U.S. Department of Energy, National Renewable Energy Laboratory, IT Sustainability Case Study

Updated: 8/31/2011

SUMMARY

The U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) designed the Research Support Facility (RSF) to demonstrate that a large office building could lead the way in energy efficiency. To support the energy efficiency goals of the building, NREL's Information Services Office pursued ways to minimize energy use both at the desktop level and in the data center, housed in the RSF.

GREEN IT AT THE RSF

The National Renewable Energy Laboratory (NREL) is the U.S. Department of Energy's (DOE) only federal laboratory dedicated to the research, development, commercialization, and deployment of renewable energy and energy efficiency technologies.

NREL's Research Support Facility (RSF) was designed and built with energy efficiency in mind. The RSF was conceived as a showcase of sustainable best practices and innovations, and it is one of the most energy efficient office buildings of its size in the world. In fact, the RSF recently received a Leadership in Energy and Environmental Design (LEED) Platinum designation from the U.S. Green Building Council.

The design goal for the RSF was to achieve a demand-side energy use intensity (EUI) measurement of 35 kBtu/ft^2. The low EUI makes it possible for the RSF to achieve net-zero-energy consumption, meaning that the building would produce as much energy as it consumed from the grid using onsite renewable energy sources. The building needed to do this without compromising performance for the 1,350 staff members and the state-of-the–art, energy efficient data center.

To reach the RSF's net-zero-energy goal, every watt of power consumed had to be considered in every step of the planning process, especially when the decision was made to house the energy-intensive data center in the building.

The RSF features the following information technology (IT) practices to support sustainability practices in the building:

- Installation of Voice-over-Internet-Protocol (VoIP) telephones in place of standard digital phones to cut back on plug loads
- Use of Energy Star and Electronic Product Environmental Assessment tool (EPEAT) computing equipment for the desktop, data center, and print needs
- Use of energy saving green power adapters at the desktop to reduce plug loads.

IMPLEMENTATION - Desktop Computing

The goal was to keep the average energy consumption level at the desktop to below 100W per workstation, which meant computing and printing practices needed to shift dramatically.

NREL conducted a rigorous review of the IT inventory for each employee moving into the RSF to make sure their equipment was optimized for energy efficiency. The decision was made to outfit each employee with Energy Star and EPEAT Gold-rated laptops or desktops and light emitting diode (LED) backlit liquid crystal displays (LCD) monitors, replacing inefficient desktop workstations, fluorescent backlit LCD monitors, and cathode ray tube (CRT) monitors. The laboratory did this because during regular working conditions (with a fully charged battery) a standard laptop consumes 80% less energy than a standard desktop computer, and LED backlit monitors use roughly 50% of the energy of a traditional, fluorescent backlit LCD monitor of the same size.

These two energy-mitigating factors together created a desktop workstation that drastically reduced the amount of energy consumed. NREL also replaced energy-hungry desktop printers, scanners, and fax machines with Energy Star- and EPEAT-rated networked multifunction devices that performed all of these functions and also produced copies. A single multifunction device serves as many as 60 employees in a single wing of the building.

Equipment purchases were made from the building budget, rather than department budgets, to remove the financial burden on departments.

To date, NREL has:

- Replaced computers for approximately 800 employees with Energy Star/EPEAT Gold rated laptops, along with fluorescent LCD and CRT monitors with LED backlit LCDs
- Virtually eliminated desktop/workgroup printers by replacing them with shared multifunction network devices
- Purchased over 900 energy-saving surge protectors which are designed to automatically turn off outlets not in use
- Deployed 2W power-over-Ethernet VoIP phones to all RSF occupants
- Remotely managed and changed the power settings on all computer systems in the RSF to further optimize their energy efficiency
- Implemented an education campaign to help employees interact with their computing equipment, such as a power management video
- Began development of a tool enabling employees to monitor the energy consumption of their workstation and the building as a whole.
- Initiated a thin client pilot
- Initiated a softphone pilot.

