institute for building efficiency
an initiative of Johnson Controls

ENERGY SAVINGS FROM MAINTENANCE

Regular scheduled maintenance of heating, ventilation and air conditioning (HVAC) systems can increase their efficiency, and a number of studies have quantified energy savings from maintenance, as well. These studies fall in two categories:

1. Analysis of failures in individual HVAC components and the energy savings possible by correcting those failures.
2. Whole-system estimates based on interviews with HVAC maintenance experts.

ENERGY PERFORMANCE AND HVAC COMPONENT MAINTENANCE

HVAC systems have over 100 components, and many common component performance issues degrade energy performance. The following chart summarizes studies of the potential energy savings from good maintenance on chiller components with the greatest energy impacts.

Causes of Degraded Energy Performance in HVAC Equipment	HVAC Maintenance Solution	Estimated Impact on Chiller Energy Consumption
Centrifugal Chillers		
Tube cleanliness. Microbes in the chiller tube bundle reduce heat transfer. Reduction in heat transfer can be compounded by the formation of scale or iron deposits on the microbe site. The increase in temperature difference needed to overcome the heat transfer losses increases energy consumed.	Water treatment program. Tube cleaning.	15% savings for eliminating microbes; 10–20% more if scale and iron deposits are present. 10% to 35% savings or more in extreme cases.[1]

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[1] Maximizing Chiller Efficiency. Maintenance Technology Magazine. http://www.efftec.com/resources/maximizing-chiller-efficiency.php

<table>
<thead>
<tr><th>Causes of Degraded Energy Performance in HVAC Equipment</th><th>HVAC Maintenance Solution</th><th>Estimated Impact on Chiller Energy Consumption</th></tr>
</thead>
<tbody>
<tr><td colspan="3"><i>Centrifugal Chillers</i> <i>(continued)</i></td></tr>
<tr><td><i>Reduced condenser flow rate</i> from partially closed or damaged valves, clogged hot-deck nozzles in the cooling tower, clogged line strainers, sediment in the condenser tubes, and air in the system piping. Common causes of reduced flow are partially closed or damaged valves, clogged hot-deck nozzles in the cooling tower, clogged line strainers, sediment in the condenser tubes, and air in the system.</td><td>Monitor condenser flow at least annually and repair the cause of the reduced flow.</td><td>A 20% reduction in the condenser flow rate will increase full-load energy consumption by 3% in mechanical and absorption chillers used in chemical process cooling.[2]</td></tr>
<tr><td><i>Sub-optimal refrigerant levels.</i> The efficiency of all chillers suffers if the system has either too little or too much refrigerant charge.</td><td>Maintain refrigerant levels according to the manufacturer's instructions.</td><td>Up to 20% savings.[3]</td></tr>
<tr><td><i>Oil contamination in refrigerant</i></td><td>Chiller refrigerant charge reclamation to clean existing refrigerant in a one-time process, or the use of a purging system that cleans the refrigerant charge on an ongoing basis.</td><td>
<table>
<tr><th>Oil in Evaporator</th><th>Performance Loss</th></tr>
<tr><td>1–2%</td><td>2–4%</td></tr>
<tr><td>3–4%</td><td>5–8%</td></tr>
<tr><td>5–6%</td><td>9–11%</td></tr>
<tr><td>7–8%</td><td>13–15%</td></tr>
</table>
[4]
2% loss in chiller efficiency for every 1% of oil found in the refrigerant. It is not uncommon to find 10 percent oil in the refrigerant of older chillers.[5]</td></tr>
<tr><td><i>Leaks in the compressor</i> in a low-pressure chiller. Any leak in the machine reduces airflow into the unit. Air collects in the condenser, blanketing tubes and displacing refrigerant vapor, resulting in higher condenser pressure and temperature.</td><td>Test compressors for leaks.</td><td>About 1 psi of air in a condenser equates to a 3 percent loss in chiller efficiency.[6]
6 to 8% efficiency loss at 60% load and 8 to 14% at full load.[7]
For every 1°F increase in condenser leaving temperature, energy consumption increases about 1.5%.[8]</td></tr>
</tbody>
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[2] Iowa State University's Center for Industrial Research and Service. Energy-Related Best Practices: A Sourcebook for the Chemical Industry. Chapter 6. http://www.ciras.iastate.edu/publications/EnergyBP-ChemicalIndustry/

[3] MEASURE 2.7.2 Maintain the proper refrigerant charge. http://www.energybooks.com/pdf/342346.pdf

[4] ASHRAE. "Effects of Oil on Boiling of Replacement Refrigerants Flowing Normal to a Tube Bundle. Part 1: R-123 and Part 2: R-134a"

[5] Kevin Graham. 5 Steps to Chiller Efficiency. 2004. http://www.facilitiesnet.com/hvac/article/5-Steps-to-Chiller-Efficiency–2192

[6] Kevin Graham. 5 Steps to Chiller Efficiency. 2004. http://www.facilitiesnet.com/hvac/article/5-Steps-to-Chiller-Efficiency–2192

