W. R. Grace: Plant Uses Six Sigma Methodology and Traditional Heat Balance Analysis to Identify Energy Conservation Opportunities at Curtis Bay Works

Benefits

- Identified savings of more than 96,000 MMBtu annually in fuel and more than 4.8 million kWh annually in electricity
- Identified cost savings of $840,000 annually
- Estimated annual cost savings of $900,000 to $1.2 million and almost 560,000 MMBtu energy savings if a separate landfill gas recovery project is implemented
- Can yield an attractive payback period

Application

Six Sigma is a rigorous and disciplined methodology that uses data and statistical analysis to measure and improve operational performance by identifying and eliminating defects in manufacturing and service-related processes. The goal of Six Sigma is to improve products and processes by eliminating variability, defects, and waste. The use of Six Sigma analysis tools provides a unique technique for energy conservation project comparison and selection. The concept can be applied across a broad section of manufacturing industries.

Summary

The plant-wide energy assessment at W. R. Grace's Curtis Bay Works in Baltimore, Maryland, identified four technically and economically viable projects with combined potential savings of $840,000 per year (approximately 96,000 million British thermal units [MMBtu] per year in fuel and 4.8 million kilowatt hours per year [kWh/yr] in electricity).

A separate, unique project that would partner W. R. Grace with the City of Baltimore to recover and use landfill gas (methane) to cogenerate steam and electricity was also identified during the assessment. If this project were implemented, gas recovered from the landfill could replace 40% of the electricity and 65% of the fuel currently required to produce steam at Curtis Bay Works. Annual savings are estimated at $900,000 to $1.2 million (approximately 560,000 MMBtu/yr in natural gas).

This assessment methodology can be employed at any large manufacturing facility. Six Sigma tools provide a unique technique for project comparison and selection. The selected energy conservation projects are not specific to a chemical process or unit operation. W. R. Grace has two other facilities of similar size to which this methodology can also be applied.

DOE-Industry Partnership

The U.S. Department of Energy's (DOE) Industrial Technologies Program (ITP) cosponsored the assessment through a competitive process. DOE promotes plant-wide energy-efficiency assessments that will lead to improvements in industrial energy efficiency, productivity, and global competitiveness, and will reduce waste and environmental emissions. In this case, DOE contributed $100,000 of the total $240,800 assessment cost.

Company Background

W. R. Grace & Company's Davison Product Line produces materials used in petroleum refining, paints, plastics, dentifrices, and edible oil refining. Davison's products are intermediates for consumer products produced by other companies. Davison, which became part of W. R. Grace in 1954, has 13 production facilities worldwide. The Curtis Bay Works in Baltimore, Maryland, is the largest and most diverse site.

The Curtis Bay Works is a multi-plant, multi-product facility covering nearly 90 acres and employing 700 people. Comprising 10 production facilities (Plant #1 through Plant #10) that manufacture thousands of products, Curtis Bay Works is separated into four complexes based on product lines. The basic products are nonorganic solids that are predominantly

W.R. Grace's Curtis Bay Works in Baltimore, Maryland

composed of silica and alumina. Production processes include mixing, filtering and washing, drying, and calcination (high temperature drying).

Assessment Approach

In 2000, the entire Curtis Bay Works complex purchased 2 billion cubic feet of natural gas and 100,000 megawatt hours (MWh) of electricity. The site also produced 700 million pounds of 200-pounds per square inch gauge (psig) steam and 4 billion cubic feet of 85-psig air. Curtis Bay Works consumed 1.5 billion gallons of city water during the year. Because of the facility's magnitude of energy consumption, management was aware that tremendous savings opportunities existed.

The production facilities' managers had traditionally concentrated on energy conservation within individual facility boundaries. Historic barriers to a site-wide energy survey included the lack of a dedicated engineering resource to perform analyses and insufficient capital funding. W. R. Grace partnered with Constellation Energy Source (CES) to provide engineering services. To solve the funding issue, W. R. Grace and CES signed an agreement that allows CES to purchase and install energy conservation equipment, add overhead and profit, then lease the equipment to W. R. Grace. Although this arrangement reduces W. R. Grace's net cost savings, it allows the company to avoid cash flow issues, provides a dedicated engineering resource, and promotes the implementation of energy conservation projects that would not historically have been considered.

