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A Method for Estimating Potential Energy and Cost Savings for Cooling Existing Data Centers

Otto Van Geet

NREL has developed a methodology to prioritize which data center cooling systems could be upgraded for better efficiency based on estimated cost savings and economics. The best efficiency results are in cool or dry climates where "free" economizer or evaporative cooling can provide most of the data center cooling. Locations with a high cost of energy and facilities with high power usage effectiveness (PUE) are also good candidates for data center cooling system upgrades.

In one case study of a major cable provider's data centers, most of the sites studied had opportunities for cost-effective cooling system upgrades with payback period of 5 years or less. If the cable provider invested in all opportunities for upgrades with payback periods of less than 15 years, it could save 27% on annual energy costs.

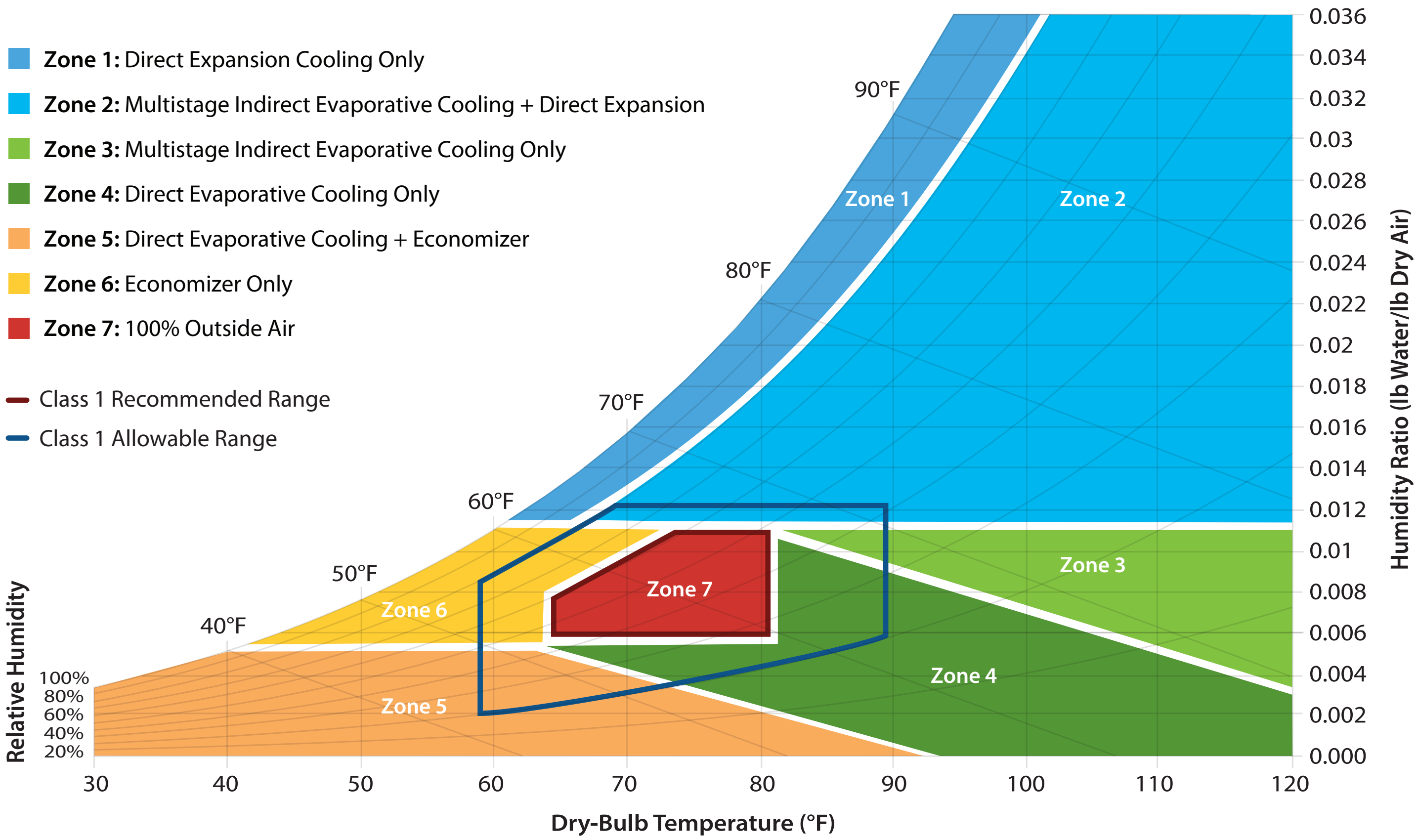

Figure 1. This psychrometric chart indicates the temperatures and relative humidities for which each cooling technology combination is most effective at supplying air within the ASHRAE recommended range (Zone 7).

