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

Case Study: Innovative Energy Efficiency Approaches in NOAA's Environmental Security Computing Center in Fairmont, West Virginia

Prepared for the U.S. Department of Energy's Federal Energy Management Program

By Lawrence Berkeley National Laboratory

Rod Mahdavi, P.E. LEED AP

May 2014

FEMP Federal Energy Management Program

Contacts

Rod Mahdavi, P.E., LEED AP
Lawrence Berkeley National Laboratory
1 Cyclotron Road
Berkeley, CA 94270
(510) 495-2259
E-mail: rmahdavi@lbl.gov

For more information on the Federal Energy Management Program, please contact:

Will Lintner, P.E., CEM
Federal Energy Management Program
U.S. Department of Energy
1000 Independence Ave SW
Washington, DC 20585
(202) 586-3120
E-mail: william.lintner@ee.doe.gov

Acknowledgements

The author would like to acknowledge the assistance of Darren Smith for facilitating the visit and making this case study possible.

Abbreviations and Acronyms:

^{0}F	Degrees Fahrenheit
AHU	Air Handler Unit
BAS	Building automation system
CFD	Computational Fluid Mechanics
EEM	Energy Efficiency Measure
GHG	Greenhouse gas
Gpm	Gallons per minute
HPC	High performance computing
IT	Information Technology
kV	Kilovolt or a thousand volts
kW	Kilowatt or a thousand watts
MWh	Megawatt hour or a million watt hours
PUE	Power utilization effectiveness, ratio of total energy use to the energy use by IT systems
RDHx	Rear Door Heat Exchanger
TES	Thermal Energy Storage
UPS	Uninterruptable power supply
VFD	Variable Frequency Drive

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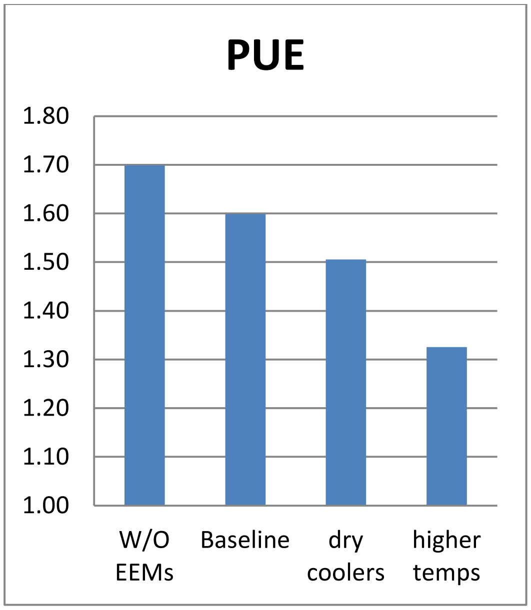
Executive Summary

Lawrence Berkeley National Laboratory (LBNL)'s staff evaluated the energy efficiency of the National Oceanic and Atmospheric Administration's (NOAA) new data center in Fairmont, West Virginia. LBNL conducted this evaluation as part of the Federal Energy Management Program's technical assistance program during the summer of 2012. The NOAA Environmental Security Computing Center (NESCC) is a 6 megawatt (MW) capacity, high density data center facility that commenced operations in October 2011. During the design phase of the project, LBNL recommended innovative ideas for improving facility energy efficiency. As a result, the following measures were implemented:

- Dry coolers were installed to partially or entirely cool the data center without chiller operation when outdoor temperatures are below the chilled water return temperature.
- Hot aisle containment was installed as an energy saving measure for more efficient air management.
- Rear door heat exchangers (RDHx) were also used on most of the racks for more efficient heat transfer.

This study estimates the impact of energy efficiency measures (EEMs) at the NOAA data center, including both new opportunities, as well as those that are already applied. During this study, the potential energy savings due to dry coolers was verified, although during the baseline (assessment period including environmental and power monitoring by assessor) period ambient temperature was high and dry coolers were not in operation. Additionally, the impacts of rear door heat exchangers and hot aisle containment were estimated. Results from the study are illustrated in Table 1.

