“Energy Management: A new imperative”

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Abstract

A number of market forces have come together in the last two years to focus everyone's attention on reducing energy consumption. In regards to the Petroleum and Petrochemical industries, the narrowing of margins coupled with increased energy cost and recent public interest in reducing global warming carbon emissions make energy reduction a priority for all process facilities. This paper is based upon the experience of recent work conducted by the authors at several US refineries. This paper highlights the requirements for a successful energy management initiative to achieve and sustain energy reductions for any process facility. New approaches to setting achievable energy targets for process units, putting in place an energy reduction culture, and sustaining these gains are also discussed.

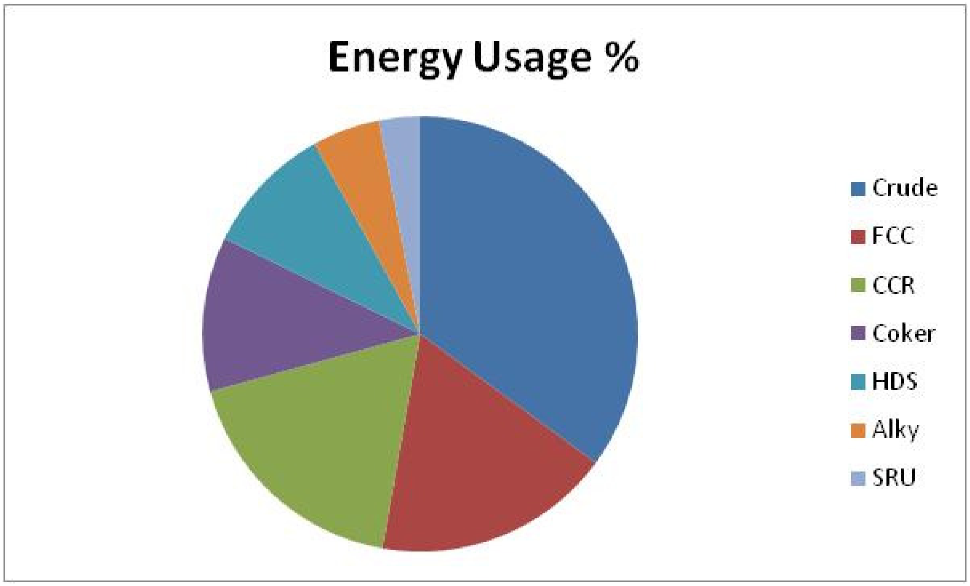
Introduction

As everyone is aware, recently there have been wild swings in the price of energy with record highs for crude oil in the summer of 2008 and a 70% drop by the beginning of 2009. Although energy costs have decreased recently, most people believe that this is a short term event and prices will be increasing in the years ahead as the global economy recovers and there is reduced exploration and development in the near-term. DOE forecasts reflect this belief.

In addition to the cost of energy, there are other concerns today, such as global warming and national security that have all of us thinking about the amount of energy we use. Although energy conservation has not be at the forefront in recent years, the US has made great strides in reducing energy consumption, in fact the US now takes about half as much energy to produce one unit of Gross Domestic Product (GDP) as it did 30 years ago(1). Even with these improvements, there is still a lot of opportunity to further reduce our consumption.

As in most business endeavors, the motivator has to be positive impact to the bottom line. As margins fall for the process industries, the focus shifts to cost reduction. Energy costs for a 152,000 barrel per day refinery were about $214 million dollars last year, which account for 58% of the operating expenses with 41% of the energy costs produced by the refineries and 17% purchased(2). Energy costs represent the largest opportunity for cost reduction in a process facility. In fact, an energy management program is one of the best refining investments in our current economic environment and has become a new imperative for all process plants.

A typical refinery will consume about 600 MBTU/BBL of charge (9), with most of that energy used by the Crude Vacuum Unit followed by the Fluid Catalytic Cracking (FCC) and Continuous Catalytic Reformer (CCR) units as shown in the figure below.



Based on our experience, an energy management program can reduce energy consumption by 6-8%. At current energy prices, refineries can reduce energy costs by $6-8 million dollars per year. A welcomed 20 to 40 percent increase in profit in today's current low margin environment.

Historical Perspective

During the 1980's, the process industries focused on energy management after the oil embargo. At that time, there were a number of energy inefficiencies that had not been addressed due to the low oil prices for many years preceding the oil embargo which made energy reduction investments uneconomic.

