Federal Facilities Are Leveraging Energy and Water Saving Heating and Cooling Technologies

This information resource from the Federal Energy Management Program (FEMP) highlights various heating, ventilation, and air conditioning (HVAC) technologies with demonstrated energy and water savings that have the potential to be more broadly utilized across federal agencies. These HVAC technologies can also be included as energy or water conservation measures to meet energy and water use intensity requirements under Section 432 of the Energy Information and Security Act.

Contents

HVAC and Energy

Space conditioning plays a large role in federal energy utilization. According to data from the 2018 Commercial Buildings Energy Consumption Survey (CBECS), federally owned buildings consume approximately 159 trillion Btu of major fuels.[1] Space heating and cooling is present in 99% and 81% of federally owned buildings, respectively. Combined, space heating, space cooling, and ventilation account for approximately 58% of federal buildings' energy consumption – an increase of 7% from 2012, according to CBECS data.[2] HVAC systems can also be water intensive; the HVAC system for a typical federal office building of around 200 people can account for around one-fourth of the building's water use.[3]

The use of high-performance HVAC equipment can result in considerable energy and cost savings (10–40%). Many federal facilities also have specialized HVAC requirements, such as laboratories with high ventilation requirements and data centers with specific low-temperature requirements. The following case studies highlight the potential for federal agencies to explore different types of HVAC technologies that bring greater efficiencies and resiliency for mission activities.

Variable Air Volume Ventilation

HVAC systems are designed to ensure the comfort of building occupants and maintain healthy and safe air quality and space temperatures. A key part of this process is supplying air at a specific temperature and airflow rate from an air handling unit (AHU) to the conditioned space. Traditionally, single-zone HVAC units use constant air volume (CAV) systems, which leverage a centralized duct system and fans to supply a constant air flow to different zones. Variable air volume (VAV) systems are seen in multi-zone systems and use a mix of fans and dampers to manage air flow and maintain temperature and humidity conditions across different zones.

At **San Diego State University**, the CAV system at a recreation center was reconfigured in 2011 with a wireless HVAC control system to adjust the airflow, similar to a VAV system.[4] These changes improved the energy performance of the facility by modulating fan speeds using variable frequency drives. When these variable frequency drives were used along with wireless sensors, an artificial intelligence engine, and a wireless gateway, fan speeds responded in real-time to changes in duct static pressure resulting from fluctuating zone temperatures. The facility saw considerable savings in electricity (18%) and natural gas (55%) after its CAV system was converted into this more dynamic VAV-approximated system.

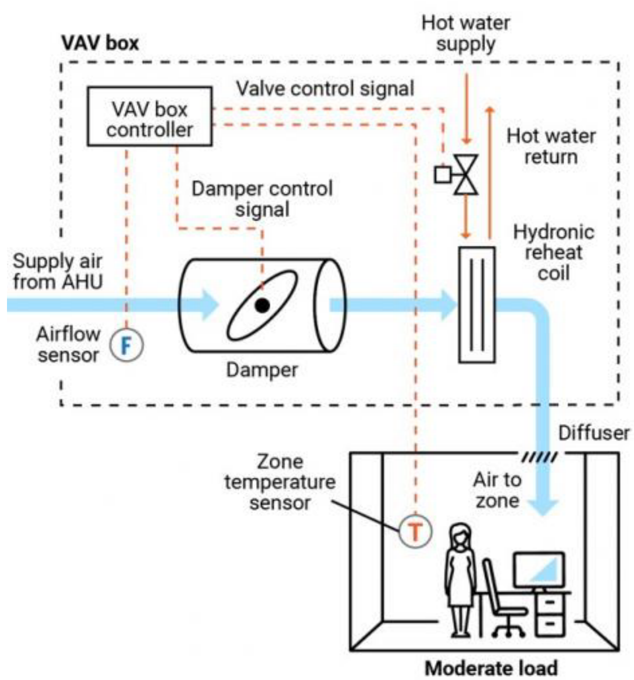

Figure 1. Schematic of a pressure-independent variable air volume (VAV) box with hydronic heat. Credit: Pacific Northwest National Laboratory O&M Best Practices.

A VAV system requires additional HVAC components, including fan speed controls at the AHU and VAV boxes with dampers. The VAV system automatically adjusts dampers to accommodate the needs (airflow and temperature) of each zone according to the zone airflow and temperature set points. VAV systems can provide both occupant comfort benefits and significant energy savings when less fan power is needed to maintain each zone.