The assessment was based on Six Sigma methodology combined with traditional heat balance analysis to identify, quantify, and rank potential energy conservation projects. The assessment team initially identified 23 projects, some competing for the same energy source or application. Using a process

Table 1. Summary of Selected Energy Conservation Projects					
	Annual Projected Economic Impact				
Project	**Fuel (natural gas) (MMBtu)**	**Electricity (kWh)**	**Annual Savings ($)**	**Capital Cost ($)**	**Payback Period (yr)**
Wastewater heat recovery	23,203	N/A	132,900	197,000	2.4
Waste gas heat recovery	54,090	N/A	292,600	614,500	2.2
Flue gas heat recovery	18,875	N/A	85,900	346,800	5.3
Compressed air distribution system upgrade	N/A	4,833,000	329,000	460,600	1.9
Total:	**96,168**	**4,833,000**	**840,400**	**1,618,900**	**1.9 (average)**

Note: A separate project to recover municipal landfill gas (methane) could save an additional $900,000 to $1.2 million and 558,700 MMBtu annually.

map and cause-and-effect matrix, followed by a traditional cost-benefit analysis, and finally by a detailed engineering analysis, the list was reduced to three desirable projects. The team identified a fourth project from a comprehensive compressed air systems audit.

Six Sigma Methodology

The Six Sigma methodology was an alternative to a conventional engineering analysis. The goal is continuous process and product improvement by removing defects and their causes. This approach emphasizes outputs that are important to customers. The assessment team used various statistical tools to measure the pertinent business processes.

A designated group managed the entire Six Sigma process. The most common way to implement the Six Sigma methodology follows the steps signified by DMAIC: Define, Measure, Analyze, Improve, and Control. In this approach, the group first defines the projects and the processes to be improved, then measures process performance. Measured data is analyzed and process bottlenecks and problems are identified. After analysis, the group develops an improvement program and determines how to remove defects. The following explains how the assessment team applied the Six Sigma methodology at Curtis Bay Works.

Define. Although the overall site heat load had never been analyzed, the team used existing data to calculate consumption of gas and steam for individual processing units. Using this data, energy users were identified. The team then plotted these users on a topographical site map.

Measure. Process energy consumption was relatively well defined, but the losses were typically unknown. In many cases, the team could directly measure energy losses from exhaust temperatures and flows. In cases where team members could not directly measure energy losses, they used fan performance curves to estimate flow rates and the corresponding energy losses. The team also identified the waste energy not thermodynamically required by the processes as potential energy sources. The energy losses were then plotted on the same topographical map as the known sources to show sources and users together. The heat balance analysis results became the project baseline.

Analyze. The team employed the Six Sigma tools of a process map and a cause-and-effect matrix in project evaluation. The process map was used to discern the outputs needed to best assess the overall value—tangible and intangible—of a project. The team used the cause-and-effect matrix to rate each project objectively, based on importance to the customer and on other considerations, such as energy savings and waste reduction potential. After the project conceptual phase and benefits estimates were complete, Javan & Walter performed a more detailed engineering analysis. Three projects met the financial criterion of a 20% internal rate of return.

Air Science Engineering performed an audit of the compressed air system concurrently with the assessment of waste energy and its potential reuse. The air system audit prompted a fourth project that was added to the final list.

Improve. The value of each project is realized in the "Improve" phase. This phase encompasses the final design, installation, and start-up of the individual projects. After completing the design-engineering phase, the team develops a separate scope of work for each project. These scopes of work are then included in bid packages given to contractors. In this case, Davison and CES personnel supervised equipment installation and start-up.

Control. W.R. Grace management wanted to ensure that cost savings were directly connected to measurable reduction in energy and/or water consumption. The company will track resource consumption against the baselines established during the "Measure" phase. Mechanisms to track monthly energy savings have already been established.

Results and Projects Identified

The plant-wide energy assessment identified four technically and economically viable projects with combined potential savings of $840,000 per year (Table 1). Once the first four projects have been implemented, management will prioritize the remaining projects that were identified during the assessment's early phases for future consideration. New projects may also be identified using the same assessment methodology.

Wastewater heat recovery

The washing process in Plant #7 produces a wastewater stream of about 145°F. Currently, this waste stream is directed to a water treatment plant. Fresh wash water in Plant #7 is currently completely heated with direct-injection steam. This project involves installing a heat exchanger to recover the heat from the wastewater stream to replace 90% of the steam used to heat the fresh water in Plant #7.

