.** To avoid vapor locking in the new heat exchanger, an existing manual bypass on the product rundown stream was opened to 50%.



▲ **Figure 6.** A better solution relocated the temperature control valve to the product rundown bypass.

A more recent example is the rise in compact fluorescent lights and light emitting diodes. These provide dramatic energy savings compared to the familiar incandescent bulbs, and they have wide-ranging domestic, commercial, and industrial applications.

Technological advances have also improved some of the key equipment prevalent in the CPI, such as heat exchangers and distillation columns.

Identifying energy efficiency improvements

Some types of energy inefficiencies are widespread in the CPI. They are relatively easy to identify, and there are established methods for dealing with them. This is particularly true of routine maintenance activities. For example, boilers and furnaces need periodic tune-ups to remain in top condition, and over time, steam systems develop leaks and a certain percentage of the steam traps fail, requiring repairs, replacements, and appropriate management systems.

Most other types of energy efficiency improvement opportunities are harder to identify. Here are some proven approaches:

- As a first step, high-level site audits identify where energy is used and misused across a facility.
- More-comprehensive site assessments identify specific inefficiencies and define opportunities such as improvements in operating practices and maintenance, as well as facility upgrades.
- Process flow diagram (PFD) reviews *(11)* are structured brainstorming sessions for identifying opportunities to improve plant operations and upgrade facilities.
- Heat integration studies can take various forms. The most commonly used technique is pinch analysis *(12)*.
- Steam system modeling and optimization are also widely used to identify inefficiencies in steam systems and to define improvements in both operating strategies and equipment configurations.
- Employee suggestions yield many very attractive energy efficiency opportunities. Welcoming and acting on employee suggestions not only improves energy efficiency; it is also a visible and valuable way to change corporate and site energy efficiency culture.
- Energy efficiency workshops should be carried out for capital projects *(10)*.
- An alert energy manager should always be on the lookout for breakthrough technologies that are relevant to his or her equipment, and also stay in close contact with the corporate research and development department both to track and to influence activities that could lead to more energy efficient processes.

Closing thoughts

Energy efficiency is important to the economic and environmental performance of CPI companies. Energy management programs are often complex and incorporate many components, but ultimately energy efficiency will only get better when both processes and behaviors change. The four pillars of industrial energy efficiency — operational improvements, effective maintenance, engineered improvements, and new technologies — are keys to making this happen. CEP

Literature Cited

1. **ExxonMobil,** "2009 Summary Annual Report," www.annualreportowl.com/Exxon/2009/Annual Report, p. 32 (2010).
2. **Chatterjee, S.,** "Energy Improvement — Making Value-Added Choices," Texas Industrial Energy Management Forum, Houston, TX (Mar. 4, 2010).
3. **Nolen, S.,** "Eastman Chemical's Energy Management Program: When Good is not Enough," in *Energy Management and Efficiency for the Process Industries*, Rossiter, A. P., and B. P. Jones, eds., John Wiley & Sons, Hoboken, NJ, pp. 37–47 (2015).
4. **Rossiter, A. P.,** "Back to the Basics," *Hydrocarbon Engineering,* **12** (9), pp. 69–73 (Sept. 2007).
5. **Dafft, T.,** "Plant Steam Trap and Leak Repair Program," Texas Technology Showcase, Houston, TX (Mar. 17–19, 2003).
6. **Rossiter, A. P., and B. P. Jones,** "Energy Management and Efficiency for the Process Industries," John Wiley & Sons, Hoboken, NJ, pp. 179–185 (2015).
7. **Walter, J. P.,** "Implement a Sustainable Steam-Trap Management Program," *Chemical Engineering Progress,* **110** (1), pp. 43–49 (Jan. 2014).
8. **Risko, J. R.,** "My Steam Trap is Good — Why Doesn't It Work?" *Chemical Engineering Progress,* **111** (4), pp. 27–34 (Apr. 2015).
9. **Risko, J. R.,** "Beware of the Dangers of Cold Traps," *Chemical Engineering Progress,* **109** (2), pp. 50–53 (Feb. 2013).
10. **Rossiter, A. P.,** "Energy Efficiency in Capital Projects," American Fuel and Petrochemical Manufacturers Annual Meeting, Paper No. AM-15-43, San Antonio, TX (Mar. 22–24, 2015).
11. **Rossiter, A. P., and J. L. Davis, Jr.,** "Identify Process Improvements for Energy Efficiency," *Chemical Engineering Progress,* **110** (9), pp. 53–58 (Sept. 2014).
12. **Rossiter, A. P.,** "Improve Energy Efficiency via Heat Integration," *Chemical Engineering Progress,* **106** (12), pp. 33–42 (Dec. 2010).

ALAN P. ROSSITER, PhD, P.E., is president of Rossiter & Associates (Bellaire, TX; Email: alan@rossiters.org; Website: www.rossiters.org/associates), a consulting firm dedicated to helping oil refineries and chemical plants achieve excellence in energy efficiency. He has more than 30 years of experience in process engineering and management. Rossiter received his BA and PhD in chemical engineering from the Univ. of Cambridge, and is a chartered engineer (U.K.) and a registered professional engineer in the state of Texas. He is a past chair of the South Texas Section of AIChE. His new book, *Energy Management and Efficiency for the Process Industries,* coauthored with Beth Jones, was published in April 2015 by the AIChE/Wiley partnership.