Updated VAV boxes, with direct digital controls, were a part of the 2021 **U.S. General Service Administration's Ronald Reagan Building and International Trade Center** deep energy retrofit project.[5] Developed as part of a larger energy savings performance contract, the update to direct digitally controlled VAV boxes also enabled 22 air handling units to be migrated to the new building automation system, allowing for more precise airflow and temperature control.

Novel Dehumidification Systems

Maintaining optimal relative humidity significantly affects energy usage in heating, cooling, and ventilation systems. In general, ASHRAE recommends that indoor relative humidity be maintained at 60% or lower to ensure thermal comfort and help reduce the presence of mold or dust mites. Lower relative humidity levels may be required for some applications (such as healthcare). Traditionally, dehumidification in large HVAC systems is accomplished by condensing water vapor from the airstream as it passes over a cooling coil; to reach the desired relative humidity level, the leaving air temperature is frequently cooler than the temperature required for space cooling. The system then needs to reheat this subcooled air, using a separate heating coil, to ensure that cool, drier air can successfully condition the space.

The High Efficiency Dehumidification System (HEDS) from Conservant Systems, a recently commercialized technology, recently completed field evaluation in a **museum in San Diego, California**, funded by the U.S. General Service Administration and the Department of Energy.

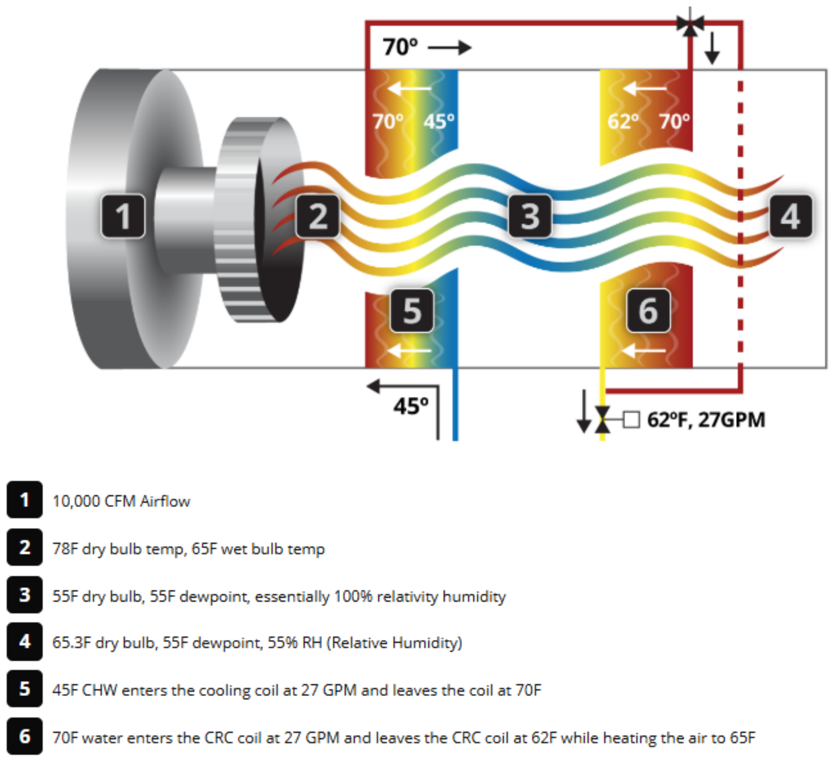

Figure 2. Conceptual diagram of the High Efficiency Dehumidification System (HEDS). Credit: Conservant Systems.

HEDS is a design and control strategy that uses energy recovery of low-quality heat generated in the cooling and dehumidification process to eliminate new reheat energy for relative humidity control and reduce the cooling load sent to the chiller plant from the AHU by the same amount of energy as the amount recovered to provide the reheat energy.[6] The low-quality heat recovery used in HEDS is made possible by large cooling coils for condensing, with the resultant warmer water cycled through large cooling recovery coils (CRC) to reheat the air, without the need for a separate heat source for reheating. With a lower pressure drop from the larger cooling coils, HEDS also reduces the required fan loads of the system.

