Title

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Improving Energy Efficiency in Pharmaceutical Manufacturing Operations — Part II: HVAC, Boilers and Cogeneration

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Significant potential exists for improving energy efficiency in the U.S. pharmaceutical industry, and a focused, strategic approach can allow any organization to identify opportunities and implement efficiency measures and practices. This article, the second in a two-part series, summarizes strategies for reducing pharmaceutical facility energy costs.

Keywords: energy efficiency, boilers, cogeneration, HVAC and Energy Star

Whereas Part I of this article ("*Improving Energy Efficiency in Pharmaceutical Manufacturing Operations — Part I: Motors, Drives and Compressed Air Systems*", Pharmaceutical Manufacturing, Feb. 2006) focused on motors, drives and compressed air systems, Part II will review, briefly, potential improvements in heating, ventilation and air conditioning (HVAC) systems, overall building management and boilers. Research in this article was first published last September, in an extensive report developed by the Energy Analysis Department at Lawrence Berkeley National Laboratories for the Environmental Protection Agency's Energy Star Pharmaceutical Focus. The 90-page guide, "Energy Efficiency Improvement and Cost Saving Opportunities for the Pharmaceutical Industry," is available in pdf format at *www.energystar.gov*.

The U.S. pharmaceutical industry spent nearly $900 million on energy in 2002. As energy costs increase, more companies are looking into energy efficiency measures   Considered individually, each measure may offer small savings, but combined they add up to significant savings and short payback periods.

HVAC

First, let's consider HVAC systems, which consist of dampers, supply and exhaust fans, filters, humidifiers, dehumidifiers, heating and cooling coils, ducts, and various sensors [1]. HVAC systems in manufacturing portions of facilities are closely supervised by the FDA and must meet other global regulatory standards, so energy efficiency measures that affect the work environment must conform to current Good Manufacturing Practices (cGMP). Although cGMP allows for new techniques, the reasons for using them must be explained — the additional time required, and the risks associated with a delay in approval of building plans, may have led some drug companies to stick with less energy-efficient designs.

Nevertheless, investing in newer technology frequently pays off. At its plant in Rzeszow, Poland, for example, Novartis installed microprocessor controls on its HVAC system that could be programmed to better balance plant heating based on outside temperatures, and reduce heating loads on the weekends. The company expects this new system to reduce overall heat energy consumption by 10% [2].

There are many energy efficiency measures that can be applied to HVAC systems; some significant opportunities are discussed below.

Non-production hours set-back temperatures. Setting back building temperatures (that is, turning temperatures down in winter or up in summer) during periods of non-use, such as weekends or non-production times, can lead to significant savings in HVAC energy consumption. Similarly, reducing ventilation in cleanrooms and laboratories during periods of non-use can also lead to energy savings.

At Merck's Rahway, N.J. laboratory facilities, HVAC systems are designed with once-through air exchange based on safety considerations. To improve the energy efficiency of these systems, Merck utilized control technologies to lower selected room temperatures from 72°F to 64°F during nights and weekends. An interlock with room lighting overrides the set-back. This control strategy was implemented for rooms where lower temperatures would not impact scientific equipment, and covered 150 individual laboratory spaces encompassing over 350,000 square feet of floor space. The energy savings from this project totaled nearly 30,000 MBtu per year. The energy-related carbon dioxide (CO_2) emissions avoided through this project amounted to over 1,700 tons per year [3].

Adjustable speed drives (ASDs). Adjustable speed drives can be installed on variable-volume air handlers, as well as recirculation fans, to match the flow and pressure requirements of air-handling systems precisely. Energy consumed by fans can be lowered considerably since they are not constantly running at full speed. Adjustable speed drives can also be used on chiller pumps and water systems pumps to minimize power consumption based on system demand. Genentech installed ASDs on variable air volume air handlers in its Vacaville, Calif. facility, leading to significant reductions in energy consumption and expected annual savings of around $23,000 per year [4].

Heat recovery systems. Heat recovery systems reduce the energy required to heat or cool facility intake air by harnessing the thermal energy of the facility's exhaust air. Common heat recovery systems include heat recovery wheels, heat pipes, and run-around loops. For areas requiring 100% make-up air, studies have shown that heat recovery systems can reduce a facility's heating/cooling cost by about 3% for each degree (Fahrenheit) that the intake air is raised/lowered.