[7] Maximizing Chiller Efficiency. Maintenance Technology Magazine. http://www.efftec.com/resources/maximizing-chiller-efficiency.php

[8] Iowa State University's Center for Industrial Research and Service. Energy-Related Best Practices: A Sourcebook for the Chemical Industry. Chapter 6. http://www.ciras.iastate.edu/publications/EnergyBP-ChemicalIndustry/

Causes of Degraded Energy Performance in HVAC Equipment	HVAC Maintenance Solution	Estimated Impact on Chiller Energy Consumption
Rooftop Units[9]		
Economizer failure	Adjust a functioning economizer; repair a broken economizer actuator or a frozen damper.	14 to 40% energy savings.
Airflow problems	Measure airflow and compare to standards; correct as needed.	10% savings (much higher in laboratories, cleanrooms, vivariums and other environments with significant outdoor ventilation air requirements.)
Thermostat control problems, including improper thermostat settings, cycling fans during occupied periods, fans running continuously during unoccupied periods, improperly installed resistors, no nighttime setup or setback.	Check thermostat settings.	Up to 40% savings.
Sensor problems: Failed sensors, snap discs that cannot be calibrated or adjusted, broken wires.	Repair failed sensors.	Savings on the order of 40% percent if it enables a nonfunctioning economizer.
Suboptimal refrigerant charge	Check and adjust refrigerant charge as needed.	5-11% energy savings.[10]

ESTIMATING WHOLE-BUILDING-SYSTEM ENERGY SAVINGS FROM MAINTENANCE

A few studies have analyzed the whole-building energy savings from HVAC system maintenance.

- The New Buildings Institute found that best practices in building maintenance and operations reduce energy use 10 to 20 percent across all climate zones in the United States. In contrast, poor maintenance practices can increase energy use by 30 to 60 percent.[11] The study included HVAC systems setpoints and schedules, economizer operation, ventilation controls and settings, and HVAC system efficiency and fan power (these last two variables were included as surrogates for adequate maintenance and balancing of the HVAC system).
- Portland Energy Conservation Inc. found that building operation and maintenance programs specifically designed to enhance the operating efficiency of HVAC and lighting systems decreased energy bills 5 to 20 percent in commercial buildings, without significant capital investment.[12]
- The National Center for Energy Management and Building Technologies conducted 45 interviews with industry experts, and concluded that effective scheduled maintenance decreases energy bills 15 to 20 percent in commercial buildings.[13]

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[9] Alan Cowan. Review of Recent Rooftop Unit Field Studies in the Pacific Northwest and California. New Buildings Institute. 2004.

[10] Alan Cowan. Review of Recent Rooftop Unit Field Studies in the Pacific Northwest and California. New Buildings Institute. 2004.

[13] Frankel, M., Heater, M. and Heller, J. "Sensitivity Analysis: Relative Impact of Design, Commissioning Maintenance and Operational Variables on the Energy Performance of Office Buildings" New Buildings Institute. August 2012.

MANAGEMENT APPROACHES TO CAPTURE HVAC MAINTENANCE SAVINGS

Often, energy savings opportunities through maintenance are missed. There are three basic approaches to maintaining HVAC systems in buildings:

1. *Reactive maintenance.* Under this management practice, used by 55 percent of companies, HVAC systems run until a problem or failure occurs.[14] (This strategy also called run-to-fail maintenance.)
2. *Preventive (or scheduled) maintenance.* This practice, used by 31 percent of companies, the periodic and maintenance of HVAC equipment, generally as prescribed by the manufacturers.[15]
3. *Predictive maintenance.* Practiced by 12 percent of companies, this strategy differs from preventive maintenance by basing maintenance on the actual condition of the machine, rather than on a preset schedule. Predictive maintenance can be the most cost-effective over the long term, but does require technology infrastructure investments up front.

CONCLUSION

Regularly scheduled maintenance of HVAC systems can increase the energy efficiency. While the initial data is encouraging, more quantification of the energy savings will lead more building owners to become interested in regular maintenance for their HVAC systems. More studies are needed to accurately quantify the energy savings from varying maintenance strategies, as well as the return on investment from maintenance activities. The HVAC industry can develop better tools to help building owners and facility managers evaluate the relationship between maintenance costs and energy costs and support investment in the appropriate maintenance approach.

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[14] Sullivan, G.P., R. Pugh, A.P Melendez, and W.D. Hunt. Operations and Maintenance Best Practices: A Guide to Achieving Operational Efficiency Release 2.0 U.S. Department of Energy. July 2004.

[15] ibid.

The Institute for Building Efficiency is an initiative of Johnson Controls providing information and analysis of technologies, policies, and practices for efficient, high performance buildings and smart energy systems around the world. The Institute leverages the company's 125 years of global experience providing energy efficient solutions for buildings to support and complement the efforts of nonprofit organizations and industry associations. The Institute focuses on practical solutions that are innovative, cost-effective and scalable.

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an initiative of Johnson Controls

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