Waste gas heat recovery

To meet state-mandated fenceline toxic air emission limits, process sweep air used to remove the gases evolved during drying in Plant #1 is heated and catalytically treated to remove nitrogen oxide (NO_x). Currently, this heated air is exhausted directly to the atmosphere. This project involves installing an air-to-water heat exchanger to use waste air (that would have otherwise been exhausted to the atmosphere) to heat incoming fresh water in Plant #4 and Plant #5. The fresh water is currently heated with 190-psig steam. The waste energy exhausted to the air from one plant can therefore be used to heat the incoming fresh water in two other plants. The recovered energy will replace 100% of the steam used for water heating in one plant and 23% of the steam used in the second plant.

Flue gas heat recovery

Air for two mills is indirectly heated using fired natural gas. A second process uses gas-fired burners to indirectly dry product. The mills and the dryer are in Plant #6. The combustion gases are currently exhausted directly to the atmosphere. This project involves installing three air-to-water heat exchangers to recover heat to replace steam injection heating of fresh water used for product washing in Plant #5. Approximately 31% of the steam used to heat wash water in Plant #5 will be replaced by implementing this project.

Compressed air distribution system upgrade

Compressed air for the entire Curtis Bay Works is currently generated in a central location using multiple compressors. The compressors are separately operated and are manually controlled to meet fluctuating demand. All compressors are operated at their maximum design pressure of 125 psig, although the system target pressure is 85 psig. There is no effective storage capacity in the system.

The air audit recommended four measures that will be consolidated into a single project financed by CES:

1) Installing a computerized compressor management system to automatically control air supply

2) Designating and operating individual compressors as either base load or trim

3) Reducing system pressure to 75 psig

4) Installing a storage unit.

The air system audit also prompted a separate recommendation to change the air supply to pulsed air bag collectors. This relatively inexpensive retrofit would reduce the required pressure and the volume of air used while maintaining efficient bag cleaning. Bag life would be extended because of less stressful pulsing. W. R. Grace decided to pursue this recommendation as a separate internal project.

Baltimore City municipal landfill methane gas recovery

The assessment team is also considering a separate, unique project that would partner W. R. Grace with the City of Baltimore to recover and use landfill gas (methane) to cogenerate steam and electricity. This landfill gas project is long term, estimated to take more than 2 years to complete. Implementation would require working with municipal government as the third-party landfill owner. Engineers have estimated that the landfill produces 558,700 MMBtu/yr of combustible gas. Energy derived from using the landfill gas in cogeneration could replace 40% of the site's electricity and 65% of the fuel required to produce steam currently required at Curtis Bay Works. Potential annual savings for natural gas and electricity replacement from this project are estimated at $900,000 to $1.2 million. The preliminary project capital cost estimate is $3 million.

Because of its unconventional nature, this project was developed separately from the other projects. Six Sigma methodology was not used in the project analysis. Two options were explored—using upgraded landfill gas (carbon dioxide and water would be removed) directly in the Curtis Bay Works steam boilers or using the upgraded gas to cogenerate electricity and steam. A financial analysis demonstrated that cogeneration would be the more desirable option. It is estimated that cogeneration would provide 40% of Curtis Bay Works' electricity requirement and 65% of its steam requirement.

The project would be composed of discrete steps, including drilling test wells to characterize gas quality and quantity, analyzing the costs required to collect and upgrade the gas, and development and implementation. This is an environmentally friendly project because landfill gas would replace purchased natural gas. The landfill gas that would have otherwise been flared to the atmosphere will be converted to useful energy. Thus, only one source of gas would be burned, not two. Total emissions to the environment would therefore be reduced. It is estimated that the NO_x would be reduced by 15,900 pounds per year (lbs/yr) and carbon dioxide (CO_2) would be reduced by 62.5 million lbs/yr.

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

W.R. Grace & Company
Columbia, MD

Constellation Energy Source
Baltimore, MD

Javan & Walter, Incorporated
Fort Washington, PA

Air Science Engineering
Chandler, AZ

For Additional Information, Please Contact:

Industrial Technologies Clearinghouse
Phone: 800-862-2086
Fax: 360-586-8303
clearinghouse@ee.doe.gov

Visit our home page at
www.oit.doe.gov

Industrial Technologies Program
Energy Efficiency
and Renewable Energy
U.S. Department of Energy
Washington, DC 20585-0121

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

DOE/GO-102003-1650
Revised December 2003