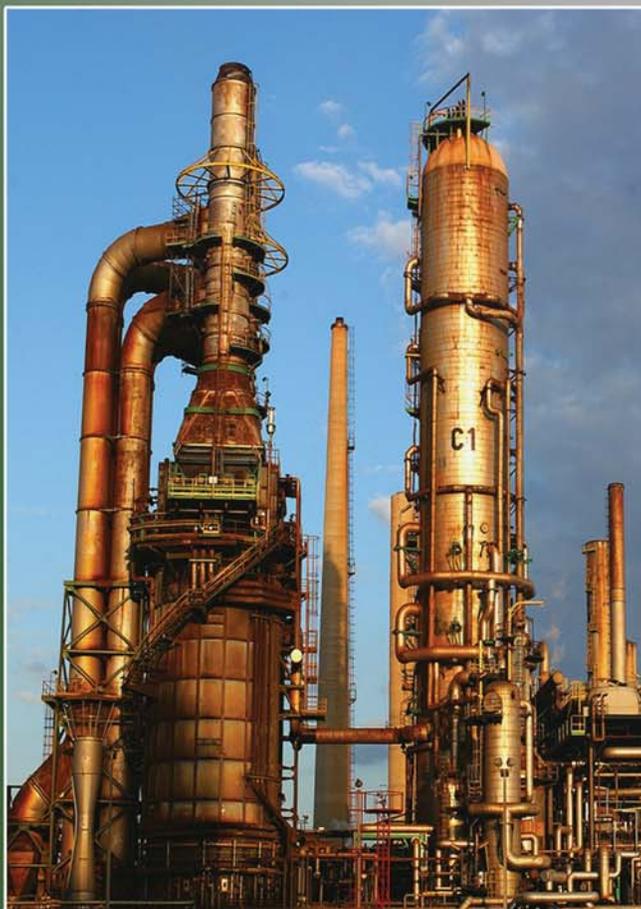


Refinery Energy Management

Latest Technologies and Strategies to Enhance Operational Economics



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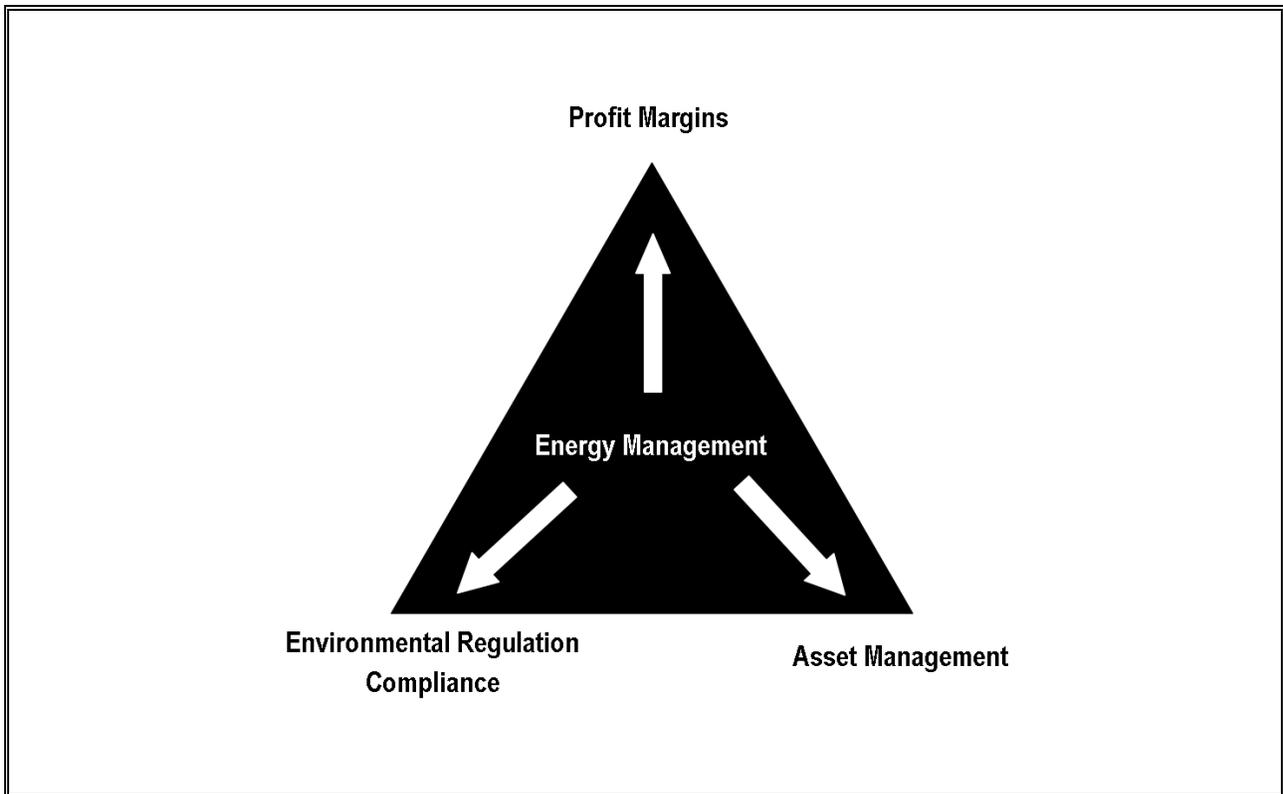
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INTRODUCTION

