Petroleum BestPractices Plant-Wide Assessment Case Study

Industrial Technologies Program

Valero: Houston Refinery Uses Plant-Wide Assessment to Develop an Energy Optimization and Management System

Benefits

- Identified potential annual cost savings of $5 million
- Found measures that could achieve annual fuel savings of nearly 1.3 million MMBtu and electricity savings of more than 5 million kWh
- Identified ways to reduce NO_x and CO emissions

Application

The Valero plant-wide assessment employed an energy systems review to identify primary energy users and to optimize the plant's energy production system. Developing an overall energy management strategy for the refinery was a key element.

Summary

Valero Energy Corporation recently undertook a plant-wide energy assessment at its refinery in Houston, Texas. The assessment consisted of an energy systems review to identify the primary natural gas and refinery fuel gas users, electricity- and steam-producing equipment, and cooling water systems and to develop an energy optimization and management system. It also addressed ways to reduce water use and environmental emissions. If all the projects identified during the study were implemented, the assessment team estimated that total annual energy savings at the Houston refinery would be about 1.3 million MMBtu (fuel) and more than 5 million kWh (electricity). Total annual cost savings would be about $5 million.

Public-Private Partnership

The U.S. Department of Energy's (DOE) Industrial Technologies Program (ITP) cosponsored the assessment. DOE promotes plant-wide energy-efficiency assessments that will lead to improvements in industrial energy efficiency, productivity, and global competitiveness, while reducing waste and environmental emissions. In this case, DOE contributed $100,000 of the total $441,750 assessment cost.

Plant Description

Valero Energy Corporation—based in San Antonio, Texas—has approximately 20,000 employees. Estimated annual revenues are approximately $50 billion. The company currently owns and operates 14 refineries throughout the United States, Canada, and the Caribbean. The refineries have a combined throughput capacity of more than 2 million barrels per day—approximately 10% of the total U.S. refining capacity. Valero is also one of the nation's largest gasoline retailers.

In 1997, Valero purchased the Houston refinery, which was built by another company in the 1940s. This crude oil processing facility produces a wide range of petroleum products, including gasoline, diesel fuel, kerosene, asphalt, jet fuel, sulfur, No. 2 and No. 6 fuel oil, and liquefied petroleum gas. It turns out approximately 60,000 barrels per day of gasoline and 35,000 barrels per day of distillates. Processing capabilities primarily involve medium sour crudes and low-sulfur residual oils.

The Houston facility is composed of several process units equipped with natural gas- or refinery gas-fired equipment. These units process raw crude oil into various finished products by means of distillation and chemical reactions. The units include the following:

- **Crude complex**—Consists of atmospheric and vacuum distillation towers with two lightends removal towers.
- **Fluidized catalytic cracking complex**—Thermally cracks heavy gas oil material into lighter products, such as gasoline and diesel.

- **Hydrotreating/reforming complex**—Processes kerosene, diesel, and naphtha in four desulfurization units; desulfurized naphtha is reformed in a fixed catalyst bed reformer to produce a high-octane gasoline blend component.
- **Sulfur removal complex**—Recovers sulfur from gas streams in an amine contacting/regeneration unit and a sulfur plant before using the gas streams as refinery fuel gas.
- **Alkylation complex**—Produces a high-octane gasoline blending component using a sulfuric acid alkylation unit; an isooctene unit converts butane streams into isooctene for gasoline blending.

Refinery fuel gas is used in process heating and steam production. Four fired boilers and waste heat recovery equipment (two cogeneration units) produce steam. Each process unit requires cooling water, supplied by six refinery cooling water towers, to remove low-level heat. The refinery's three flare systems vent and burn light gases produced by the process equipment. The facility has access to three water sources: the Coastal Water Authority (CWA) supply, City of Houston municipal water, and well water.

