Highly Energy-Efficient Data Center Incorporated in New Research Support Facility

The National Renewable Energy Laboratory (NREL) has become world renowned for its commitment to green building construction and is living up to its reputation with the inclusion of an ultra energy-efficient data center at the laboratory's new Research Support Facility (RSF).

Even before the RSF data center was built, its expected energy performance was getting considerable media attention as exemplified in Figure 1.

Figure 1. RSF data center energy performance was featured in serveral publications.

In typical computer centers you can feel the energy consumption from racks of servers radiating heat, while icy air blows through the room to cool them. NREL's fully contained hot and cold aisle data center configuration minimizes this problem. The configuration includes effective air-side economizer cooling with an evaporative boost when needed. Waste heat is also captured for use throughout the RSF building. The use of blade servers and server virtualization has lessened the energy consumption by approximately 65% to support the same workload of our legacy systems. Plug loads in the RSF are also minimized with extensive use of laptops and high-efficiency office equipment.

Sustainability Measures

NREL delivers its administrative IT products and services from its world-class energy-efficient data center located in the RSF, which has been designed to achieve a LEED Platinum rating. To support the RSF's energy goals, NREL's data center was designed to minimize its energy footprint without compromising needed service quality. This section will discuss the sustainability measures NREL incorporated to design and operate the RSF data center.

Power Usage Effectiveness (PUE) is the industry standard metric used to measure the energy efficiency of data centers. PUE is calculated as a ratio using the formula shown in Figure 2. The PUE for NREL's Legacy data center was estimated to be 3.3. In contrast, the measured PUE for NREL's RSF data center ranges from 1.11 – 1.15 as shown by the graph in Figure 3. The extremely low PUE is unique among data centers worldwide.

$$\text{PUE} = \frac{\text{Cooling} + \text{Power} + \text{Equipment}}{\text{Equipment}}$$

Figure 2. Power Unit Effectiveness (PUE) formula

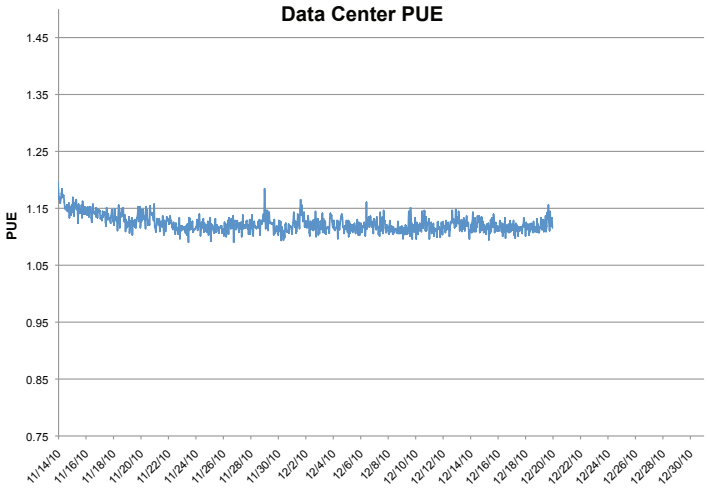

Figure 3. Data Center PUE

Figure 4 contrasts the energy requirements for cooling, power systems and equipment between the RSF data center and the Legacy data center. Figure 5 shows a comparison of the PUE from the Legacy data center with the RSF data center. As shown, the energy requirements for cooling and power systems have been heavily optimized.