In this 2023 evaluation, the technology yielded chiller electric load savings of 39% in CAV mode and 42% in VAV mode, reducing reheat (natural gas) by 64% in CAV mode and 97% in VAV mode.[7] This technology has also been tested in **two Department of Defense facilities** under a 2018 Environmental Security Technology Certification Program project. Testing at **Fort Bragg, North Carolina, and Tinker Air Force Base, Oklahoma**, showed savings of over 50% for the cooling, dehumidification, and reheat process.[8]

Magnetic Bearing Chiller Compressors

As the federal government increasingly prioritizes artificial intelligence, there will be a growing need for efficient, high-capacity cooling systems that are reliable. Space cooling accounts for 7% of energy consumption in office buildings,[1] and because cooling is primarily driven by electricity (which can be a higher-cost energy source), it can account for an even larger percentage of a facility's energy bill. According to CBECS data, 24% of commercial buildings greater than 50,000 square feet had central chillers in 2012.[9] CBECS data from 2018 indicate that central chillers are only used in 3% of buildings, but those buildings account for 19% of total floor space, with 88,000 square feet being the average building size supported by this cooling type.[10]

Magnetic bearings are used in these chiller compressors instead of traditional mechanical bearings, allowing for greater energy efficiency and cost reductions because of less friction between the bearings and fewer maintenance requirements. The chiller's heat transfer is also more efficient, without the presence of oil in the evaporators or condensers. Finally, the variable speed drive allows the compressors to operate more efficiently at partial loads than standard compressors. Many new chillers are capable of operating under partial load conditions as well.

Federal facilities have been exploring the use of this more efficient chiller compressor technology for decades. The **Navy Technology Validation Program** evaluated its usage at sites in San Diego, Newport, and Florida between 2005 and 2007 and found average energy savings of 49%, with payback periods ranging from 3.8 to 8.4 years.[11] In 2011, a traditional rotary-screw chiller was replaced with a new chiller that was configured with variable-speed oil-free centrifugal compressors with magnetic bearings as part of an energy savings performance contract in the **George Howard, Jr. Federal Building and Courthouse** in Pine Bluff, Arkansas. Field data indicated that this new chiller reduced electricity consumption and provided energy consumption savings of 42.3%, with a calculated 4.7-year payback period.[12]

Magnetic bearing centrifugal chillers continue to be selected in federal energy efficiency projects, including in the recent **Ronald Reagan Building and International Trade Center** deep energy retrofit.[13] The manufacturer of this technology also notes that the technology has been advantageous for data centers' high cooling needs.[14]

Thermal Energy Storage

Thermal energy storage (TES) involves the use of a medium—either sensible heat (chilled or hot water), latent (molten salts or ice), or thermochemical (gas) mediums—to store heating or cooling for later use.[15] TES is a promising cost-effective technology that may be underutilized within the federal energy space. Considering the high energy demand for space heating and cooling in federal buildings, TES has the potential to reduce operating costs by supplementing heating and cooling loads during peak times with stored thermal energy. By providing this demand flexibility, TES reduces the sizing requirements of chillers and boilers, allowing for these chillers and boilers to better match average loads.

Electricity rates are among the nation's highest in Massachusetts. The **John J. Moakley U.S. Courthouse in Boston, Massachusetts**, has used an ice-based thermal storage system to reduce the amount of electricity needed to cool the building during high heat days since the 1990s. The system relies on a series of subbasement thermal "batteries" that are frozen during periods of lower grid demand and then melted to provide daytime cooling.[16] The facility has also connected emergency generators to thermal pumps, enabling continual space conditioning even in the event of a grid outage.

Similarly, the **Federal Center South Building in Seattle** was completed in 2012 to serve as an office building for the U.S. Army Corps of Engineers. This facility included an integrated design strategy that focused on energy conservation measures rather than on-site energy generation. In addition to a facade designed to reduce heating and cooling needs, the facility includes a thermal storage tank that contains phase change material.[17] The phase change material tank is filled with stacked containers of eutectic salts that change phase—or melt—at 55°F. This tank acts as a direct source of chilled water for the chilled beams, a heat source for the heat recovery chillers to deliver hot water, and is able to store cooling energy generated from the economizers that run overnight. It was designed for a typical day in Seattle requiring morning warm-up and afternoon chilling.[18]

TES technologies are continuing to evolve. Since 2021, Stor4Build, a **consortium of four national laboratories** (Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, National Renewable Energy Laboratory, and Pacific Northwest National Laboratory) and the American Council for an Energy-Efficient Economy, has been advancing research for optimizing cost-effective TES technology innovations, including novel phase change materials, thermochemical materials, equipment, and controls. Prototypes for TES integration with heat pumps are being researched by the consortium to make this technology more widely applicable to smaller-scale buildings and HVAC systems.