Four scenarios (no EEMs, baseline, dry coolers, and higher chilled water temperatures) were considered, with data center power utilization effectiveness (PUE) and annual energy use compared between each of these scenarios. The PUE is the ratio of total data center power (or energy) use to the power (or energy) use of the information technology (IT) equipment within the data center. At the NOAA Data Center, facility PUE can be reduced from a baseline amount of 1.62 to 1.33, and the annual energy use can be reduced from 11,600 megawatt hours (MWh) to 9,600 MWh, under the most favorable scenario. Annual savings are estimated at 2,100 MWh that would result in an avoidance of 2,000 metric tons of greenhouse gas (GHG) emissions and a concurrent reduction in electricity costs of $125,000. Estimated power consumption by different users under four different states, original design, current installation (baseline), functional dry coolers, and after implementation of the EEMs recommended in this report, are listed in Figure 1 and Table 1.



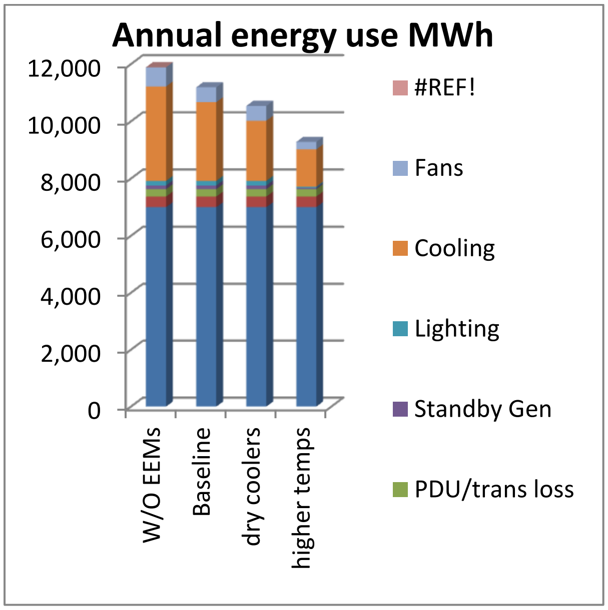


Figure 1. Impact of EEMs on PUE and Annual Energy Use

	Estimated Annual Energy MWh			
Use Point	**W/O EEMs**	**Baseline**	**dry coolers**	**higher temps**
Current IT Load	7,000	7,000	7,000	7,000
UPS Loss	370	370	370	370
PDU/trans loss	260	260	260	260
Standby Gen	130	130	130	45
Lighting	160	160	160	45
Cooling	3,300	2,750	2,100	1,300
Fans	670	520	520	260
TOTAL	11,890	11,190	10,540	9,280
PUE	1.70	1.60	1.51	1.33

Table 1. Impact of EEMs on PUE and Energy Use

Facility Systems

Cooling System

Cooling air for the data center is provided exclusively by three air handler units (AHU), rated at 47,000 cubic foot/minute each. Cooling air from the AHUs is supplied under the raised floor from one side of the data center. Return airflow is through the ceiling registers and ceiling plenum, back to the AHUs as illustrated in Figure 2. The AHU fans have variable frequency drives (VFD) that are currently controlled by manually adjustable set-points. Chilled water valves are controlled by the supply air temperature set-point. Chilled water is provided by the central chilled water plant. The chilled water plant is comprised of three 500 ton air-cooled chillers, eight 150 ton dry coolers each with eight fans, primary and secondary pumps, and a 10,000 gallon thermal storage. A building automation system (BAS) monitors and controls the plant. As Figure 2 shows, the facility has conventional air cooled racks as well as racks with rear door heat exchangers. This presents an opportunity, since the air from contained hot aisle is mixed with the relatively cool air from other areas. This dilutes the return air temperature, making it cooler than it needs to be, and reduces the chilled water return temperature.