Plants contained a lot of intermediate tankage requiring many streams to be cooled down after leaving one unit before being reheated by the next process unit. Capturing waste heat produced by one process unit for use by the process unit or another process unit was not exploited. This all changed once energy conservation became a focus. Initial cost cutting efforts were directed at the utility systems to improve boiler and heater efficiencies, repairing steam leaks and traps and improving insulation. However, the largest gains were made after capital projects were implemented that increased heat integration between units, installation of higher efficiency power and heat transfer equipment, reduced intermediate tankage, and added waste heat recovery systems.

As compared to the early 1980's, there is a lot more work to do today when reducing energy consumption at process facilities, as the low hanging fruit was picked in the 1980's.

Energy Management

We see the next wave of energy cost reduction being achieved by a comprehensive energy management program. A recent successful refinery program quoted savings of between $4 million to $12 million dollars a year (3).

In addition to producing measureable results quickly, the goals of an energy management program typically include creating an energy focused culture at the facility that provides baseline measurement of current energy consumption, defines a path to reduce future energy consumption, sets achievable goals and timelines to achieve these reductions, and provides tools for management oversight and long-term sustainability of the benefits achieved. This is a multi-year program that must involve everyone at the facility: management, operations, engineering, and maintenance.

In the energy management program, we take advantage of the large installed base of distributed control systems (DCS) that automatically collect operational data from the process unit, along with web pages and other display tools. This infrastructure provides all the major building blocks necessary for a comprehensive energy management program.

This infrastructure allows energy reduction efforts to focus not only on utility systems, but also on the process units themselves to reduce fuel gas, natural gas, steam, and power consumption while increasing waste heat recovery. Energy savings are realized by:

- Improving heater charge preheat temperatures,
- Lowering heater stack O2%,
- Lowering tower pressures,
- Reducing reboiling of towers,
- Decreasing or eliminating unnecessary recycles flows,
- Preventing steam leaks
- Maximizing waste heat recovery

Implementation of energy management programs is well documented in the literature (see references (2), (4), (5), (6), (7), and (8)). A summary of the recommended steps includes the following:

- Measurement
- Opportunity Capture
- **Dynamic Targets**
- Energy Dashboard
- Long-term Support

All of the elements listed above are discussed in part or whole in the references provided at the end of this paper with the exception of Dynamic Targets. That is the portion of the work in which we have been most involved and is, in our view, unique. Therefore, this paper will focus on the creation of Dynamic Targets which requires selecting the basic energy measurement, developing the energy targets, making these targets visible, and then providing long-term support. Each of these steps is discussed below.

Measurement

The measurement of energy usage is fundamental to the success of any energy management program. Before you embark on the program you must develop a common mental model and language of measurement. This requires reaching agreement on a common methodology to calculate actual energy consumption and production (e.g., waste heat capture). Ideally, the resulting metrics will correlate directly with actual energy cost for the facility or unit, as the goal is to reduce actual energy consumption. One metric that is already in place for the refining industry is Solomon's Energy Intensity Index (EII) that was created to help the industry benchmark an individual refinery's energy consumption against an industry standard taking into account the facilities complexity (i.e., more complex refineries use more energy).

We have found using an index, such as EII, in an Energy Management program has several limitations. The EII index was designed to provide a refinery wide index over a relatively long time frame, such as a month or year, not a measure of real-time energy usage. The concept of complexity adds additional structural variables into the metric that are not directly related to actual energy consumption and is not process specific. As an example, in the event a high complexity process unit like a Fluid Catalytic Cracker is shutdown, The EII increases in value, even though the actual energy consumption is lower. These issues make this metric unsuitable for our purposes. In energy management, we focus on systemically reducing energy consumption for each process unit over time, on a real time basis.

In our experience, the best metric to measure and reduce is MBTU/BBL of charge (in the case of the overall refinery metric, the charge would include all feed sources not just crude runs) as this relates directly to actual plant energy consumption. However this metric is harder to calculate than one might think and requires some business rules to ensure a consistent meaningful measurement. At a minimum, the energy management programs needs to address the following:

- What are the conversion units for power, steam, and fuel gas flows to MBTU/Hour?
- Will catalytic coke or acid gas burned be considered?
- How will waste heat captured be accounted?
- What will be the lowest level of energy usage calculation – equipment, unit, complex?
- What will be the hierarchy of these calculated ratios?