Geothermal Heating and Cooling

Geothermal heat pumps leverage the constant temperatures of the ground beneath our feet as a heat source or sink to provide buildings with heat energy in the winter or cooling energy in the summer. Thus, with proper operation and maintenance, geothermal heat pumps can serve as potentially cost-effective and more energy-secure HVAC systems that tap into a free source of constant temperature from the shallow earth, reducing the raw energy inputs required to heat and cool buildings. A 2024 analysis of the Federal Energy Management Program's energy savings performance contract project database revealed that 32 projects had used geothermal heat pump systems as an energy conservation measure, representing a project investment of approximately $200 million (in 2024 dollars).[19] Together, these systems are estimated to represent at least 13,000 tons of cooling capacity and provide annual energy savings of over 300,000 MMBtu across energy types, including electricity, steam, district hot water, and fuel oil.[20]

The **Seattle Federal South building**, referenced above, also leverages geothermal systems. The facility's 150-foot foundations are integrated with a hydronic loop system for cooling and heating. The geothermal system consists of high-density polyethylene piping in the piles and standard base-mounted pumps across approximately 160 piles. It was one of the first buildings in the Pacific Northwest region with this integration of structural piles, geothermal heating and cooling, and integral hydronic loops for efficient conditioning.[21]

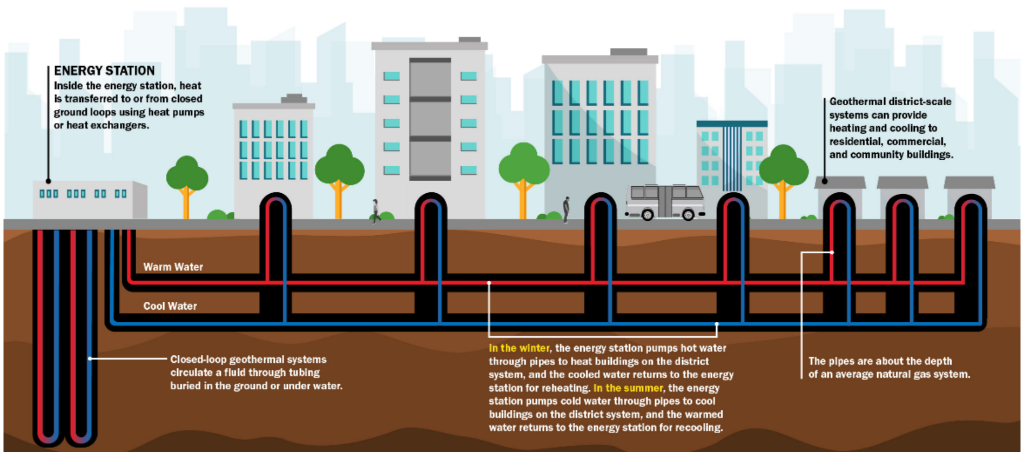

Figure 3. Conceptual diagram of district-level geothermal heating and cooling.
Credit: Department of Energy Geothermal Technologies Office.

In 2024, one of the first **Department of Defense geothermal wells** was initiated at **Detroit Arsenal** to pilot a district-level geothermal heat pump system.[22] The site was one of the first to employ such a system as part of the Federal Geothermal Partnerships with the Department of Energy, with technical assistance from **four national laboratories** (Oak Ridge National Laboratory, National Renewable Energy Laboratory, Lawrence Berkely National Laboratory, and Pacific Northwest National Laboratory), Oklahoma State University, University of Wisconsin–Madison, Illinois State Geological Survey, and the International Ground Source Heat Pump Association. Together, the partners provided a feasibility study consisting of specialized subsurface thermal characterization, hydrogeologic analysis, and preliminary design of the low-temperature geothermal heat pump system for optimal performance and applicability across future Department of Defense installations. The study found that retrofitting a portion of the installation's office buildings could result in a 67% reduction in annual energy consumption for those buildings and an associated 43% annual energy cost savings. If certain tax incentives could be leveraged for the project, the payback period could be as short as six years.[23]