The global refining business is cyclical in nature, depending on the economic cycle of expansions and contractions on which the industry has no direct control. However, refiners can attenuate the economic impacts during the down cycles by efficiently managing internal operations and, in particular, operating expenses. Among significant refinery expenses, utility costs based on consumption of electricity, steam, heat, fuel gas, and hydrogen can be reduced through management and conservation efforts.

As a matter of fact, energy management (EM) via constant efficiency improvement plays a synergistic role of the refinery operation that connects refining margins, asset management, and environmental regulation compliance, as portrayed in the following diagram.

SYNERGISTIC ROLE OF ENERGY MANAGEMENT IN REFINERY OPERATIONS



EM directly affects refinery margins as energy-savings go straight to the bottom line. In a highly competitive environment, low-cost producers will most often come out on top. For US refiners, energy accounted for the largest share of operating costs at 43%, followed by maintenance (24%), other (17%), and personnel (16%). Therefore, a small fraction in savings can translate into billions of dollars. As refining margins are rather slim in the down cycle, cost reduction via energy improvement may turn a loss into a profit for a refinery. At the June 2012 Industrial Energy Technology Conference (IETC) in New Orleans, Louisiana (US), LyondellBasell received the Energy Award for reducing energy consumption at its Houston, Texas (US)

plant by 12% via the implementation of an energy efficiency program. The program helped save the refinery 42 trillion Btu since 2007, with the flare optimization program alone saving over 500B Btu/y. At an assumed energy cost of \$5.5/MMBtu, the refiner saved an average of \$46.75MM a year via the implementation of the energy efficiency program.

Asset management is known to yield profitability and productivity improvements, primarily through the minimization of downtime. According to consultancy ARC, unscheduled shutdowns coupled with poor maintenance practices cost the global process industries 5% of their annual production which is equivalent to \$20B. The firm estimates that 80% of the losses are avoidable. Ineffective maintenance practices also lead to unscheduled downtime costing operators an additional \$60B a year.

In terms of environmental regulations, flaring is an area that is directly linked to energy management programs. Although a consensus on CO₂ reduction legislation or action is unlikely in the short term, refiners are already forced to deal with regulations involving the emissions of SO_x, NO_x, and VOCs. Excess flaring, in particular, can result in negative publicity and also fines from local and national governments. As mentioned in LyondellBassel example relayed previously, optimization of flaring can lead to massive monetary savings. Furthermore, flare gas recovery—sending the gas that would normally be sent to the flare back through the unit for use as fuel or feed—provides a dual benefit of saving fuel and reducing emissions. In April 2012, US refiner Marathon Petroleum announced an agreement with the EPA to reduce volumes of natural gas sent to flares. The company has already invested around \$45MM to boost combustion efficiency at its plants and intends to spend another \$6.5MM to comply with the agreement. According to the EPA, the proposed changes will cut emissions from Marathon's six refineries by about 5.4K t/y. In the longer term, EM is able to minimize the risk of violating pending carbon legislation and supporting corporate sustainability goals. Also, with energy consumption monitoring being built into the asset management system, refiners will be provided with an easy path to monitoring, accounting, and managing carbon emissions if/when it becomes mandated at a future date.