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Background

Data centers consume large amounts of energy. The United States cable industry alone spends $1 billion per year on energy. A significant portion of that energy is spent to cool data centers to the temperatures recommend by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) for class 1 computer equipment. Implementing the best practices for low-energy cooling technology can, in many cases, significantly reduce the energy consumption of data centers.

NREL's Alternative Cooling for Data Centers Tool

NREL has developed a methodology to help existing data center facilities prioritize which data center cooling systems should be upgraded based on estimated cost savings and economics. The methodology uses annual energy use and cost; PUE; cooling system size (in tons); and location data as inputs.

At the heart of this methodology is NREL's Alternative Cooling for Data Centers Tool[1], which determines the maximum possible cooling energy savings (percent reduction) for a location (climate). The tool analyzes four cooling technologies (see sidebar) for climate appropriateness and cooling energy reduction in data centers. These technologies are examined individually and in combination with others to categorize seven distinct alternative cooling strategies. These alternative cooling strategies are characterized by zones on the psychrometric chart in Figure 1. These zones are bound by the capability of each technology to achieve the temperatures and humidities required by the ASHRAE recommended or allowable ranges for IT equipment.

Estimating Energy and Cost Savings at Large Scales

For companies with more than one data center, the Alternative Cooling for Data Centers Tool can quickly assess the energy savings for all desired data centers. The tool leverages NREL web services to identify the unique weather file (the World Meteorological Organization [WMO] station identifier for the TMY file) for each data center's location. The weather file is then combined with company-provided data on energy use and cost; cooling system size (in tons); and PUE to systematically evaluate the potential energy savings from alternative cooling strategies for each of the locations.

Four Cooling Technologies

Direct Expansion (DX) – Packaged DX air conditioners are the most common type of cooling equipment in smaller data centers. They are generally available as an off-the-shelf technology and commonly described as Computer Room Air Conditioning (CRAC) units. They are the least efficient of the four cooling technologies.

Airside Economizer – Airside economizers take advantage of favorable outside air conditions, such as at nighttime and during mild winter conditions. This approach is typically the lowest-cost option to cool data centers.

Direct Evaporative Cooling – Evaporative cooling cools air by evaporating water into the air. The temperature of dry air can be reduced significantly via the phase change of liquid water to water vapor (evaporation). This cools air using much less energy than DX cooling.

Multistage Indirect Evaporative Cooling – A recent development, these high-performance evaporative coolers surpass historic evaporative cooling paradigms. Specifically, an internally manifolded design has made dew point temperature, rather than wet-bulb, the new low temperature limit for evaporative cooling. These units significantly enhance the climate range for evaporative cooling.

The cost to implement cooling-system efficiency upgrades in $/ton, is based on the experience of the data center owner. The economic simple payback in years is estimated by dividing the implementation cost by the potential cooling-energy cost savings ($/year). The results can be sorted by a variety of metrics such as payback and largest savings to prioritize opportunities.

The best savings are usually in cool or dry climates where "free" economizer or evaporative cooling can provide most of the cooling; locations with a high cost of energy; and facilities with high power usage effectiveness. To determine which facilities ultimately receive upgrades, consider both results from the tool and the age of the facilities' existing cooling systems. For example, a facility with an old CRAC-based cooling system that is near its end of life would be a high priority for an upgrade.