In 2004, Merck installed a glycol run-around loop system to recover heat from HVAC exhaust air at a 37,000-square-foot laboratory building in Rahway. After installation, the building could pre-heat and pre-cool up to 120,000 cubic feet per minute (cfm) of outside air with recovered energy. The savings associated with this measure amounted to roughly 265 MBtu per year, which led to avoided CO2 emissions of over 30 tons per year [3].

Improving HVAC chiller efficiency. The efficiency of chillers can be improved by lowering the temperature of the condenser water, thereby increasing the chilled water temperature differential. This can reduce pumping energy requirements. Another possible efficiency measure is installing separate high-temperature chillers for process cooling [5].

Sizing chillers to better balance chiller load with demand is also an important energy efficiency strategy. At Genentech's facility in Vacaville, two 1,400-ton chillers and one 600-ton chiller were chosen instead of three equally-sized chillers. This selection was made in an effort to operate the chillers at as close to full load as possible, where they are most efficient. The two larger chillers are run at full load and the smaller chiller is run to supply additional cooling only on an as-needed basis, reducing energy needs. The cost savings associated with this chiller selection strategy were estimated to be $113,250 per year [4].

Cleanroom HVAC

A recent study found that HVAC systems accounted for 36-67% of cleanroom energy consumption [6]. Another recent study [7] estimated the following energy distribution for cleanroom operation: 56% for cooling, 36% for heating, 5% for fans, and 3% for pumps.

The following measures can improve energy efficiency in cleanrooms:

Reduce recirculation air charge rates.

Improve air filtration quality and efficiency. High Efficiency Particulate Air (HEPA) filters and Ultra Low Penetration Air (ULPA) filters are commonly used in the pharmaceutical industry to filter make-up and recirculated air. The adoption of alternative filter technologies might allow for lower energy consumption. For example, new air filtration technologies that trap particles in the ultra-fine range (0.001-0.1 microns), a range for which current filter technologies are not effective, might reduce the energy necessary for reheating/re-cooling cleanroom air [8].

Use cooling towers. In many instances, water cooling requirements can be met by cooling towers in lieu of water chillers. Water towers can cool water much more efficiently than chillers and can therefore reduce the overall energy consumption of cleanroom HVAC systems.

Reduce cleanroom exhaust. The energy required to heat and cool cleanroom make-up air accounts for a significant fraction of cleanroom HVAC energy consumption. Measures to reduce cleanroom exhaust airflow volume can therefore lead to significant energy savings.

Boilers
Boilers and steam distribution systems are major contributors to energy losses at many industrial facilities; they are therefore an area where substantial efficiency improvements are typically feasible. The following measures can improve energy efficiency in boilers:

Reduce flue gas quantities. Often excessive flue gas results from leaks in the boiler and/or in the flue. This reduces the heat transferred to the steam and increases pumping requirements. These leaks are often easily repaired. Savings amount to 2-5% of the energy formerly used by the boiler [9].

Reduce excess air. The more excess air is used to burn fuel, the more heat is wasted in heating this air rather than in producing steam. A rule of thumb often used is that boiler efficiency can be increased by 1% for each 15% reduction in excess air or 40°F (22°C) reduction in stack gas temperature [10].

Properly size boiler systems. Correctly designing the boiler system at the proper steam pressure can save energy by reducing stack temperature, reducing piping radiation losses, and reducing leaks in traps and other sources. In a study done in Canada on 30 boiler plants, savings from this measure ranged from 3-8% of the total gas consumption [11].

Properly insulate boiler.

Perform regular maintenance. A simple maintenance program to ensure that all components of a boiler are operating at peak performance can result in substantial savings. On average, the energy savings associated with improved boiler maintenance are estimated at 10% [10].

Reuse condensate. Reusing hot condensate in boilers saves energy, reduces the need for treated boiler feed water, and reclaims water at up to 100°C (212°F) of sensible heat. A Pfizer plant in Groton, Conn., upgraded their condensate recovery system and realized a 9% reduction in electricity consumption, and an 8% reduction in water consumption and wastewater discharge [12]. As a result, Pfizer saved roughly $175,000 per year through avoided oil, gas, and water purchases.

