Building Energy Cost Savings From Six-Sigma Process Improvement Methods

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ABSTRACT

Over the past several years, more and more companies have adopted Six Sigma process improvement methods to manage their businesses. Six Sigma has gained credibility among business executives and managers for its ability to reduce cycle time, eliminate product defects, lower costs, and significantly increase customer satisfaction. At General Electric, Jack Welch (CEO) wrote in the 1997 annual report that in just three years, Six Sigma had saved the company more than $2 billion.

In 2002, Armstrong World Industries adopted the Six Sigma business initiative throughout the corporation. This article describes two Six Sigma energy usage and cost reduction efforts initiated during 2003, both addressing the main sources of energy costs at the corporate campus. These projects were process improvements, one a trailblazing effort, the other a Green Belt project—both Six Sigma methodologies. Together, these projects have resulted in significant energy usage reductions and cost savings. Aggregate annual savings are expected to be about $230,000 or 12 percent of total campus energy costs, compared to the 2003 base year period.

COMPANY AND ORGANIZATION

Armstrong Holdings, Inc. is the parent company of Armstrong World Industries, Inc., a global leader in the design and manufacture of floors, ceilings, and cabinets. In 2003, Armstrong's net sales totaled more than $3 billion. Founded in 1860 and based in Lancaster, Pennsylvania, Armstrong has 44 manufacturing plants in 12 countries and approximately 15,200 employees worldwide.

Armstrong's campus center and corporate headquarters are located in Lancaster, Pennsylvania. Campus facilities are located on a 600-acre plot, with approximately 150 acres of developed property including buildings, roadways, and parking areas. There are 28 buildings, enclosing just under 1,000,000 square feet of conditioned space for about 1,500 employees. The buildings range in age from those initially constructed in 1950 to the newest corporate headquarters building, #701, completed in December 1998.

The facilities management organization supports business unit and corporate facilities at the campus center. Services provided include building and equipment maintenance, HVAC management, capital improvements, mail and copying, and security. Our goal is to meet and exceed campus customers' needs in support of business unit and corporate goals.

PROJECT SUMMARY

Armstrong World Industries corporate campus spends more than $1.8M annually for energy. Electricity and natural gas costs are the significant components, with fuel oil contributing about $50,000. Two formalized energy cost reduction efforts were initiated during 2003, addressing both primary sources of energy cost. These projects were categorized as process improvements, one a trailblazing effort, the other a Six-Sigma green belt project. Trailblazing is a process designed to analyze and improve key business challenges quickly. Six-Sigma is a more comprehensive process improvement methodology with a key outcome of reducing the number of "defects" in a process. Both process improvement projects have resulted in significant energy use reductions (approx 1.6 MM kWh through 2004, an additional 860,000 kWh in 2005), environmental improvements, and reduced campus energy expenses.

ELECTRICAL ENERGY REDUCTION

Armstrong's campus center uses more than 21,000,000 kWh of electricity annually, at a cost exceeding $1,000,000. Of this total, about 12,500,000 kWh, or 60 percent, is consumed during building *unoccupied* periods (overnight, weekends, and holidays). In 2002, this off-period expense was about $650,000. A Six Sigma green belt project analyzed these off-period electrical usages. Using power measurement devices installed for each building's electrical system, significant electricity users and operational characteristics were identified and benchmarked. Figure 1 displays a typical week's campus power use, and clearly shows the non-occupied period usage (area under the 1,500 kW grid line). These types of graphs were key to identifying operational measures and equipment improvements.