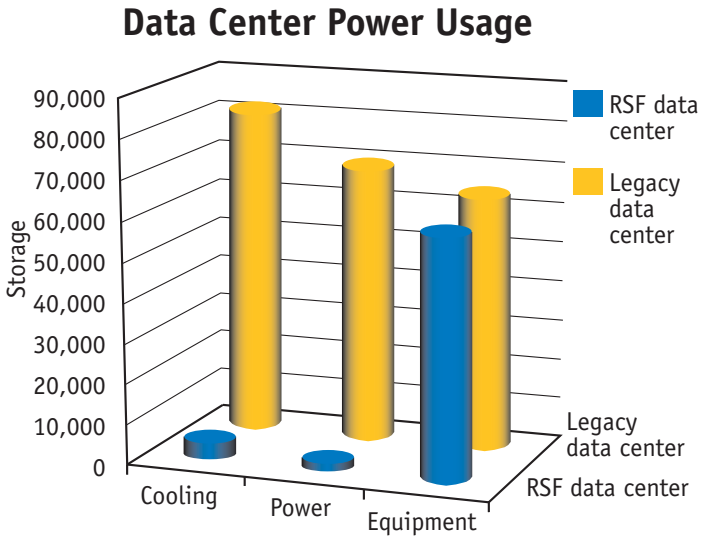

Figure 4. Energy requirements for cooling

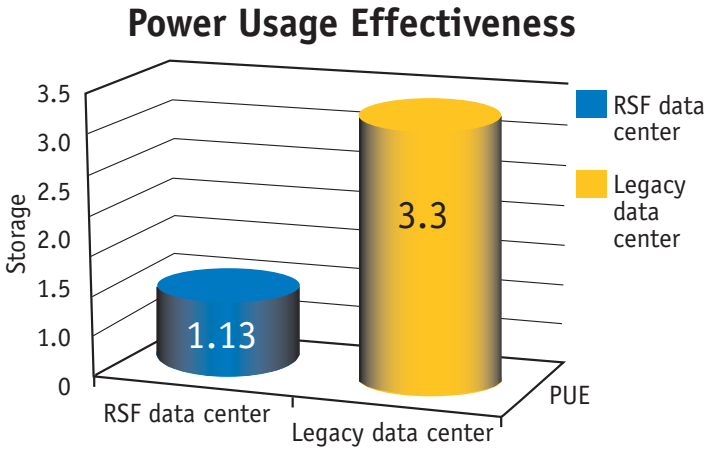

Figure 5. PUE comparison of RSF data center to the Legacy data center

NREL is located in a climate that is favorable for "free cooling," using outside air to provide the majority of the data center's cooling needs. Hourly data for an entire year plotted as a function of temperature and humidity is illustrated in the Psychrometric plot shown in Figure 6. The cooling system for the RSF data center was designed to minimize the use of traditional air conditioned cooling. Based on this historical climate data, NREL's cooling system was designed to use direct air and evaporative cooling methods for almost the entire year. The cooling system was designed to provide cooling ranging from 65°F – 80°F to the data center with humidity ranging from 20% – 60%. This system is projected to cool the data center for all but 10 days a year (except for the most hot and humid days) without air conditioning as represented in the pink colored data points. The equipment racks for the data center have been arranged in a hot aisle / cold aisle configuration with hot aisle containment. Air from the hot aisle is extracted from the data center for reuse in the RSF building. Figure 7 is a picture of the hot aisle containment system used in NREL's RSF data

