The U.S. Department of Energy's (DOE) Federal Energy Management Program (FEMP) facilitates the Federal Government's implementation of sound, cost-effective energy management and investment practices to enhance the nation's energy security and environmental stewardship.

PURCHASING SPECIFICATIONS FOR ENERGY-EFFICIENT PRODUCTS

Water-Cooled Electric Chillers

Legal Authorities

Federal agencies are required by the National Energy Conservation Policy Act (P.L. 95-619), Executive Order 13423, and Federal Acquisition Regulations (FAR) Subpart 23.2 and 53.223 to specify and buy ENERGY STAR® qualified products or, in categories not included in the ENERGY STAR program, FEMP designated products, which are among the highest 25 percent of equivalent products for energy efficiency.

Performance Requirements for Federal Purchases[a]		
Compressor Type and Capacity	Part-Load Optimized Required IPLV[b] (kW/ton)	Full-Load Optimized Required Full-Load[c] (kW/ton)
Positive Displacement (greater than or equal to 150 tons)	0.51 or less	0.61 or less
Centrifugal (150 tons to 300 tons)	0.37 or less	0.59 or less
Centrifugal (300 tons to 2,000 tons)	0.36 or less	0.55 or less

a) Depending on the application, buyers should specify chiller efficiency using either full-load or integrated part-load values as shown.
b) Values are based on standard reference conditions specified in ARI Standard 550/590-2003.
c) Full-load efficiency is measured at peak load conditions described in ARI Standard 550/590-98.

Buying Energy-Efficient Water-Cooled Chillers

The decision to specify chiller performance using full-load or part-load efficiency (in kilowatt (kW)/ton) levels depends on the application. Integrated part-load value (IPLV) is preferred for more variable loads accompanying variable ambient temperature and humidity, which is the more common situation. Full-load is appropriate where chiller load is high and ambient temperature and humidity are relatively constant (i.e., for baseline chillers). To further optimize selection, compare chillers based on non-standard part load value (NPLV), which maintains the same weightings as IPLV but allows the designer to prescribe other critical variables (i.e., entering condenser water temperature, evaporator leaving water temperature, flow rates, etc.). Proper determination of NPLV is described in ARI 550/590-98.

Where to Find Energy-Efficient Chillers

The U.S. General Services Administration (GSA) has a basic ordering agreement (BOA) that offers a streamlined procurement method for chillers based on lowest life-cycle cost. Contact GSA for more information. For chillers purchased through commercial sources, the BOA can still be used as a guide in preparing specifications, as can Air-Conditioning, Heating, and Refrigeration Institute (AHRI) and American Society for Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) sources.

An energy savings performance contract (ESPC) may be used to finance a new chiller, as well as other associated energy conservation measures, with payments based on energy cost savings. For more information, contact your regional FEMP Federal Financing Specialist (*femp.energy.gov/financing/espcs_financingspecialists.html*).

Environmental Tips

Refrigerants with ozone-destroying chlorofluorocarbons (CFCs) were common in older chillers but are no longer used in new equipment. The 1992 Montreal Protocol banned the production of CFCs in the U.S. beginning in 1996. More-recent equipment used hydrochlorofluorocarbon (HCFC) refrigerants, but these have also been eliminated for use in new equipment.

Owners and operators of chillers with CFCs are faced with three options: 1) continue to operate their chillers with CFCs, which exposes them to the high cost of obtaining the refrigerant from a dwindling reclaimed supply; 2) convert the chillers to use a non-CFC refrigerant, which usually results in some loss in cooling capacity (see "Sizing," below); or 3) replace the equipment, which requires a substantial capital outlay. These options should be evaluated using life-cycle cost analysis. A detailed life-cycle cost analysis can be performed using Building Life-Cycle Cost (BLCC) software available through FEMP.

It is important when considering the continued operation of chillers with CFCs to assess the process of refrigerant recovery, followed by recycling or reclamation, and to factor in the likely increase in the cost of obtaining replacement CFCs.