Thermosyphon Cooler Hybrid Systems

Newer technologies also provide the opportunity to address the higher water use intensities of HVAC systems at large data centers. Thermosyphon coolers are highly efficient, passive cooling systems that use refrigerant instead of traditional compressors to dissipate heat. In this hybrid system, cooling shifts between thermosyphon coolers and evaporative coolers (e.g., cooling towers), depending on ambient temperature and system operations.[24] In subfreezing conditions, such a hybrid system takes advantage of the thermosyphon's dry-cooling capabilities, reducing the risk of damage to evaporative cooling components as well as the high demand for water to operate them.**Error! Bookmark not defined.**

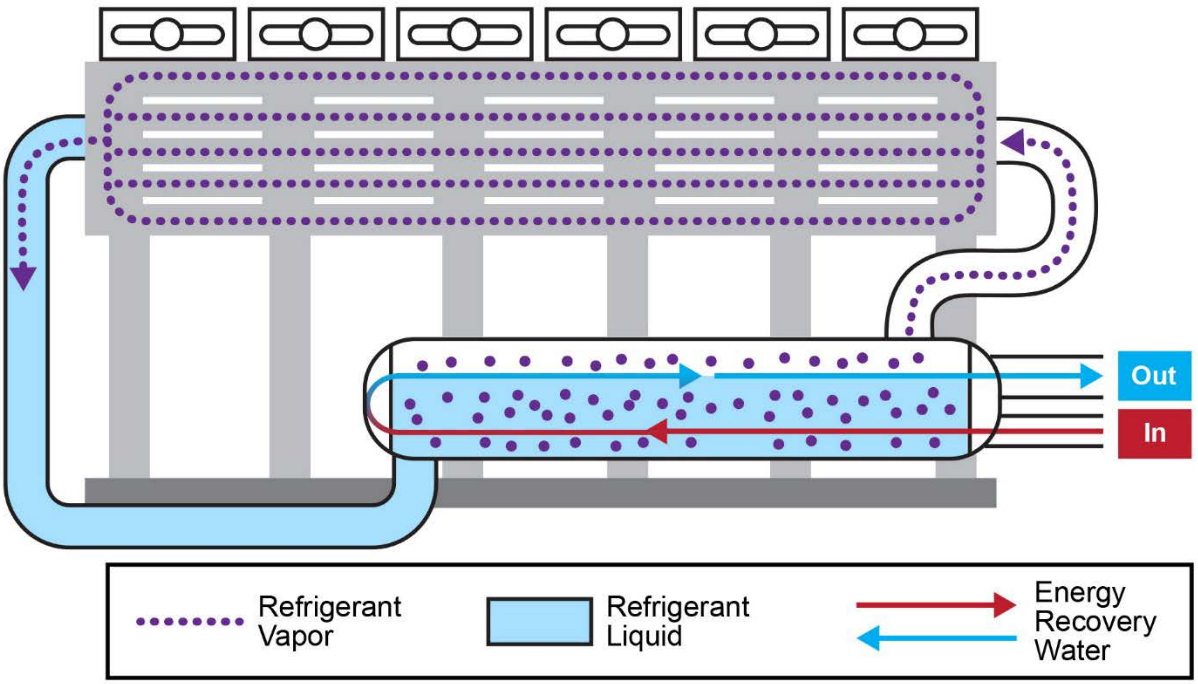

Figure 4. Conceptual diagram of a thermosyphon cooler. Adapted from Carter et al. 2017.

As part of a partnership with Johnson Controls, the **National Renewable Energy Laboratory** installed thermosyphon cooling units for high-performance computing data centers at its location in Golden, Colorado,[25] and at **Sandia National Laboratory** in New Mexico.[2624] In Colorado, the on-site water demands were reduced by more than 50%, saving 1.16 million gallons of water. Over the course of two years, the system cut water usage at the data center in half while still operating at an annualized power usage effectiveness of 1.036.[26] In New Mexico, where ambient temperatures are relatively low and outside conditions are dry during the summer, the hybrid system was modeled to save up to 56% of annual water use compared with a system that solely relies on evaporative cooling towers.[24]

Conclusion

Considering the increase in energy needed for federal buildings to meet heating and cooling needs across federal agencies, several high-performance technologies have been demonstrated in recent years to provide significant savings opportunities. These newer strategies, when employed as energy or water conservation measures, can help agencies continue to flexibly and reliably fulfill their missions.

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