Assessment Approach

The plant-wide assessment consisted of two primary activities:

- **Energy systems review**—The assessment team reviewed all the primary energy systems: natural gas, refinery fuel gas, electricity production, steam, and cooling water. They identified major natural gas and refinery fuel gas users, electricity- and steam-producing equipment, and cooling water systems. They also gathered energy-use data to identify major energy-consuming equipment and processes.
- **Energy optimization and management system development**—Assessment data and energy system information were gathered to develop an Aspen Utilities[1] computer model of the primary refinery processes and the energy production and distribution systems. The model can be used to determine the most efficient loading of individual pieces of equipment.

Results and Projects Identified

Table 1 lists projects identified during the plant-wide energy assessment. Details about individual projects follow.

Upgrade steam system insulation. Using 3E Plus software from the North American Insulation Manufacturers Association, the assessment team identified several uninsulated or underinsulated steam system lines and equipment. They recommended upgrading the steam system insulation to reduce energy losses.

Install a new air compressor. The team recommended replacing two rented diesel air compressors with one new steam-driven compressor. Savings would include 108 gallons per day of diesel fuel and $160,000 per year in rental fees.

Install carbon monoxide (CO) control system. The assessment team recommended installing two Bambeck CO control systems on the crude unit's atmospheric and vacuum heaters. Energy savings would result from reducing excess oxygen from about 3.5% to 1.5%. In addition, nitrous oxide (NOx) and CO emissions would be lower because of the lower flame temperatures. The Bambeck CO control systems use a CO analyzer on the heater flue gas, a stack damper control system, heater draft instrumentation, and computer software to minimize excess oxygen.

Install cooling tower automatic blowdown control. The team recommended installing instrumentation and controls on four cooling towers to automatically control each tower's conductivity, which is a measure of solids in the circulating cooling water. High conductivity reduces makeup water costs, chemical use (for water treatment), and downstream processing costs, but it increases cooling water system fouling and corrosion while reducing heat transfer. Low conductivity has the opposite effects. Keeping conductivity within a suitable range is thus important to the overall performance and cost of the cooling water system. This project could reduce makeup water and chemical costs by $130,000 per year.

[1] Valero selected Aspen Technology, a software modeling company, to supply and support its software needs.

Table 1. Projects Identified During Valero's Houston Refinery Plant-Wide Assessment					
Project Description	**Cost Savings ($/year)**	**Capital Cost ($)**	**Payback (years)**	**Fuel Savings (MMBtu/year)**	**Electricity Savings (kWh/ year)**
Upgrade steam system insulation	166,100	100,000	0.6	51,906	NA
Install new air compressor	200,000	400,000	2.0	5,125	NA
Install CO control system	247,700	401,000	1.6	77,406	NA
Install cooling tower automatic blowdown control system	130,000	240,000	1.8	NA	NA
Incorporate an Energy Optimization and Management System	2,200,000	270,000	0.1	687,500	NA
Inspect, repair, and maintain steam traps	656,000	100,000	0.2	205,000	NA
Install boiler automatic blowdown control system	100,000	180,000	1.8	NA	NA
Replace boiler house boilers	161,000	3,000,000	18.6	50,313	NA
Install flare gas recovery compressor	420,000	1,000,000	2.4	131,250	NA
Install evaporative coolers on cogeneration units	174,700	249,000	1.4	-17,035	4,987,000
Clean the CWA water supply line	13,000	6,000	0.5	NA	NA
Assign an energy coordinator	200,000	130,000	0.7	NA	NA
Turn off outdoor lighting during daylight hours	6,000	NA	0	NA	175,000
Install liquid ring vacuum compressor	306,000	450,000	1.5	95,625	NA
Total	**$4,980,500**	**$6,526,000**	**1.3 (avg.)**	**1,287,090**	**5,162,000**

Incorporate an Energy Optimization and Management System (EOMS). Aspen Technology was chosen to develop an EOMS using its Aspen Utilities software. The EOMS will be used in assessing, implementing, and tracking process unit energy system changes and new project implementation effects on the refinery. Aspen Technology estimated that the EOMS would reduce annual energy use by 2% to 6%.