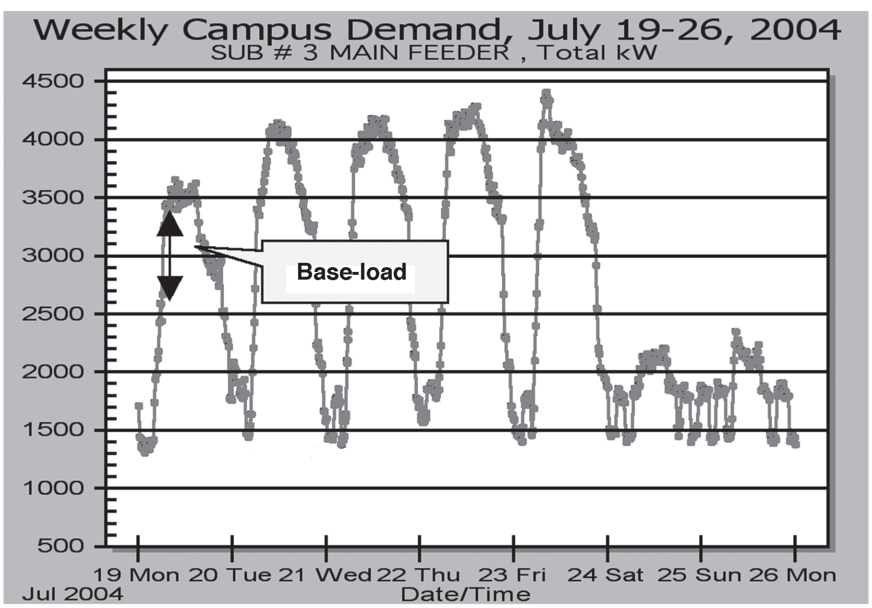

Figure 1. Weekly Campus Power Profile

A green belt project team was formed in May 2003 for this effort. Building "focus teams," which included building representatives and facility management representatives, were created to brainstorm savings ideas.

Thirty-seven (37) specific reduction measures were identified. Of these, 23 were implemented beginning in May 2003, continuing through 2004. The remaining items were budgeted for 2005, and will be complete by the third quarter. Capital expended in 2004 was about $62,000, with $96,000 budgeted for 2005. The overall project is expected to show about a 1.2-year simple payback.

Improvement measures include:

- **HVAC Changes—**Air handler schedules, speed changes, make-up and exhaust air reductions, non-occupied period space set points.
- **Reducing Losses—**Disconnected unused equipment, eliminated excess electrical substation capacity (3), resized equipment for current customer or conditioned space requirements.
- **Equipment Improvements—**Air conditioner replacements, installing switches/automatic controls, more efficient UPS converter.
- **Lighting—**T8 fixture installations, lamp and ballast retrofits, installing switches, motion sensors, eliminating incandescent lamps, installing compact fluorescent lamps.

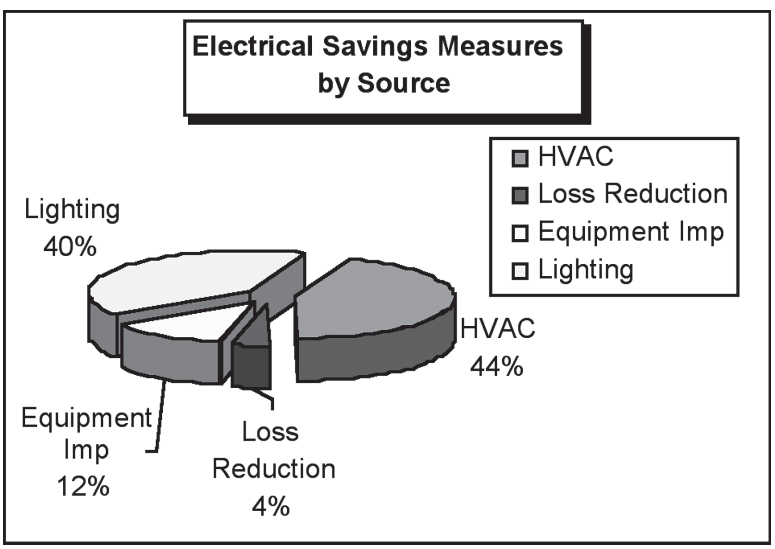

Figure 2. Savings by Source

TECHNOLOGY APPLICATIONS

The campus employs two technologies that are key to measuring and analyzing energy information. A power monitoring system provides real-time electrical system data for all the main campus buildings and the main utility revenue meter. This system, and the reports it produces, provides instant measurements and feedback when changes are implemented. These data are used to establish monthly and annualized usage benchmarks for all campus buildings.

An energy management control system (EMCS) is also employed on the campus. There are approximately 8,000 hardware and software points, controlled by 700 individually programmed algorithms. These processes control all HVAC functions for fourteen (14) buildings, the central chilled water plant, and the boiler steam operation. In the boiler plant, the EMCS monitors all critical mechanical systems, burner management systems, and steam parameters. It is Ethernet based, and is accessible from eight operator workstations around the campus.