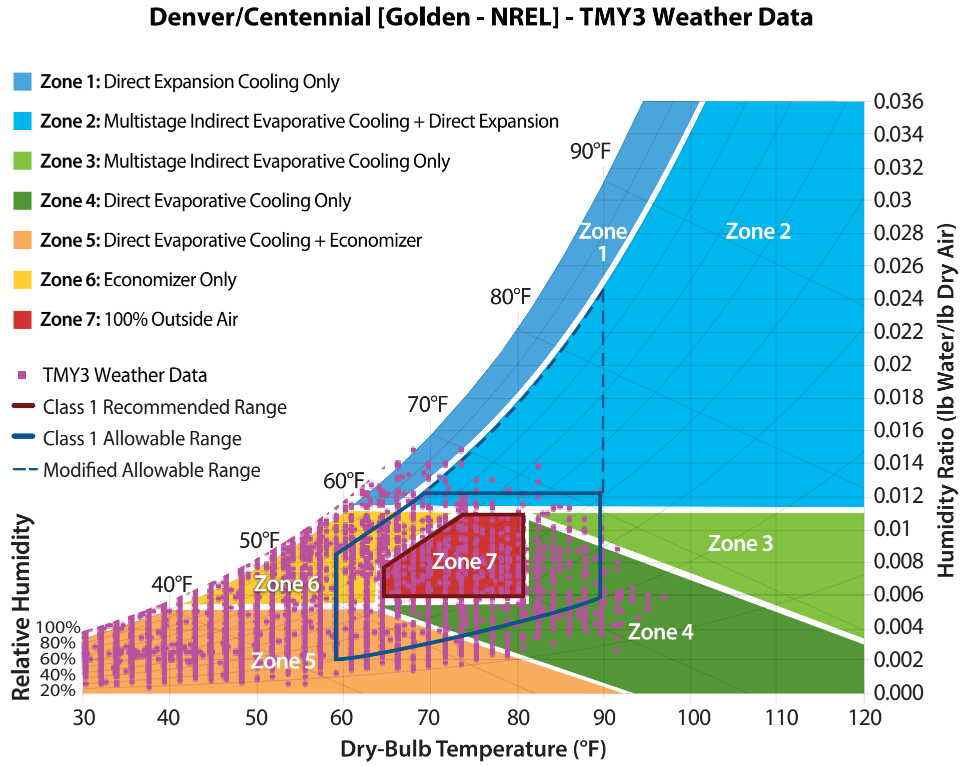
1. Learn more about NREL's analysis of alternative cooling strategies in data centers: *http://www1.eere.energy.gov/buildings/publications/pdfs/rsf/psychrometric_bin_analysis_alternative_cooling_strategies_data_centers.pdf*

Case Study: Estimating Energy Savings at a Data Center in Denver, CO

To understand how the Alternative Cooling for Data Centers Tool can be used to analyze cost savings, consider an example for a facility near Denver, CO (Figure 2). The tool calculated that the facility could reduce energy use for cooling by 95% if the conditions inside the facility were kept within the ASHRAE recommended range. The "Modified Allowable Range" column in the table is the ASHRAE allowable range with up to 80% relative humidity allowed and is shown as a dashed blue line on the chart.

Each of the pink dots in the chart represents the temperature and humidity of an hour from the typical meteorological year (TMY) file for Denver, CO. There are 8,760 dots (hours) distributed into 7 zones. The hours for Recommended, Allowable, and Modified Allowable ranges in each zone are shown in the table, along with the energy required to condition the air to each range. In "Zone 6: Economizer Only," for example, there are 1,250 hours; 4,019 hours; and 4,021 hours, respectively, in the Recommended, Allowable, and Modified Allowable ranges; and zero added energy use during those hours.

"Estimated % Savings" in the table is the savings compared to conventional DX, or CRAC, cooling. It assumes that all alternative cooling technologies were installed and that the data centers are operated in the recommended range. For the Denver example, this would result in an 95% energy savings for cooling. If some of the alternate cooling technologies are not installed the savings would be less. If the data center is operated in the allowable range, then the savings would be even greater.



	Recommended Range		Allowable Range		Modified Allowable Range	
Results	**Hours**	**Energy Used (kWh)**	**Hours**	**Energy Used (kWh)**	**Hours**	**Energy Used (kWh)**
Zone 1: DX Cooling Only	36	11	2	0	0	0
Zone 2: Multistage Indirect Evap. + DX	26	14	1	0	0	0
Zone 3: Multistage Indirect Evap. Only	2	0	0	0	0	0
Zone 4: Direct Evap. Cooling Only	644	74	479	55	479	55
Zone 5: Direct Evap. Cooling + Economizer	5,907	412	1,912	119	1,912	119
Zone 6: Economizer Only	1,250	0	4,019	0	4,021	0
Zone 7: 100% Outside Air	895	0	2,347	0	2,348	0
Total	**8,760**	**512**	**8,760**	**175**	**8,760**	**175**
Estimated % Savings	**-**	**95%**	**-**	**98%**	**-**	**98%**

Figure 2. This chart and table show the output of NREL's Alternative Cooling for Data Centers Tool for a typical data center facility in Denver, CO.

A Tool with Proven Results

In one case study for a major cable provider, NREL used its Alternative Cooling for Data Centers Tool to evaluate 744 sites. It found 728 of the sites had opportunities for cost-effective cooling system upgrades with payback periods of less than 15 years. In fact, most of the sites (504) had payback periods of 5 years or less. If the cable provider invested in all opportunities with payback periods of less than 15 years, it would save 27% on annual energy costs.