Aspen Utilities is a model-based, equation-oriented simulation and optimization software tool. It optimizes the purchase, supply, and use of fuel, steam, and power at the refinery, based on process unit energy demands and system constraints caused by equipment or environmental regulations. The software analyzes conditions such as supply contract variability, alternative fuel options, optimum loading of steam boiler equipment, motor versus turbine driver decisions, and importing versus exporting of steam, fuel, and power. To construct a refinery-wide energy flow sheet model, the software performs these functions:

- Facilitates optimal planning of utility equipment
- Assists in optimal operation of the utility plant and associated equipment
- Provides real-time information on site-wide energy performance, utility costs, and revenues
- Provides real-time information for use in prioritizing maintenance tasks.

Inspect, repair, and maintain steam traps. Because leaking or failed steam traps can cause significant energy losses and create process problems, the team surveyed steam systems for leaking or failed traps. They recommended that these be repaired and a maintenance program implemented.

Install boiler automatic blowdown control system. The team recommended installing instrumentation and controls on three steam boilers to automatically control boiler blowdown conductivity. High conductivity reduces boiler feedwater expenses and chemical use but increases boiler system fouling and corrosion while reducing heat transfer. Low conductivity has the opposite effects. Controlling conductivity within a suitable range is important to overall boiler system operation and costs. This project could reduce boiler feedwater and chemical costs by $100,000 per year.

Replace boiler house boilers. The team recommended replacing the four 1940s-era 50,000 pounds per hour (lb/hr) induced draft boilers with a new 200,000 lb/hr boiler to improve operating efficiency and reduce fuel gas usage. By reducing NOx and other emissions, this project would have economic and environmental benefits.

Install flare gas recovery compressor. The assessment team recommended installing a compressor and associated equipment to recover flare gases from three existing flare systems. Recovered gas can be amine-treated to remove hydrogen sulfide and routed to the refinery fuel gas balance drum. This would reduce natural gas makeup to the gas balance drum, except when there is excess recovered fuel gas because one or both off-site refinery fuel gas purchasers are shut down.

Install evaporative coolers on cogeneration units. The assessment team recommended installing intake air coolers to increase the cogeneration of electric power either to offset purchased power or to sell to the local power grid. However, the cogeneration units will probably be replaced because of their aging components, inefficiency, and NOx emissions.

Clean the CWA water supply line. The team recommended cleaning a raw water supply line to reduce pressure drop and increase flow. This project was implemented; the system now supplies the added water needed to meet refinery demands without having to bring in more expensive municipal water.

Assign an energy coordinator. Before the plant-wide energy assessment, no one was responsible for monitoring refinery energy use and developing energy projects. The assessment team recommended assigning a full-time energy coordinator and support personnel. This team would be responsible for such activities as ensuring that steam trap surveys are conducted, developing energy use simulation models, reviewing flare system losses, developing energy projects, and monitoring energy use.

Turn off outdoor lighting during daylight hours. The assessment team found that lighting was being left on unnecessarily during the day. Therefore, operations personnel were reminded to turn off these lights when they were not needed. The team also found that most areas in the refinery are equipped with photocells. However, several photocell switches had become dirty or had been accidentally painted over, so they were repaired or replaced.

Install liquid ring vacuum compressor. The team recommended installing a liquid ring vacuum compressor on the vacuum tower overhead system to replace the third-stage vacuum steam jets and water cooler. This project will reduce steam use at 285 pounds per square inch (gauge) by about 6,000 lb/hr. Additional steam savings should result from the improved suction pressure on a downstream compressor.

These recommendations could save Valero about $5 million per year in costs while reducing environmental emissions.

BestPractices is part of the Industrial Technologies Program, and it supports the Industries of the Future strategy. This strategy helps the country's most energy-intensive industries improve their competitiveness. BestPractices brings together emerging technologies and energy-management best practices to help companies begin improving energy efficiency, environmental performance, and productivity right now.

BestPractices emphasizes plant systems, where significant efficiency improvements and savings can be achieved. Industry gains easy access to near-term and long-term solutions for improving the performance of motor, steam, compressed air, and process heating systems. In addition, the Industrial Assessment Centers provide comprehensive industrial energy evaluations to small- and medium-size manufacturers.

Project Partners

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