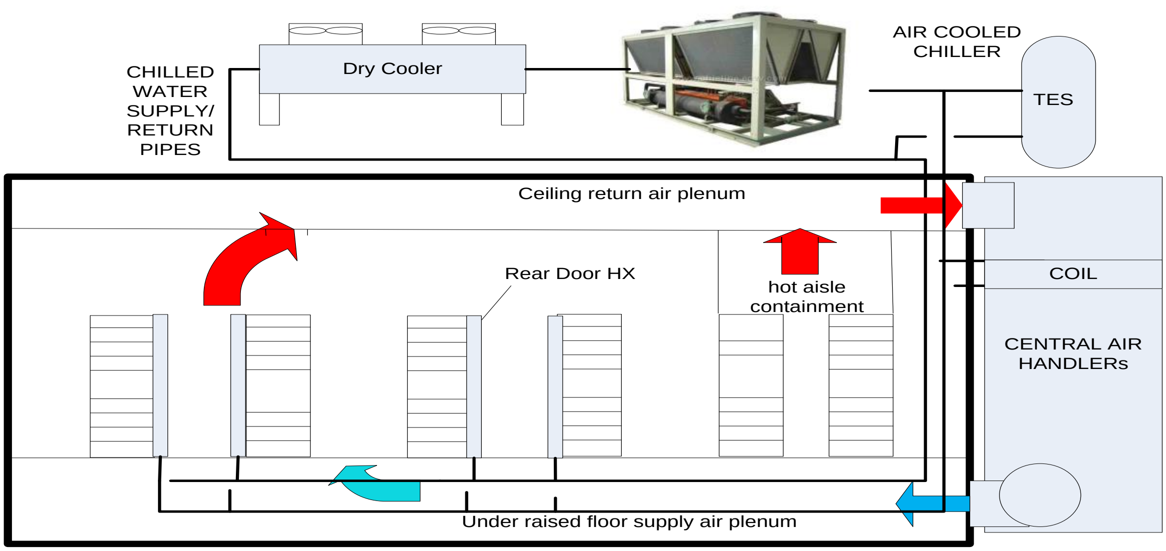


Figure 2. HVAC Schematic

Electrical System

The building is served by two main 12.47 Kilovolt (KV) utility feeders. Two 2,000 Kilowatt (kW) diesel standby generators are provided to power selected critical loads, including the IT load and the mechanical equipment loads serving the IT. A flywheel rotary uninterruptable power supply unit (UPS) is provided to supply short term un-interrupted power to the high performance computational (HPC) equipment. This system is more efficient than a conventional UPS system. A conventional double conversion UPS system provides uninterrupted power to other loads. Each UPS system is sized for 970 kW.

Implemented Energy Efficiency Measures During Original Construction

NOAA's data center has already adopted several energy savings measures, including dry coolers, rear door heat exchangers, hot aisle containment, and a rotary UPS system. Without the availability of these EEMs, facility PUE would have been approximately 1.7. Additionally, the PUE would have been even higher if computer room air handlers were used instead of central air handlers. The baseline included hot aisles, rotary UPS, and rear door heat exchangers but no dry cooler operation. The calculated PUE during baseline was 1.60.

Dry Coolers

Dry coolers take advantage of cold seasons and nights to provide chilled water without compressor use. Estimated hours of dry coolers at the current chilled water temperature is 4,500, or about half of the total. The PUE is estimated to be reduced to 1.58 with dry coolers fully operational. Figure 3 shows the dry coolers, chillers, and Thermal Energy Storage (TES).