When taking a step back, we can further relate the areas of asset management and environmental compliance to plant profitability. The link between improvements in asset management is clear, as the reduction of downtime will lead to significant improvements in productivity and, thus, profitability. As far as energy consumption and use is concerned, if we include energy both purchased and generated within the refinery as value-holding assets, there will be a clear link between the efficient allocation and management of these assets and profitability. Refiners need to look no further than considering savings in operational costs as positive contributors to refinery profits. In terms of environmental emissions, satisfying local and national regulations can help refiners to avoid penalties and fines. Accordingly, money saved by achieving environmental compliance can be considered profit generated by energy management programs. On the other hand, it is clear that due to the wide-reaching benefits of energy savings, projects oriented toward efficiency

improvements can often be "piggy-backed" on other improvement measures that are oriented toward enhancing asset management; improving maintenance reliability and safety; or achieving environmental compliance. When refiners are able to capitalize on the synergy between these concepts via energy management project, profits are improved and a more efficient, productive plant is born.

REPORT METHODOLOGY

Primary sources of information include personal communication with technology holders and catalyst and additive suppliers, extensive literature searches and evaluations, in-depth patent analyses and reviews, and insightful technology and business strategy assessments by a team of analysts and consultants.

REPORT SCOPE AND FOCUS

Key discussions begin in [Section 3](#) looking at major drivers for energy efficiency. Refiners' motivation may come from legislation mandating efficiency and limiting pollutant and CO₂ emissions, prices between competing combustion fuels and future trends, and others such as unit reliability. [Section 4](#) highlights general approaches adopted by the refining industry including energy management programs currently being implemented. A direct survey of refiners around the world was performed during the fourth quarter in 2011 to help gain a better understanding of refiners' views on energy efficiency and find out experiences had by others. [Section 5](#) reveals sources of refinery inefficiency. This Report identifies and discusses at length many areas where inefficiency can be found, such as equipment fouling, waste heat, electrical equipment, hydrogen production and use, steam production and use, and plant layout. [Section 6](#) concentrates on the solutions to rectify inefficiency in areas identified in Section 5. Relative energy savings are prioritized to help refiners target the most rewarding items first. It also delineates the benefits of process and heat integration as well as cogeneration. [Section 7](#) focuses on improving the energy efficiencies of major processing units, i.e. CDU, delayed coker, visbreaker, hydrotreater, hydrocracker, FCCU, catalytic reformer, and alkylation unit. Discussions lay out three investment options with low, medium, or high cost. [Section 8](#) presents overall strategic analyses and provides refiners with recommendations on which projects will give the most return on investment based on budget constraints and refinery configurations. Most importantly, a macroscopic approach is used to discuss the central role of energy management in refinery operations, particularly its intricate relationship with profit margins, asset management, and compliance with environmental regulations.

Major Drivers for Energy Efficiency

In recent years, several issues have, once again, pushed the task of energy management to the top of oil refiners' to-do lists. Drivers for energy efficiency can loosely be categorized as internal or external. Primary internal drivers for energy efficiency include the desire to improve productivity and profitability, reduce fuel

consumption costs in the face of volatile prices, improve plant safety and personnel satisfaction, and optimize plant operations and maintenance. External drivers for energy efficiency can come in the form of government regulations and mandates, industry competition, technology advances, suppliers, consumers, and from the public in regard to the social responsibilities of an industrial company.

Obviously, social and environmental factors will be significant driving forces behind energy management, but refinery decisions are most often based on productivity and profitability factors. It is important to realize that energy management also can make a significant impact on a refiner's bottom line while offering a range of intangible benefits both internally and externally. The goal of any energy management program is to reduce production costs without affecting yields, but many of the projects discussed throughout this report will offer additional benefits as well. Investment in energy efficiency programs will be a strategy of the utmost importance for refiners moving forward to ensure a profitable, responsible, and sustainable future.