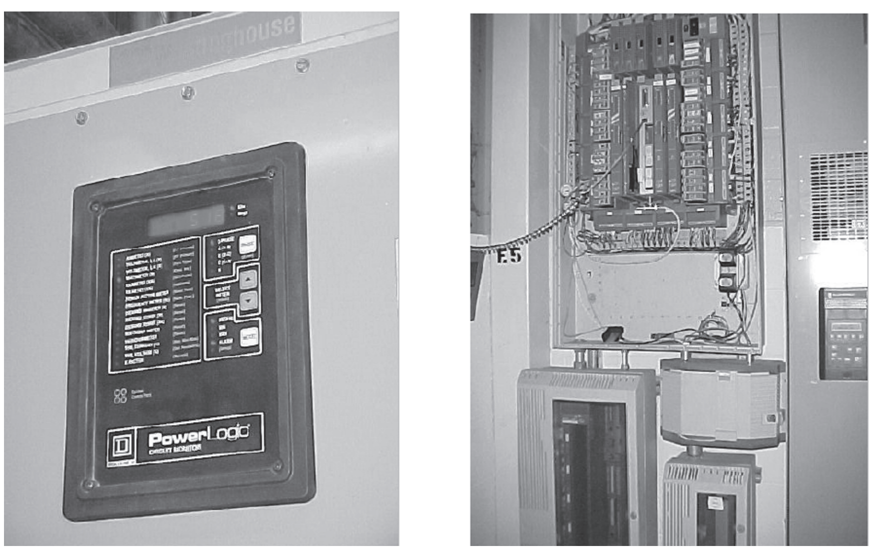

Figure 3. Power and EMCS controls

ELECTRICAL PROJECT BENEFITS

Permanent, sustainable electrical energy cost reduction was the primary goal for the project. Initially, a target of 15 percent of off-hour usage, or $100,000 annually was established. Other anticipated benefits include:

- Reduced lamp recycling costs when ECOLOGIC© (environmentally friendly) type lamps eventually replace existing inventories and replacement cycles in buildings are complete.
- Installed electricity measurement systems facilitate monthly building comparisons with electrical usage benchmarks established during the project.
- Involving building "focus teams" on the campus for brainstorming, and facilities technicians to implement improvements increased awareness by campus employees of energy use and costs.
- Documented process improvements that will maintain savings over time.

Actual power reductions and savings are summarized in Table 1. The 2005 year column estimates annualized savings for in-progress projects. The monthly comparison for the first complete year (May 2003-2004) in Figure 4 shows average usage reductions of 7 percent.

Table 1. Electrical Cost Savings

Building 2004 kWh Reduction	*2003 & Reduction*	*2005 kWh Reduction*	*Total kWh Savings*	*Total $*
Campus	217,900	200,000	417,900	$24,900
1,2,3	903,200	140,000	1,043,200	$58,150
4 & 5	0	292,200	292,200	$14,600
19	178,140	64,860	243,000	$12,150
301	86,500	166,900	253,400	$14,300
701	218,900	0	218,900	$10,900
TOTALS	1,604,640	863,760	2,468,000	**$135,000**

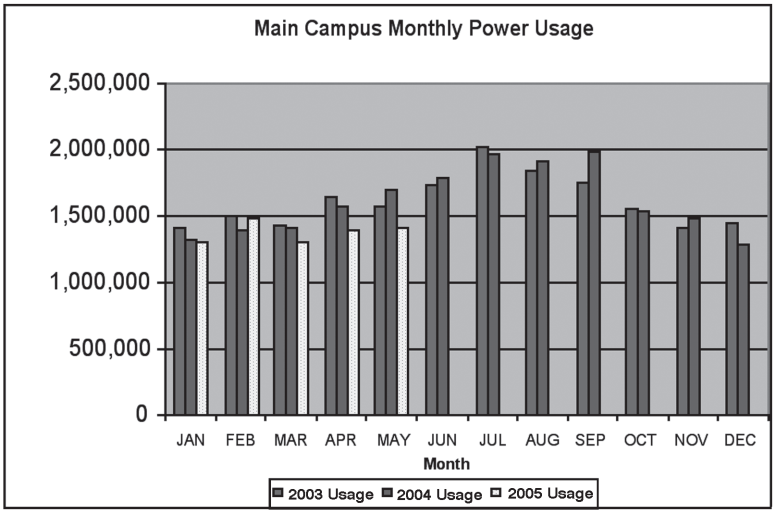

Figure 4. Monthly Electrical Usage

STEAM SYSTEM DELIVERY IMPROVEMENTS

The campus steam delivery system has an annual operational cost of about $1M, $850,000 of which is fuel cost for generating steam. The 90 million pounds of steam produced from three boilers is used for research manufacturing line processes and HVAC in all buildings.

A two-day trailblazing team exercise, involving campus facilities associates and external (out-sourced) consultants identified two primary actions to lower these costs. First, a steam header pressure reduction was implemented at the boiler plant, lowering it from 145 psig to 100 psig. The expected benefits include boiler fuel savings, reduced maintenance (boiler refractory repairs, make-up water usage), and water chemical treatment reductions. The second measure, to begin regular inspection and repair of faulty steam traps, was also an energy savings measure. Conservative estimates projected that there were at least 50 faulty traps in the system of approximately 1,800 devices. Depending upon the type of trap, its size and function in the steam distribution system, each faulty trap had the potential to waste more than $2,000 of steam annually.