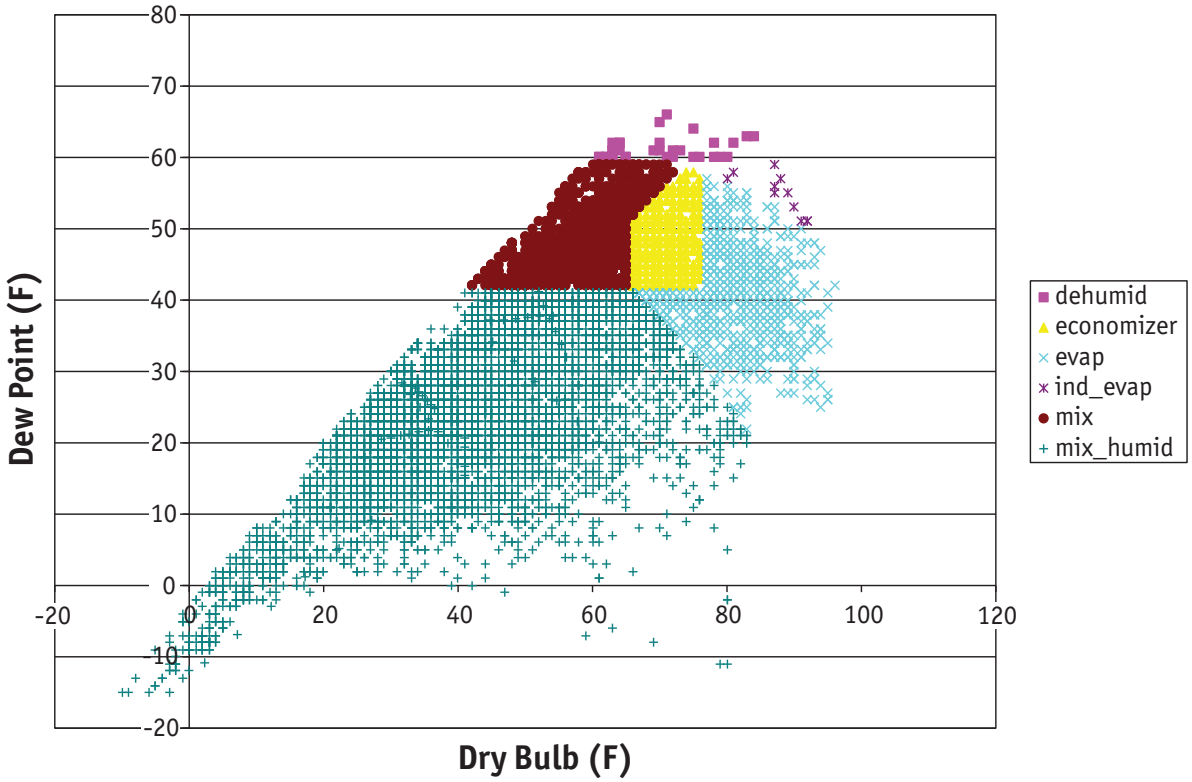

Figure 6. Hourly temperature and humidity data for one year

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Figure 7. Hot aisle containment system used in NREL's RSF data center

center. The diagram in Figure 8 shows how the data center cooling is generated and how the heat from the hot aisle containment system is reused.

NREL is using a 97% efficient APC Symmetra PX 500 kW uninterruptable power supply (UPS) to supply 15 minutes of backup power to servers, storage and network gear located in the data center. The UPS was designed to perform two functions: 1) condition line power, and 2) sustain the data center until the emergency power generator kicks on. Currently, the UPS is configured with 125 kW worth of batteries and scales in 25 kW increments. Ultra-efficient APC power distribution units (PDU's) are used to distribute power to the equipment racks within the data center. In contrast, the UPS used in NREL's Legacy data center was only 80% efficient and produced excess heat, which required additional cooling. The new UPS is effectively saving roughly 37 kW of energy while running a 100 kW equipment load.

To support the energy goals for the RSF, NREL IT staff made a concerted effort to avoid over provisioning capacity for IT equipment and implement newer technologies to save energy. NREL replaced 90% of its Legacy server environment with HP Blade servers that utilize variable speed fans and energy-efficient power supplies. To reduce the power footprint even further, NREL uses Vmware to decrease the required number of physical servers. Currently, 70% of NREL's server environment is virtualized. The original goal was to reach a 20:1 ratio for server virtualization, meaning that the workload that used to run on 20 physical servers