General Approaches for Improving Energy Efficiency

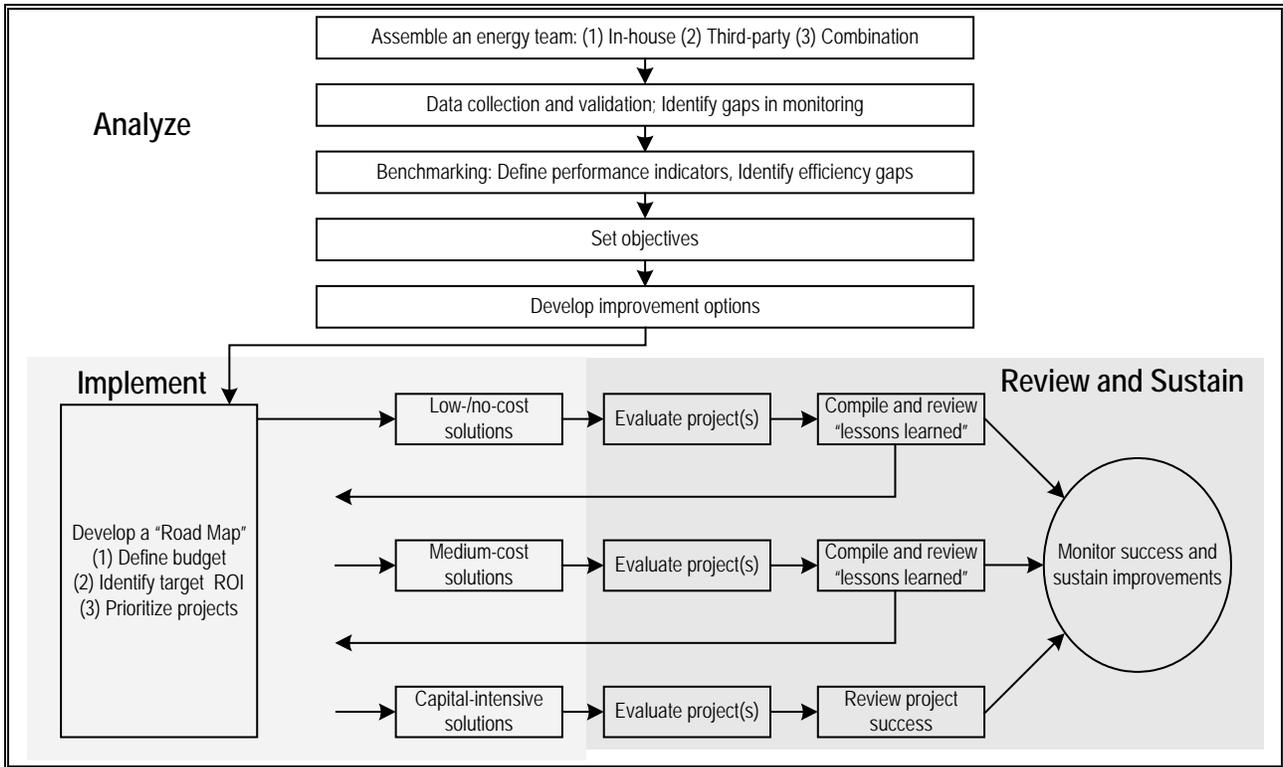
Refinery energy use comprises a significant share of operating budget, and aside from feedstock costs, is likely the second largest expense on a day-to-day basis. Clearly, even small gains in energy efficiency can become profitable, with the added benefit of improving environmental performance (i.e., lowering carbon footprint). It is estimated that a one point reduction in the Solomon Energy Intensity Index (EII) is estimated to save approximately \$1.7MM/y in terms of fuel costs at a fuel price of \$5/MM Btu, making energy efficiency programs economically attractive regardless of the price assigned to CO₂ emissions. So, just what options does a refiner have to trim energy consumption and start saving money? The report discusses several theoretical strategies and approaches to achieving energy management.

As indicated by the results of our direct survey among refiners worldwide, refiners' involvement and commitment to energy management and conservation differ significantly on a company-to-company and even site-to-site basis. Regardless of the current level of involvement, however, an energy management program begins by gaining a thorough understanding of energy use and of the basic options available as illustrated in the following diagram.

The report covers various approaches to energy management, along with techniques to prioritize energy efficiency, to define and assess an energy management system, and to plan for the implementation of energy management and conservation programs and initiatives. Whether implementation is done by an in-house energy team, a third-party consultancy, or a combination of the two it is imperative that a refiner

understand what, where, and how much energy is being consumed throughout the plant. A thorough assessment process followed by the formulation of a long-term energy roadmap is a critical first step, but must be followed up by regular re-assessments with a focus on improvement over the initial baseline and on the lessons learned. Furthermore, the favorable coupling of new or existing asset management systems with the energy management information system and action plan will lead to improved energy savings while also improving maintenance at the plant to enhance reliability, safety, and productivity.

GENERALIZED REFINERY ENERGY MANAGEMENT METHODOLOGY



Sources of Energy Inefficiency and Likely Solutions

An average refinery consumes between 330K and 550K Btu for every barrel of crude processed. Although not all of this lost energy can be eliminated, improving equipment efficiency and reducing waste heat and heat losses can significantly reduce the amount of energy lost. While every refinery has opportunities to improve energy efficiency, the key is to focus on opportunities that will provide noticeable benefits and result in short payback time. In order to achieve the most "bang for the buck," the report identifies which areas are the major sources of wasted energy, then examines a list of potential improvements, and then trims down the list to focus on those that achieve the greatest energy savings at the lowest cost.