Both steam system measures were implemented. Beginning in July 2003, boiler header pressure was lowered. Results were immediate, and somewhat surprising. During the summer months, average production volumes were about 8 percent lower, compared to previous year periods. During the winter heating period when a larger, single boiler is utilized, steam produced was about 13 percent lower each month, as shown in Figure 5.

Formalized steam trap maintenance began January 2004. Fifty-one traps were repaired during 2004, with several identified as blow-through type failures. Since this project was started *after* lowering campus steam pressure, actual steam savings are already reflected in the total plant comparisons in Figure 5.

Steam Delivery Project Benefits

The savings target established during the Trailblazing session for pressure reduction was estimated at $10,000 annually. Steam trap savings were estimated at $40,000. Actual results have been much better. Reduced fuel usage was 13,238 MMBtu, resulting in annualized cost savings of $108,000 since beginning the projects. Estimated YTD 2005 savings are $51,000.

Reduced steam production has other economic and environmental benefits. Less make-up water is required for all the boilers. This saves about 140,000 gallons of city water yearly, proportionately reducing water treatment costs, and chemical treatment usage for this make-up water.

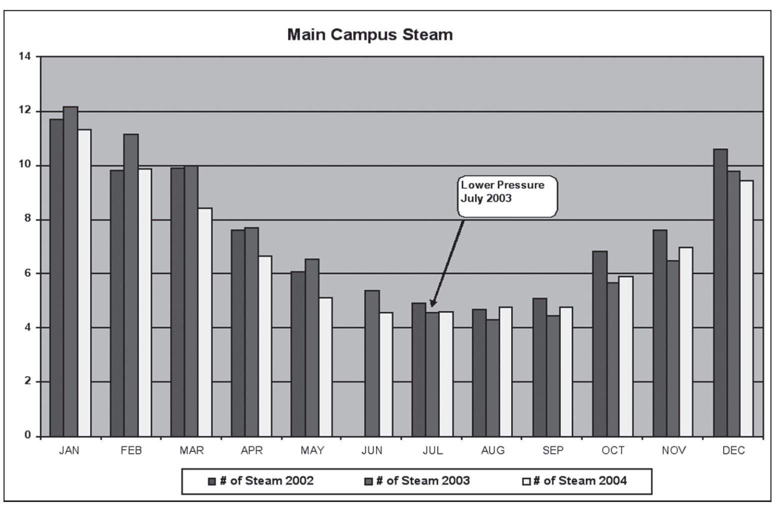

Figure 5. Total Steam Produced

ENVIRONMENTAL RESULTS

Direct and indirect air emission reductions have resulted from these projects. Indirect emissions are a result of electrical power savings. Direct air boiler emission reductions are estimated from the natural gas fuel savings, and calculated using AP-42 emission factors. Electrical power emission reductions are calculated using EPA regional estimates (see references).

Table 2. Environmental Emission Reductions, Tons

Polluant	*Boiler Fuel*	*Elect Power*	*Totals*
CO_2	764	2,587	3,551
SO_2	--	14.8	14.8
NO_x	.64	3.6	4.2

OVERALL ECONOMIC IMPACT

As noted, some electrical projects are in progress, or scheduled to be completed by the third quarter in 2005. When completely implemented, the campus will see an annualized reduction of 2,400,000 kWh, saving about $135,000. Boiler fuel cost savings will exceed $100,000, compared to periods before process improvements were implemented. Both dollar reductions are dependent upon future purchased energy costs, and pricing from respective local utilities. Aggregate annual savings are expected to be about $230,000, or 12 percent of total campus costs.

References:

1. EPA Emissions brochure, *Emission Factors, Global Warming Potentials, Unit Conversions, and Related Facts*.
2. Environmental Protection Agency website: *www.epa.gov*.

ABOUT THE AUTHOR

David A. Eberly, P.E., C.E.M. is a senior staff engineer in corporate facilities management for Armstrong World Industries, Inc. At Armstrong for more than 30 years, Dave has held several energy management positions including corporate energy engineer. In 2001, he implemented a 2,000 kW power generation, curtailment system, reducing corporate campus electricity costs by 25 percent. A certified green belt, he most recently implemented Six-Sigma process improvement projects that save more than 12 percent of annualized energy costs at the same campus location.

Dave is a graduate of the Pennsylvania State University with a B.S. in electrical engineering and an M.A. in business administration. Dave is also a registered professional engineer in Pennsylvania, a Certified Energy Manager (CEM), a member of ASHRAE (American Society of Heating, Refrigeration, and Air-Conditioning Engineers) and a life member of the AEE (Association of Energy Engineers).