When retiring a chiller that contains CFCs or HCFCs, the Clean Air Act requires that the refrigerant is recovered on-site by a certified technician. (For more information, call the Stratospheric Ozone Information Hotline at 800-296-1996.)

Early Replacement

Many facility managers are opting for early replacement of older chillers with high-efficiency units using non-CFC refrigerants. Good candidates for early retirement are CFC-based chillers with poor efficiencies or histories of high maintenance costs. Energy cost savings can add to the environmental benefits of non-CFC refrigerants. For example, replacing a 500-ton CFC chiller (0.85 kW/ton efficiency) with an efficient non-CFC chiller (0.55 kW/ton) can save $27,000/year, assuming an electricity price of $0.09/kilowatt-hour (kWh). In some cases, demand charge savings may substantially increase this amount. Additionally, some utilities offer financial incentives for replacing inefficient chillers.

Sizing

When choosing a chiller, careful attention to appropriate sizing is critical for achieving maximum energy savings. Many existing units are oversized. An oversized chiller costs more to both purchase and operate due to substantial energy losses from excessive cycling. Use the ASHRAE calculation procedure to determine the cooling load properly. It is often cost-effective to combine chiller replacement with other measures that reduce cooling load, permitting installation of smaller equipment (see "Integrated Chiller Retrofits," below).

Replacing a single chiller with two or more smaller chillers to meet varying load requirements may be cost effective. Parallel staging of multiple chillers is a common method of meeting peak load in larger installations. Multiple chillers also provide redundancy for routine maintenance and equipment failure. For many typical facilities, sizing one chiller at one-third and another chiller at two-thirds of the peak load enables the system to meet most cooling conditions at relatively high chiller part-load efficiencies. These staged units can also be sized optimally for different conditions. For example, one chiller could be optimized for peak efficiency at summer conditions (85°F condensing water) and the other chiller could be optimized for winter conditions (75°F condensing water).

Integrated Chiller Retrofits

An integrated chiller retrofit can provide enormous energy savings. It combines the chiller replacement or a refrigerant change-out with other energy conservation measures that reduce the cooling load or increase the efficiency of the cooling system itself. Examples of cooling system efficiency improvements are control system upgrades and increased cooling tower capacity. Cooling load reduction measures include tightening the building envelope and updating lighting systems. The additional cost of these and other load reduction measures can be significantly offset by the savings realized from downsizing the chiller. Lawrence Berkeley National Laboratory's Cool $ense project provides guidance on integrated chiller retrofits at *ateam.lbl.gov/coolsense*.

The first step in implementing an integrated chiller retrofit is a preliminary energy audit to assess the savings potential of various efficiency measures. A preliminary audit can often be provided by energy service companies, architecture and engineering firms, or utilities. FEMP can also provide this technical support on a reimbursable subcontract basis. For information, contact FEMP at 202-586-5772.

Cost-Effectiveness Assumptions

The *Annual Energy Use* for the centrifugal chiller example is based on 2,000 full-load hours per year for a 500-ton chiller. The rotary screw (positive displacement) chiller example uses a 250-ton machine operating for 2,000 equivalent full-load hours per year at IPLV efficiency, since rotary chillers are often installed in applications with variable load conditions. The assumed electricity price is $0.09/kWh, the Federal average electricity price (including demand charges) in the U.S. Since this average cost figure does not incorporate the disproportionately large portion

Cost-Effectiveness Examples

Performance	Base Model[a]	Required Level	Best Available
500-ton Centrifugal Chiller			
Full-Load Efficiency (kW/ton)	0.58	0.55	0.46
Annual Energy Use (kWh)	580,000	550,000	460,000
Annual Energy Cost	$52,000	$49,500	$41,100
Lifetime Energy Cost	$811,710	$769,725	$643,770
Lifetime Energy Cost Savings	**—**	**$41,985**	**$167,940**
250-ton Positive Displacement Chiller			
IPLV Efficiency (kW/ton)	0.56	0.51	0.33
Annual Energy Use (kWh)	280,000	255,000	165,000
Annual Energy Cost	$25,200	$22,950	$14,850
Lifetime Energy Cost	$391,860	$356,873	$230,918
Lifetime Energy Cost Savings	**—**	**$34,988**	**$160,943**

a) The efficiency of the base models are just sufficient to meet ASHRAE Standard 90.1-2007.