Figure 3. Dry Coolers/Chillers

Figure 4. RDHx and Piping

Rear Door Heat Exchanger

As is shown in Figure 4, the Rear Door Heat exchanger (RDHx) option was developed to extract heat at the rack level. A water-cooled door closes behind the rack and provides energy savings by removing heat at the rear door closest to the heat source. This made it very efficient, as air movement can be provided solely from the IT equipment fans. RDHx greatly reduces the requirement for additional cooling in the server room by cooling the exhaust from the racks. There is an opportunity to increase cooling water temperature, thus reducing cooling energy even more.

Hot Aisle Containment

All of the air cooled racks were located in an aisle with the exhaust side contained. Sealed containment separates hot air from cold air and eliminates potential mixing. The result can be a higher temperature difference between the AHU's supply and return temperature. The air flow can be reduced and fan energy can be saved. Also a higher supply air temperature can be adopted, resulting in a higher chilled water supply temperature. A higher chilled water supply temperature will result in better chiller efficiency and more hours of free cooling using the dry coolers. Figure 5 exhibits the hot aisle as well as a thermal image of the west side of the data center where hot aisle with temperatures above 90^{o}F (red color) is identified.

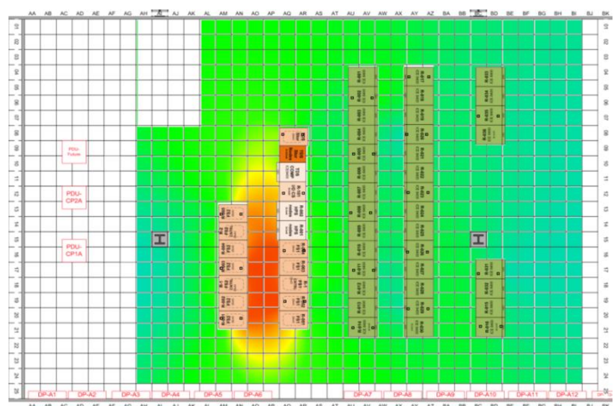


Figure 5. Hot Aisle Containment Photo and Thermal Map

EEMs Implemented During Baseline Period

Thermal energy storage (TES) is employed to provide a few more minutes of chilled water to AHUs when the chillers are down due to power failure. TES control was based on maintaining 1000gpm of chilled water supply flow to the TES at all times, supposedly to keep the tank cool. This cold water mixed with return water from the building reduced return water temperature going back to the chillers, thus reducing system efficiency while greatly increasing pumping power. During the baseline period, the energy use assessment team implemented a plan for reducing chilled water flow through the TES down to 300gpm, as illustrated in the Building Automation System (BAS) screens (Figures 6,7).