Significant time and consideration was put into how best to minimize the impact of such a vast cultural and environmental change on the employee. NREL conducted several presentations for laboratory staff demonstrating how the RSF environment would look and feel. These sessions educated staff on how each feature contributes to the goal of creating one of the most energy efficient office buildings in the world a reality.

IMPLEMENTATION—Data Center

Data centers typically consume half of the energy expended by an office building. For the data center to be feasible in a building like the RSF, NREL had to plan for equipment and an operational environment that significantly reduced its energy footprint.

To support the RSF energy goals, NREL's data center was designed to use all best practices for data centers to minimize its energy footprint without compromising service quality. This section discusses the sustainability measures NREL took to design and operate the RSF data center.

NREL is located in a climate that is favorable for the use of "free cooling." The cooling system for the RSF data center was designed to use passive cooling methods that minimize the use of traditional air conditioned cooling by bringing the cool outside air into the data center through innovative air handling techniques.

Based on Colorado's climate, the cooling system was designed to use air-side economizing and direct evaporative cooling methods for almost the entire year, providing cooling ranging from 65^0F – 80^0F with humidity ranging from 20% – 60%. This system was designed to cool the data center for a significant number of days per year (except for the most hot and humid days) without air conditioning.

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 data center was built in a hot and cold aisle configuration with hot aisle containment. This minimizes hot air from the servers mixing with the cool supply air, lessening the cooling requirements, which are met efficiently with air-side economizing, direct evaporative cooling, and chilled water coils when needed.

Figure 1 shows the hot aisle containment system. Air from the hot aisle is extracted from this system and is either ducted through the building for reuse in the cooler months, or is vented to the outside.

Figure 1. NREL's data center hot aisle containment system.
Photo by Dennis Schroeder, NREL/PIX 18781.

NREL is using a 97% efficient 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 for 125 kW worth of batteries and scales in 25 kW increments. In contrast, the UPS used in NREL's legacy data center was only 80% efficient and produced a lot of heat, which required cooling. The new UPS saves approximately 37 kW of energy while running a 100 kW equipment load. Additionally, ultra-efficient APC power distribution units are used to distribute power to the equipment racks within the data center.

NREL IT staff made a concerted effort to avoid over provisioning the capacity for IT equipment. They replaced energy-intensive standalone servers with Energy Star/EPEAT blade servers. Coupled with server virtualization, this best practice implementation lessened server equipment energy consumption by approximately 65% to support the same workload of the legacy systems, without degradation to the quality and service staff expects.

NREL replaced 90% of its legacy server environment with blade servers that use variable speed fans and energy efficient power supplies. To reduce the power footprint even further, the laboratory implemented server virtualization 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 would only require a single blade server. In the example shown in Figure 2, the energy footprint is reduced by more than 96% for each server. In some environments, NREL has experienced as much as a 29:1 ratio.

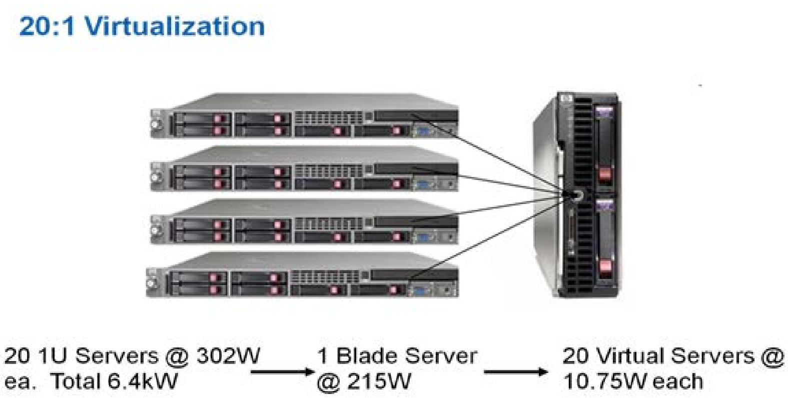

Figure 2. Data center blade server virtualization ratio.
Illustration courtesy of NREL.