For More Information:

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www.femp.energy.gov

FEMP Product Procurement
www.femp.energy.gov/procurement

Lawrence Berkeley National Laboratory
202-488-2250
www.lbl.gov

LBNL Cool $ense
ateam.lbl.gov/coolsense/

American Council for an Energy-Efficient Economy (ACEEE)
Guide to Energy-Efficient Commercial Equipment
202-429-0063
www.aceee.org

American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE)
Cooling and Heating Load Calculation Manual
800-527-4723
www.ashrae.org

Air-Conditioning, Heating, and Refrigeration Institute (AHRI)
Applied Directory and Prime Net
703-524-8800
www.ahrinet.org

E Source
Electric Chillers Buyer's Guide
303-440-8500
www.esource.com

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of demand costs that chillers usually contribute, actual cost savings may be greater. *Lifetime Energy Cost* is the sum of the discounted value of the *Annual Energy Cost*, based on average usage and an assumed chiller life of 23 years. Future electricity price trends and a discount rate of three percent are based on Federal guidelines (effective April 2010 to March 2011).

Using the Cost-Effectiveness Example

In the first cost-effectiveness example, a 500-ton centrifugal chiller with a full-load efficiency of 0.55 kW/ton is cost effective if its purchase price is no more than $41,985 above the price of the *Base Model*. The *Best Available* centrifugal model, with an efficiency of 0.46 kW/ton, is cost effective if its price is no more than $167,940 above the *Base Model*. Similarly, in the second example, the 250-ton *Required Level* and *Best Available* rotary screw chillers are cost effective if their respective purchase prices are no more than $34,988 and $160,943 above the *Base Model*.

How Do I Perform a Life-Cycle Cost Analysis for My Situation

The basic formula for estimating a chiller's annual energy use multiplies the average system load (in tons) by the relevant efficiency (full-load or IPLV) and by the annual number of equivalent full- or part-load operating hours. The resulting annual kWh figure can then be multiplied by the average cost per kWh for electricity, yielding the annual energy cost:

Annual Energy Cost = Average Load × Efficiency × Operating Hours × Electricity Rate

For full life-cycle cost analysis, this annual energy cost should then be multiplied by the regional electricity uniform present value (UPV) factor for the estimated lifetime of the equipment, and then added to the initial cost of the chiller (or present value of the chiller's financed cost):

Life Cycle Cost = (Annual Energy Cost × Uniform Present Value Factor) × Initial Cost.

Note that this simplified formula excludes operation and maintenance costs because they were assumed to be equal. Therefore, it does not represent a true life-cycle cost calculation. If the operation and maintenance cost of the base and recommended models are substantially different, the buyer should include these in the life-cycle cost calculation to get a more accurate picture of the potential savings. A manual with the appropriate UPV factors (*Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis*), a life-cycle cost analysis guidebook (*NIST Handbook 135, Life-Cycle Costing Manual for the Federal Energy Management Program*), and BLCC software are all available through the FEMP Web site at *femp.energy.gov*.

A large proportion of chiller energy costs are often attributable to demand charges (in kW). To incorporate demand and ratchet charges into the cost estimation of chiller options, the ERATES software is also available from FEMP. Rate schedules from ERATES can be imported by the BLCC program, enabling much more accurate estimates of life-cycle costs.

FEMP provides a Web-based chiller calculator tool that simplifies the energy and cost comparisons between chillers with different efficiencies. This cost calculator is available online at *femp.energy.gov/technologies/eep_wc_chillers_calc.html*.

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

For additional information please contact:
EERE Information Center
1-877-EERE-INFO (1-877-337-3463)
www.eere.energy.gov/informationcenter

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