Cogeneration

The use of cogeneration in the U.S. pharmaceutical industry is still limited. Currently, most large-scale CHP (combined heat and power) systems use steam turbines. In general, the energy savings of replacing a traditional system (i.e., a system using boiler-based steam and grid-based electricity) with a standard gas turbine-based CHP unit is estimated at 20-30%. The efficiency gain will be higher when replacing older or less maintained boilers.

Combined cycles (combining a gas turbine and a back-pressure steam turbine) offer flexibility for power and steam production at larger sites, and potentially at smaller sites as well. Steam-injected gas turbines (STIG) can absorb excess steam (e.g., due to seasonal reduced heating needs) to boost power production by injecting steam into the turbine.

New CHP systems offer the option of trigeneration, which provides cooling in addition to electricity and heat. Cooling can be provided using either absorption or adsorption technologies, which both operate using recovered heat from the cogeneration process.

Absorption cooling systems take advantage of the fact that ammonia is extremely soluble in cold water and much less so in hot water. Thus, if a water-ammonia solution is heated, it expels its ammonia. In the first stage of the absorption process, a water-ammonia solution is exposed to waste heat from the cogeneration process, whereby ammonia gas is expelled. After dissipating the heat, the ammonia gas — still under high pressure — liquefies. The liquid ammonia flows into a section of the absorption unit where it comes into contact with hydrogen gas. The hydrogen gas absorbs the ammonia gas with a cooling effect. The hydrogen-ammonia mixture then meets a surface of cold water, which absorbs the ammonia again, closing the cycle.

In contrast, adsorption cooling utilizes the capacity of certain substances to adsorb water on their surface, from where it can be separated again with the application of heat. Adsorption units use hot water from the cogeneration unit. These systems do not use ammonia or corrosive salts, but use silica gel (which also helps to reduce maintenance costs). Adsorption units were originally developed in Japan and are now also marketed in the United States.

In March 2004, Johnson & Johnson Pharmaceutical Research & Development officially dedicated the installation and operation of a new CHP trigeneration system, as part of a major R&D expansion at its La Jolla, Calif. facility. The 2,200 kW system will produce 15 GWh per year of electricity plus 360,000 therms of heat and 1.6 million ton-hr per year of chilled water. This will provide more than 90% of the facility’s electric power and much of its heating and cooling needs and allow the facility to operate independent of the state electrical grid, if needed. It will also reduce emission of more than 3 million pounds of CO_2 per year.

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SUMMARY OF SELECT ENERGY EFFICIENCY MEASURES FOR THE U.S. PHARMACEUTICAL INDUSTRY

The measures below are explained in detail in the authors' report, available at www.energystar.gov.

General	HVAC Systems	Cleanrooms	Pumps	Refrigeration	Heat and Steam Distribution	Cogeneration
Energy management programs Energy monitoring systems	Energy efficient system design Energy monitoring and control systems Variable-air-volume systems Heat recovery systems Cooling water recovery Building reflection Low-emittance windows Recommissioning Non-production hours set-back temperatures Discharge air temperature management Adjustable speed drives Chiller efficiency improvement	Reduced recirculation air change rates Optimized chilled water systems Reduction of cleanroom exhaust Improved filtration quality and efficiency Cooling towers Declassification	Maintenance Pump demand reduction High-efficiency pumps Multiple pumps for variable loads Monitoring Controls Properly sized pumps Impeller trimming	Operations and maintenance Monitoring of refrigerant charge Monitoring of suction line filters Cooling line and jacket insulation Operation at lower system pressure Systems monitoring Optimization of operating parameters Monitoring of refrigerant contamination Waste heat recovery Absorption chillers	Boiler process control Reduction of excess air Boiler insulation Flue gas heat recovery Blowdown steam recovery Distribution system insulation Steam trap maintenance Leak repair Preventive maintenance Reduction of flue gas quantities Properly sized boiler systems Boiler maintenance Condensate return Boiler replacement Process integration and pinch analysis	Combined heat and power Power recovery turbines Trigeneration