In addition, 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.

RESULTS

The energy measures implemented both in the data center and at the desktop have significantly lowered the energy foot print for this traditionally power-intensive function.

At the desktop level, load tests confirmed that a laptop computer with two 22" LED backlit LCD monitors consumed an average of 54 watts during occupied hours and 5 watts during unoccupied hours. This is an energy savings of approximately 80%, based on the average load of a desktop computer with a single fluorescent-backlit LCD monitor (150 watts).

In data centers, power usage effectiveness (PUE) is the industry standard metric used to measure the energy efficiency. PUE is calculated as a ratio using the formula shown in Figure 3.

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

Figure 3. Power Usage Effectiveness Equation.

The PUE for NREL's legacy data center was estimated to be 3.3. The measured PUE for NREL's RSF data center ranges from 1.11 – 1.15 during the cold winter months where chilled water cooling is not required, as shown by the graph in Figure 4. The PUE rises slightly to 1.20 – 1.25 in the warmer months.

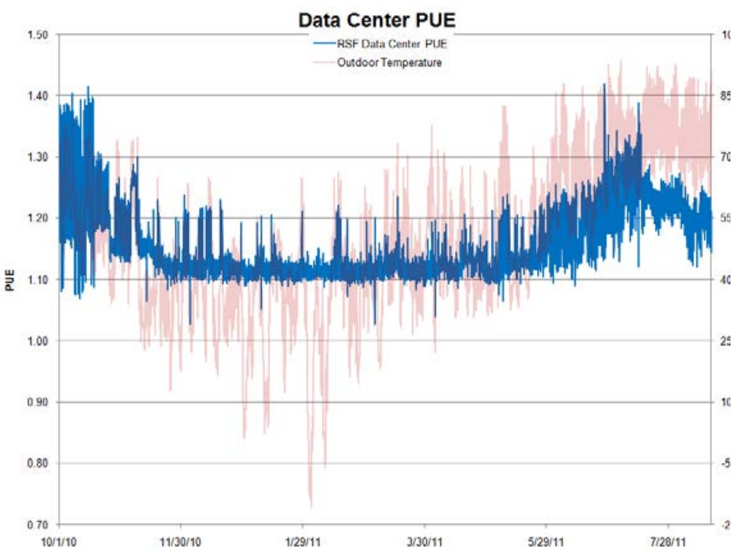

Figure 4. NREL's data center PUE.

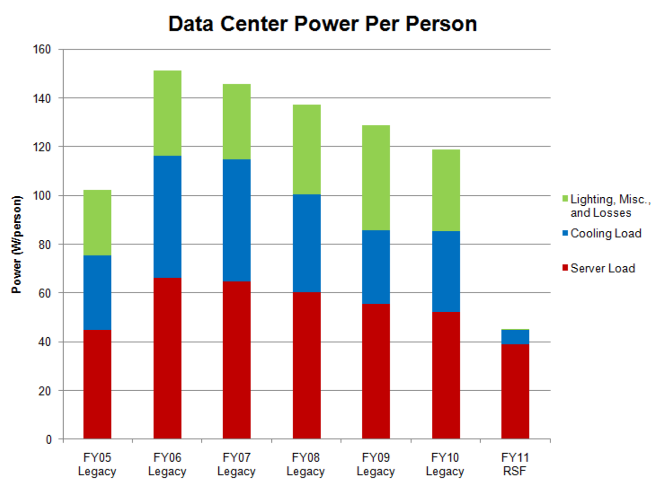

Figure 5. Watts per user comparison of NREL's RSF data center to the legacy data center.

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, or network infrastructure running within the data center. Watts per user for total data center power consumption may provide a more comprehensive evaluation of overall data center energy efficiency. Figure 5 compares watts per user for the legacy data center with the RSF data center. Over the past two years, NREL has reduced data center energy requirements per user by 81%, resulting in an annual cost savings of $200,000 (at $0.06 per kWh) in utility bills and an annual reduction in carbon dioxide emissions of nearly 5,000,000 pounds.