NREL uses four alternative cooling technologies at its data centers. NREL's Energy Systems Integration Facility (ESIF)[2] houses the High Performance Computing (HPC) data center, one of the most energy-efficient data centers in the world. Using best-in-class technologies, the data center serves as a showcase facility for demonstrating data center energy efficiency. This data center achieved an annualized average PUE rating of 1.04 in 2016. The HPC data center uses warm-water liquid cooling to achieve this very low PUE, then captures and reuses that waste heat as the primary heat source in ESIF offices and laboratory spaces, and to condition ventilation make-up air. These technologies substantially reduce the amount of energy used by the entire building, saving energy and money in new and effective ways.

There are no mechanical or compressor-based cooling systems for the NREL HPC data center. The elimination of mechanical cooling saved millions of dollars in construction costs, and saves millions of dollars in operation costs annually. Cooling liquid is supplied indirectly from evaporative cooling towers (indirect evaporative cooling).[3]

Learn More

To learn more about NREL's Alternative Cooling for Data Centers Tool, visit *https://techportal.eere.energy.gov/technology.do/techID=1175*.

If you are interested in partnering with NREL to evaluate your potential data center energy savings using the tool, contact Otto Van Geet at *Otto.VanGeet@nrel.gov*, or call 303-384-7369.

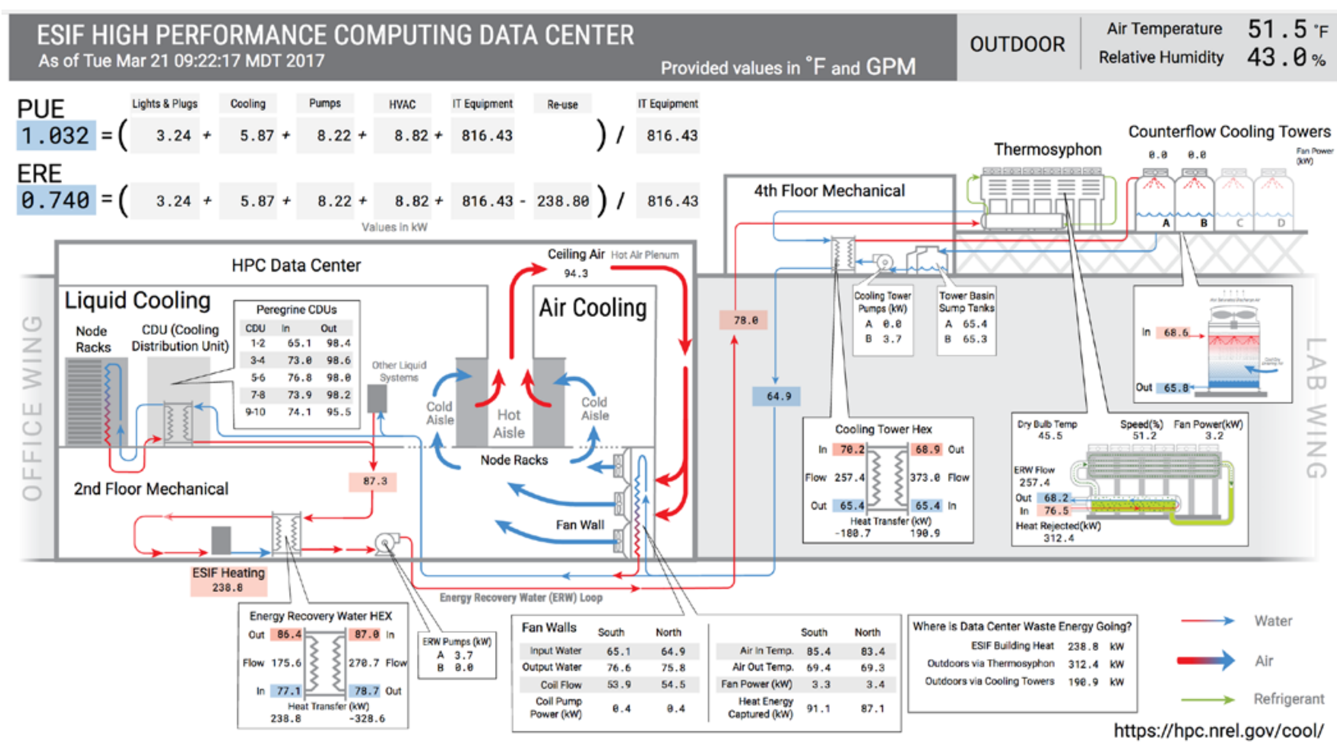


Figure 3. Energy performance of the NREL High Performance Computing data center, which is cooled by indirect evaporative cooling.

2. For more information about NREL's Energy Systems Integration Facility, see *http://www.nrel.gov/esif*.

3. For more information about NREL's HPC data center, including real time performance, see *https://hpc.nrel.gov/datacenter*.

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National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

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