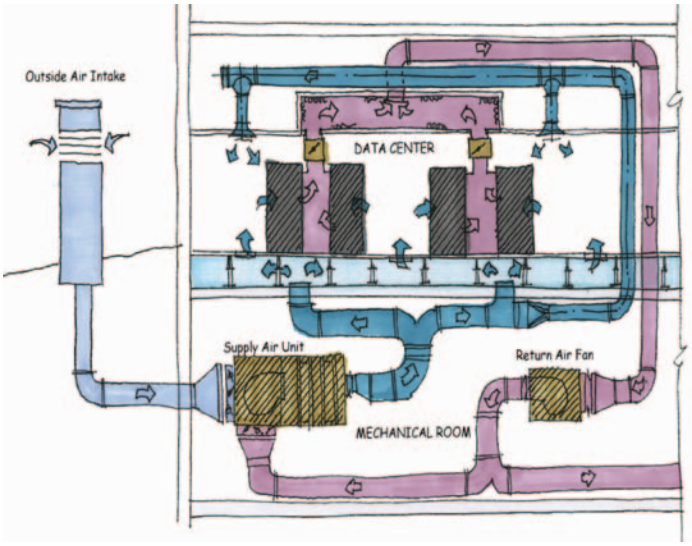
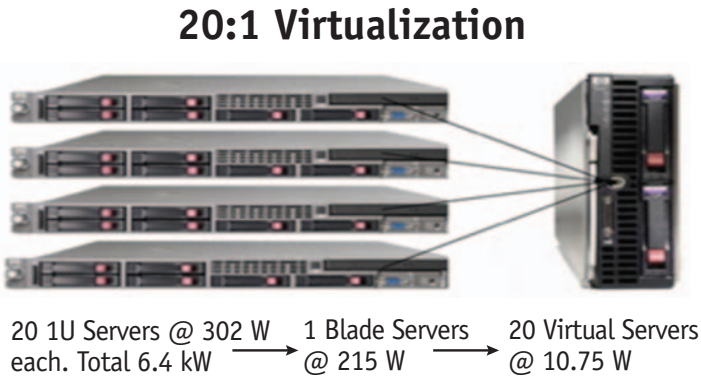


Figure 8. RSF data center cooling and reuse of heat from hot aisle containment system

would only require one single blade server. However, in some environments, NREL has experienced as much as a 29:1 ratio. Dell Equallogic Storage area networks (SAN's) are used to pool storage resources in an effort to reduce the amount of hardware that would typically be required for storage dedicated to server resources.

Figure 9 illustrates the server virtualization effects of running the workload that used to require 20 servers on one blade server. In this example, the energy footprint is reduced by more than 96% for each server.



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It should be noted that PUE only measures how well an organization has optimized its energy use for data center cooling and power systems. It does not take into account efforts to optimize energy use for servers, storage and network infrastructure running within the data center. Comparing watts per user for total data center power consumption provides a more comprehensive evaluation of overall data center energy efficiency. Figure 10 compares watts per user for the Legacy data center with the RSF data center.

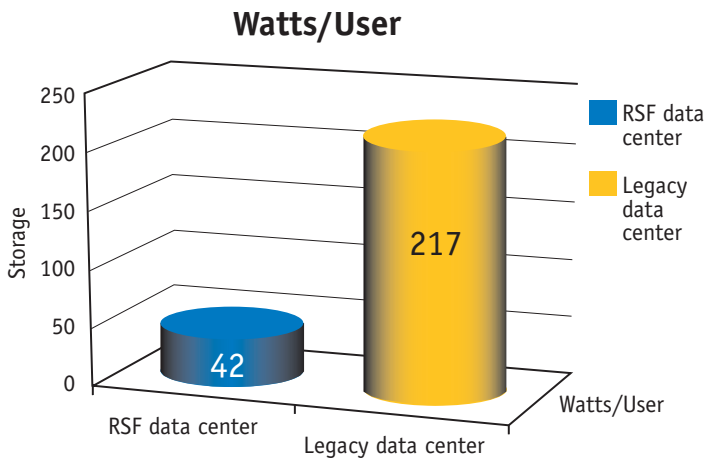

Figure 10. RSF data center's watts per user compared to the Legacy data center

Energy and Cost Reductions

Over the past two years, NREL has reduced per user data center energy requirements by 81% resulting in an annual cost savings of $320,000 in utility bills and an annual reduction in carbon dioxide emissions of nearly 5,000,000 pounds.

Industry and other governmental organizations have taken notice of NREL's green data center accomplishments and innovation. The continual requests for speaking engagements and RSF data center tours have established NREL's leadership in green data center design and sustainable IT operations. The decision to put NREL's administrative data center in an ultra high efficiency LEED Platinum significant building demonstrated the opportunities to achieve energy and cost savings. NREL has succeeded in this effort, and in the process, built one of the world's most energy efficient data centers that supports DOE's goal to lead by example while upholding high quality IT products and services hosted in the RSF.

NREL
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