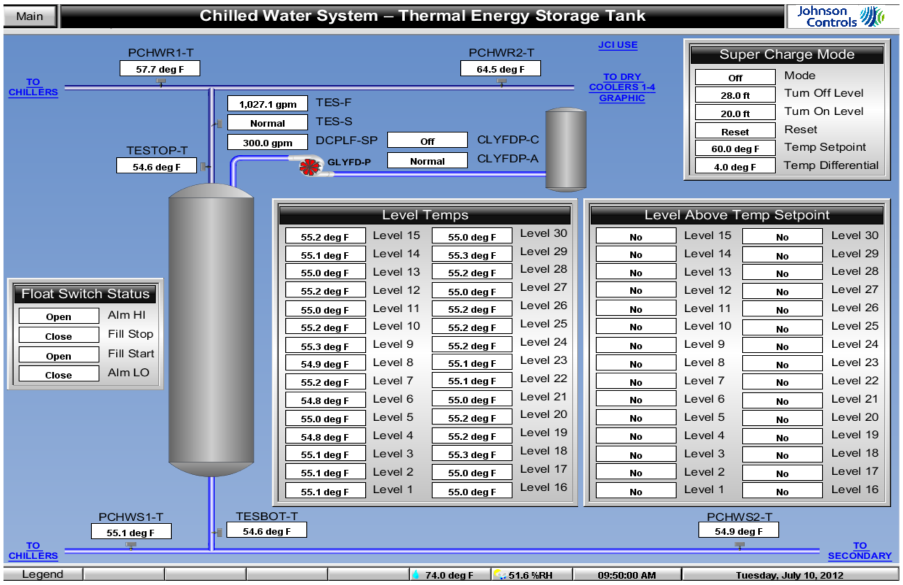


Figure 6. TES and Chilled Water System Data in BAS screen

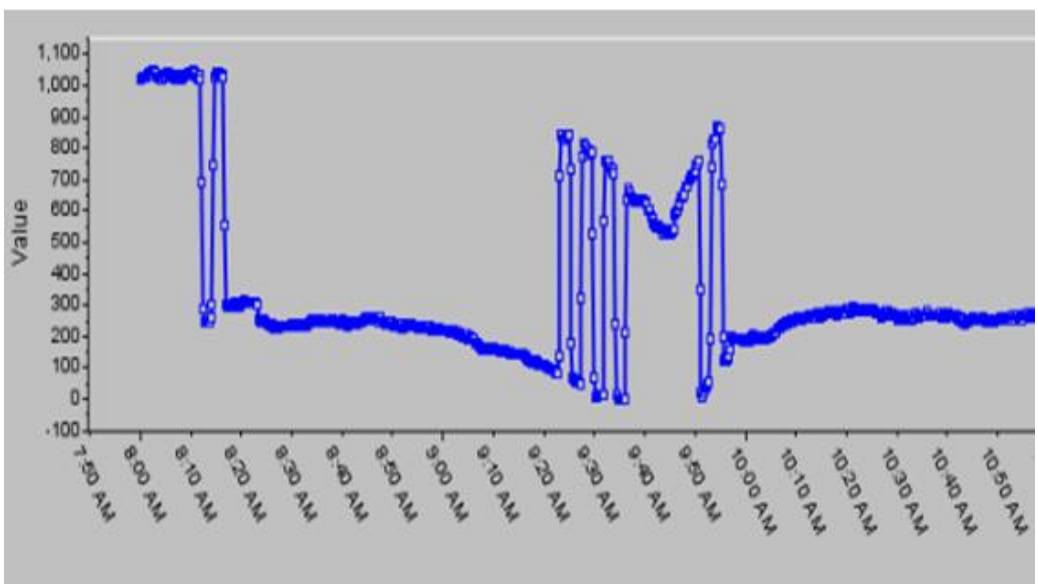


Figure 7. Water Flow Stabilized After 2 Hours at 300gpm

As the result of the reduced water flow to the TES, one chiller shut down, pumping energy was reduced, and PUE improved immediately, as illustrated in Fig. 8.

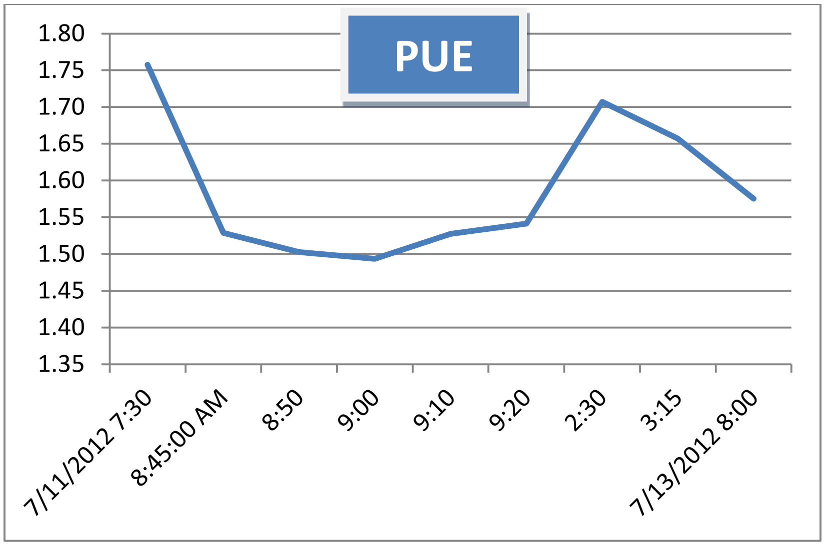


Figure 8. PUE Improvement Because of Reduced Water Flow to TES

Opportunities

Some of the opportunities the team observed during baseline period were:

- The main barrier to increasing the intake air temperature is the IT equipment maximum temperature requirement specified by vendors. Clearly, no requirement of under 80^{o}F for air intake temperature is acceptable, and the higher the air intake temperature can be adapted the more energy can be saved.
- Since the control room had a large window to the data center, any movement in the control room activated the data center motion detector and turned on all the lights in the data center.
- The AHU supply and return air temperature difference was very low, as a result of excessive air flow and mixing of return air with the already cooled air coming out of the RDHxs.
- Several racks equipped with RDHx were located in the contained hot aisle, causing a reduction in the return air temperature (dilution).
- During the baseline period, rack air intake temperatures were between 69^{o}F and 72^{o}F, while return air temperature to the air handlers was about 73^{o}F. The high air flow required to maintain the low delta T results in a high fan power requirement.

Recommendations

Improve Air Management

- Install differential pressure sensors above and below the floor to control the airflow of the AHUs. The airflow set-point can be can then be reset by the rack top air intake temperature. This should result in reducing airflow and power used by fans.
- Limit the cooling air flow to the racks without RDHx. This can be done by replacing perforated tiles and ceiling registers with solid ones.

Improve the Cooling Efficiency

- Install rack sensors for measuring the temperatures at the server level, to allow for the implementation of EEMs without concerns for interrupting data center operations. A case in point was the temporary installation of the temperature sensors during the baseline period, in which changes were made to the cooling system sequence without any risk to the IT operation.
- Allow higher IT air intake temperature (upper side of ASHRAE recommended range). With this, the air handler supply air temperature set point can be increased (from about 60^{o}F to 75^{o}F). With the air handler at a higher supply air temperature, the chilled water supply temperature set point can be higher (about 65^{o}F instead of 55^{o}F). The chiller efficiency will improve (approximately 1.5% for each degree Fahrenheit of set point temperature). Also, the number of "free cooling"/compressor-less hours will increase. This needs to be done gradually (approximately 2^{o}F at each step), and the impact will need to be monitored until the highest possible temperature is reached without compromising the reliability of the cooling system. The impact of such an increase (more than 10^{o} F) can substantially improve the PUE, primarily by increasing the annual compressor-less cooling hours to 5,900 hours and by increasing the chiller efficiency.
- Raise the chilled water temperature to eliminate the likelihood of condensation allowing an expansion of the n relative humidity range to 20-80%. Raising the chilled water temperature will enable NOAA to remove the heat pumps. In this case, heat pumps that were present for a tighter control of the humidity can be removed.
- Shut down the outside airflow to the data center by sealing the dampers or replacing the existing dampers with higher quality dampers to eliminate the source of the humidity that caused condensation. This is another option to allow for the removal of the heat pumps.
- Change the TES control from water flow to TES temperature monitoring for bypass water flow control. It will reduce bypass water to the TES which saves pumping power and increases the efficiency of the chiller.

Other Efficiency Measures

- Improve the control of the lights by separating the circuits and allowing the occupancy sensors to activate only the occupied area and not the whole data center. Additionally, adjust the occupancy sensors to resolve the issue of the data center's occupancy sensors being activated by movement from the control room occupants.

- Improve the block heater controls for the generators by resetting them to lower temperatures, thus reducing the power used by the heaters.
- Discuss the thermal requirements of the servers with the vendors and negotiate relaxing the requirements. Also consider the procurement of new IT systems, including liquid cooled systems. This measure was not considered in the savings calculations in this report, but could increase reliability as well as decrease energy costs.

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DOE/EE--1076 ▪ May 2014

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