Once the above has been decided, then the individual energy ratios can be defined by identifying all of the consumption and production meters and measurements needed to perform this calculation. Time is required to verify the accuracy of the metrics, units of measure, conversion factors for each meter, and define process charge flows and their conversion factors (4). After the individual calculations are developed, then the hierarchy and roll up calculations are detailed. These calculations are then built as new tags into the data historian allowing base-lining energy consumption. Over time the plant personnel become familiar with the measure of energy consumption for their process units.

Dynamic Targets

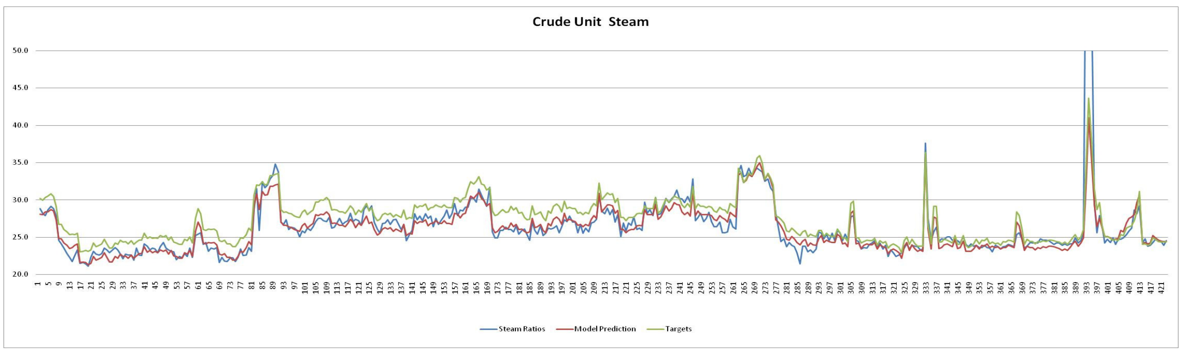
The most visible portion of any energy reduction program is the energy targets that are crucial to sustaining the gains from the energy management program. These targets drive the continued reduction in energy consumption, based on the premise that "what gets measured gets done". If process unit targets are set as a constant value, say 150 MBTU/BBL of charge, then these targets will soon be ignored by operations, since there are many uncontrollable operating conditions and economics factors that drive energy consumption in a process unit. The challenge in setting targets for process units is to accurately reflect the actual operating conditions of the unit and predict the achievable minimum energy consumption at any point in time. Examples of Process Unit variables that impact the achievable energy consumption include:

- Feed quality,
- Preheat exchanger fouling,
- Tower pressures,
- Reflux rates,
- Pump around optimization,
- Heater stack O2,
- Catalyst activity,
- Bypass valve positions
- Recycle flow rates,
- Product specifications, etc.

One way to address these challenges is to make these targets “dynamic” in the sense that the target changes as the process unit energy requirements change. This requires the ability to predict the process energy requirements with some sort of model such as first principle process models, empirical models, or a mixture of both. Once the actual energy consumption has been predicted, targets can be set for controllable energy variables such as:

- Preheat Temperatures
- Heater stack O2%
- Stripping Steam Ratios
- Reflux Ratios
- RVP
- Tower Pressures
- Splitter Product Quality
- Amine to Reboiler Steam Ratio
- Sour Water Stripper Bottoms NH3

Once the target variables have been selected, then the actual targets need to be developed. This can be as simple as fixed values representing the 1st quartile performance or reflux ratio values with a minimum reflux rate, or much more complicated target calculations such as optimized targets for overhead and bottoms splitter stream qualities from on-line simulation models. Typical overall unit dynamic energy targets maybe subject to 5 to 15 of these specific energy target values of varying complexity. For example, recent work on a crude/vacuum unit dynamic target resulted in the specific targets for preheat temperature, heater O2's, crude tower overhead pressure, vacuum tower flash zone pressure, vacuum tower wash oil rate, stripping steam to bottoms ratio, and side stripper steam to product ratios – a total of 12 targets. An example of the resulting ratio calculation, model prediction, and dynamic target are shown on the graph below:

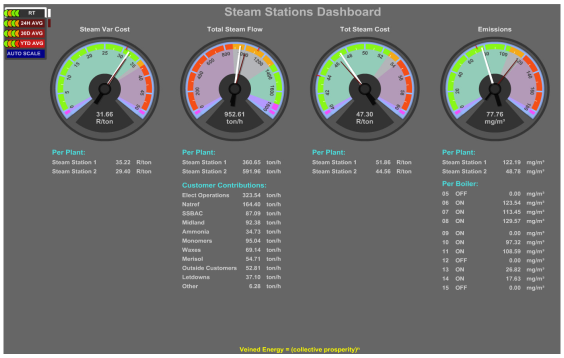


Energy Dashboards

The key to management oversight is visibility of the program's success in reducing overall energy consumption with the ability to drill down into specifics to analyze additional opportunities on a "real time" basis using the established Dynamic Targets. A natural hierarchy for such a dashboard is the already established plant's unit, area, complex structure with some differences to ensure integrity of the energy ratio calculations and models. This hierarchy also provides the drill-down structure and a natural responsibility matrix to address energy consumption issues. Unlike the situation twenty years ago, there are many commercially available IT tools, many of which are already in place at modern facilities, to construct an energy dashboard. Although the tools are there, the same IT challenges remain: inconsistent data formats, delivery, and timeliness, multiple disparate source systems, system performance. The basic software required includes:

- Data historian
- Middle-ware to collect , transform, and present the data
- Graphics composer
- Web portal

These tools allow the building and support of very rich robust displays; an example from a recent implementation (5) is shown below:



As seen above, the dashboards typically contain traffic lights, speedometers, graphs, flags, that are updated with real-time values from the historian and may be combined with other displays built within the data historian.

Long-term Sustainability

The support requirements for Dynamic Targets are very similar to advanced control applications. Both rely on the accuracy of fundamental measurements from the plant control system (flows, pressures, temperatures, and on-line analyzers) and periodic lab analysis. They are also susceptible to process changes from equipment failures (such as a leaky by-pass valve), changes in operating strategy, process unit modifications, shut-downs of existing units, and start-up of new units. Each of these issues must be addressed to ensure long-term sustainability of the energy dashboard and the subsequent benefits.

In summary there are four possible failures sources for the Dynamic Targets that must be addressed to ensure long-term sustainability:

1. Measurement error (most common – ~1 per week)
2. Target changes (frequent – ~1-2 per month)
3. Minor process changes (once in awhile – ~1 per quarter)
4. Major process changes (infrequent – ~1 per year)

In order to ensure long-term sustainability of this program, the maintenance program must be designed to address each of the above. This includes an agreed detailed workflow as each issue will require multiple people to contribute to the solution. In particular the target setting work practice is critical to sustaining benefits. The natural inclination is to relax the targets over time as short-term circumstances prevent their achievement. For example a fouled preheat exchangers would reduce the available preheat temperature until they are cleaned and the inclination is to reduce the target instead of cleaning the heat exchangers. However, to achieve the maximum benefit from the energy management program, the targets must be continually reviewed and pushed towards ever decreasing energy consumption.

Summary

As discussed at the beginning of this paper, energy conservation matters. It is even more important to the process industries in a down economy – this is a *New Imperative* for our industry. Reducing energy consumption is the best investment a refiner or chemical manufacturer can make when margins are tight. The starting point is to put in place an energy management program that follows a methodology similar to "MODEL":

Step 1 – Measurement; define the measurement basis and baseline your energy consumption

Step 2 – Opportunity Identification and Capture; use your resources to find, prioritize and capture the best energy reduction opportunities

Step 3 – **Dynamic Targets**; create process unit targets that dynamically track the current operating conditions of the units to set achievable targets for operations

Step 4 – Energy Dashboard; put in place a visual representation of the day to day, hour to hour energy consumption to support management oversight and focus for continual improvement

Step 5 – Long-term sustainability; an energy management program is similar to an advanced process control application and requires the same "care and feeding" to prevent the system from falling into disuse.

We believe that the Dynamic Targets are a required ingredient for a sustainable energy management program providing a real-time update of the plant's energy performance for operations and management personnel. These dynamic targets must reflect the actual operating conditions at any moment in time and predict the minimum energy consumption or maximum waste heat capture to be useful. This requires the ability to predict the process energy requirements with some sort of model such as first principle process models, empirical models, or a mixture of both.

The key to sustainability is managing the continuous process of setting and resetting the energy targets and addressing the four failure sources in the maintenance program – measurement error, target changes, minor process changes, and major process changes. This includes an agreed detailed workflow as each issue will require multiple people to contribute to the solution. Once these processes are integrated into the plant's daily routine the program will be sustained.

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