Figure 6 contrasts the power requirements for cooling, power systems and equipment between the RSF data center and the legacy data center. Figure 7 shows a comparison of the PUE from the legacy data center with the RSF data center. As you can see, the energy requirements for cooling and power systems have been heavily optimized.

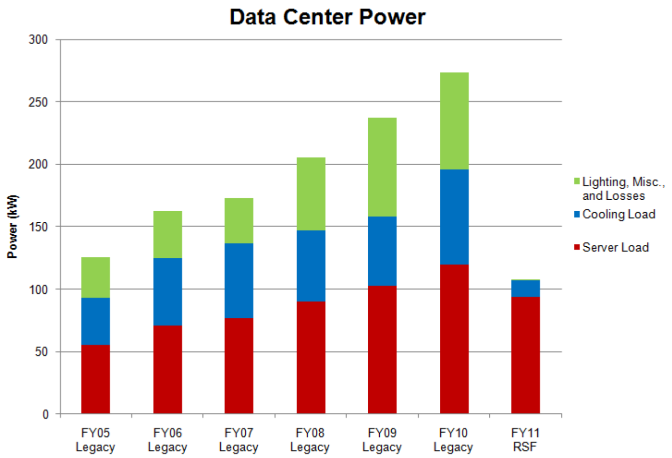

Figure 6. Energy requirements comparison of NREL's RSF data center to the legacy data

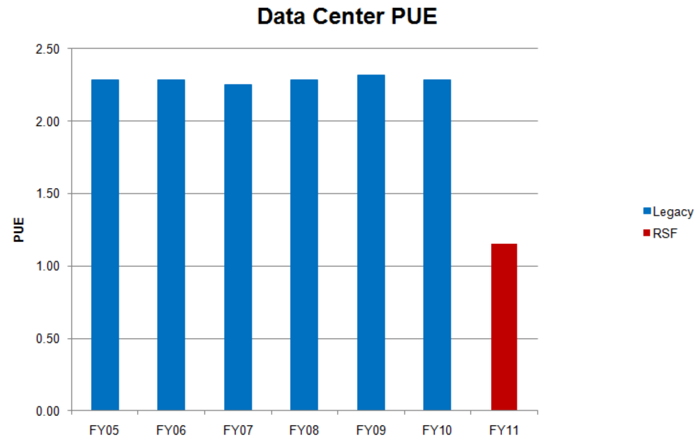

Figure 7. PUE comparison of NREL's RSF data center to the legacy data center.

As NREL moves forward as a model of electronics stewardship and energy efficiency, plans are in motion for a thin client deployment and expansion of the virtual desktop infrastructure environment. NREL is also putting together an electronics stewardship program focused on developing and refining policies on energy efficient electronics. NREL's goal is to fully integrate staff interaction with IT operations, aligning office staff with the Laboratory of the Future concept.

CONCLUSION

NREL is proud to be an FEC Platinum Facility Partner for the laboratory's focus on energy-efficient equipment life cycle management. Additionally, industry and other government organizations have taken notice of NREL's green data center accomplishments and innovation. The continual requests for speaking engagements and RSF data center tours underscore NREL's leadership in green data center design and sustainable IT operations.

The decision to put NREL's administrative data center in the RSF office building was an exercise to demonstrate that a building of this size and type could be cost-effective and approach net-zero energy usage. NREL has succeeded in this effort, with the RSF achieving LEED Platinum status in 2011. NREL's computing environment is part of the laboratory's living laboratory and is constantly measured so adjustments can be made to improve efficiency.

REFERENCES

For more information on NREL's Research Support Facility, please visit the NREL website at http://www.nrel.gov/sustainable_nrel/rsf.html.

CONTACT INFORMATION

If you have questions related to this resource or need other assistance with the Federal Electronics Challenge, please contact your Regional Champion: http://www2.epa.gov/fec/technical-assistance.

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