The table below summarizes the approximate amount of energy lost to each of eight categories in an average refinery.

SOURCES OF ENERGY INEFFICIENCY IN A REFINERY

Source	Energy lost, K Btu/bbl crude	Cost for a 100K-b/d refinery, MM \$/y
Waste heat	90	17.2
Steam system	87	16.6
Furnaces	74	14.2
Motor systems	17	3.2
Fouling	12	2.3
Hydrogen production/use	49K Btu/kg H ₂	N.A.
Fractionation	N.A.	N.A.
Plant/equipment layout	N.A.	N.A.

Unique Solutions to Individual Process Units

To help plant management and personnel zero-in on the refining units with the most room for energy improvement, the following table summarizes the specific average energy use for each processing unit and the target energy use for each unit.

PROCESS UNIT ENERGY CONSUMPTION AND LOSS

Unit	Specific energy use, K Btu/bbl	Target energy use, K Btu/bbl	Energy loss, K Btu/bbl
Atmospheric distillation unit	109.1	50	59.1
Vacuum distillation unit	89.1	54	35.1
Delayed coker	140.5	119	21.5
Visbreaker	88.5	88.5	33.6
Hydrotreater	80.8	55	25.8
Hydrocracker	158.9	N.A.	N.A.
Fluid catalytic cracker	182.8	132	50.8
Catalytic reformer	263.9	203	60.9
Alkylation	244.6	154	93.3

Many of the inefficiencies in the crude distillation unit are the same as those for other distillation columns including reflux rate, pumparound duty, poor liquid distribution and tray/packing inefficiencies, but the size of the CDU magnifies the issues.

Delayed coking is a fairly energy-intensive process. The majority of the fuel consumed during coking involves process heating and is due to the high temperatures that must be achieved.

The majority of energy consumed in visbreaking operations is attributed to heating the feed to cracking temperatures and distillation of the visbroken products. Therefore, the major efficiency losses are typically in the heat exchangers, furnace, and fractionator.

In hydrotreating units, major sources of inefficiency stem from catalyst deactivation, liquid maldistribution, reactor pressure drop buildup, and hydrogen consumption.

Energy consumption in hydrocrackers is driven by several key aspects/pieces of equipment in the process: pumps and compressors; supplying process heat and steam; and product separation. Some major sources of inefficiency stem from catalyst deactivation, fouling and corrosion, and hydrogen consumption.

Inefficiency in the FCCU can come from a number of sources, with the unit experiencing inefficiency from systems common to other refinery units: preheat train exchangers, fractionators, auxiliary equipment, etc. Furthermore, due to the unique nature of the riser-regenerator configuration that is applied in FCC processes, poor heat transfer between the hot catalysts and process stream will be a large source of inefficiency, as will be waste heat from the regenerator.

The primary sources of inefficiency present in catalytic reformers involve process heating, catalyst regeneration, and the hydrogen recycle/recovery system.

The majority of the energy used in alkylation processes is in the form of fuel for steam boilers. Steam is used in stripping units such as depropanizers and debutanizers. Therefore, inefficiencies in fractionation are one of the factors affecting the overall process energy efficiency.

The report is designed to provide in-depth discussions of energy demand and opportunities to improve the energy efficiency of each processing unit. Energy improvement opportunities are broken down into three categories: (1) operational adjustments, (2) solutions requiring additional investment, and (3) major revamps and grassroots projects. In general, operational adjustments will be the simplest and lowest capital projects, while the second and third categories will require increasing amounts of capital investment but potentially will provide higher energy efficiency improvements.

Strategic Analysis and Recommendations

The motivation to implement an energy efficiency program in a refinery is driven by three major factors: profit margins, asset management, and environmental regulation compliance. However, there are many constraints which make it difficult for some refiners carry out the energy improvements. The obstacles to implementation include the types of crudes refiners decide to process because of lower costs, production of energy-intensive fuels to meet market demand, availability of operating and capital budgets, companies' levels of commitment, pending governmental fuel standards and/or emission regulations that result in higher energy use, and so on. Nevertheless, reduction in refinery energy consumption offers short-term benefits and helps companies achieve the long-term sustainability goal. We have identified options and offer recommendations that refiners may consider based on two major criteria: budget constraint and plant

configurations (i.e. gasoline-centric refineries, complex refineries for producing both light and middle distillates, and complex refineries capable of processing opportunity crudes.)

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