Data Center Research and Lawrence Berkeley National Lab

Data Centers have come a long way. Considered a "Data Vampire" 40 years ago in a Time magazine article about the debate regarding the U.S. Budget Bureau's proposed National Data Center at the time the data center was considered a fact vampire.

In 1966, Congress conducted a subcommittee investigation to determine the threat toward privacy and individual liberty that a new computer and information warehouse would have. Well, 40 years later data centers are everywhere from government agencies to private facilities.

Data centers continue to absorb facts and information. Our perception of them has changed considerably over the years and more recently a new moniker of "Power Vampire" has been placed on them. The issue of privacy and security has not gone away and continues to be a struggle for most organizations. Today, however, the issue gaining the most publicity has been data center energy conservation.

The intense power requirements needed to run and cool data centers now account for almost a quarter of global carbon dioxide emissions from information and communications technology, according to analyst firm Gartner.

It is this issue along with the growing operational expense and increasing demand for data center facilities that has created a new area of research: data center energy efficiency.

In 2001, as the Dot Com bubble was bursting, a Master Thesis Project conducted by Jennifer D. Mitchell-Jackson while attending the Masters of Science program in the Energy and Resources Group of the University of California, Berkeley provided the first official glimpse into energy usage in data centers for Lawrence Berkeley National Lab.

With about 4000 employees, Lawrence Berkeley National Laboratory (LBNL) is a multi-program national laboratory within the U.S. Department of Energy System. Research ranges from basic scientific theory to applications. A major component of the core mission focuses on national and international energy issues, including the development of technologies and policy analysis to help catalyze positive market transformation. As the only national lab co-located with a university, LBNL's mission also includes helping educate the next generation of scientists and engineers. LBNL has about 500 students and post-docs on staff at any one time.

The data center research project approved at the time by Jonathan Koomey, Staff Scientist with Lawrence Berkeley National Lab uncovers the crystal ball to look closer at data centers and the impact that they will have on energy consumption. The title of the project was called "ENERGY NEEDS IN AN INTERNET ECONOMY: A CLOSER LOOK AT DATA CENTERS."

The project concludes that "the electricity requirements of this industry do not translate into a national crisis. Even high estimates of power densities indicate that demands from these facilities will require less than one percent of U.S. electricity consumption or only 22 TWh per year by 2003. However, power requirements in data centers are much larger per unit of floor area than the requirements of a commercial office building. Therefore, there is room for energy efficiency gains in current facilities as well as in data centers that will be built in the future. Lower power servers and better-designed HVAC systems, in particular, offer options for significant energy savings. Energy efficiency improvements will help to reduce local impacts that may occur in data center hubs."

Seven years later the industry is not faced with a national power crisis, but we are certainly getting closer if nothing is done about it. As the project report concluded, there is room for energy efficiency gains and better designed IT and facilities equipment that will help slay the energy vampire.

Since that project Lawrence Berkeley National Lab has been looking closely at energy consumption in data centers and other high tech facilities.

One of LBNL's first efforts with data center research was prompted by California utilities who were receiving huge requests for power for new data centers.

LBNL began benchmarking data centers and found that on average, centers of all types were loaded at less than 25 watts/sf (for IT loads). As a result, the utilities gradually realized that the power projections were not an immediate concern and this was further alleviated when the dot-com bust occurred.

As a result of the first glimpse into data center power usage in 2001 and the study conducted for California utilities it was noted that enormous opportunities for efficiency improvement were not being pursued to their fullest. California was among the first states to realize that there was a large efficiency opportunity with data centers.

This opportunity lead to LBNL's creation of a 10 year data center roadmap developed for the California Energy Commission. This roadmap defined and identified energy efficiency areas that data center owner and operators could take advantage to conserve energy. Since that time, over 5 years ago, LBNL has been working on selected research activities identified in the roadmap.

To gain more insight on LBNL's research on data center energy efficiency, we interviewed Bill Tschudi and Evan Mills; both are Staff Scientists with Lawrence Berkeley National Lab.

DCJ: Why has data center related research become important?

LBNL: Data centers represent a large and growing percentage of the nation's energy use and it is becoming a worldwide concern as well. In the early stages of the energy efficiency era, most efforts were focused on simpler conventional buildings such as homes and offices. Data centers can be 100-times more energy intensive and the

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opportunities to save energy go far beyond "old tricks" such as improved windows and lighting. The EPA report to Congress authored in large part by LBNL, helped to quantify the energy impact of this sector and suggested that there is much that can be done. Rising concerns about the reliability of the national electric grid have also brought attention to data centers since, due to full-time operation, they are always operating coincident with the local grid's peak demand – thus, any reductions in energy tend to bring valuable demand savings.

DCJ: Can you bullet point the subjects that LBNL has covered via research that directly relates to the data center?

LBNL: The following list covers the broad areas of focus. A full listing of reports can be found here: < http://hightech.lbl.gov/library.html>

- Cross-cutting Processes/energy analysis
- Benchmarking energy use
- Performance metrics development
- Best practices identification
- Power consumption of data centers in CA and US
- Technology Assessment
- Efficiency of power supplies in IT equipment
- Efficiency of UPS systems
- Efficiency of network equipment
- Efficiency of standby generation
- Efficiency of modular cooling systems
- Use of wireless sensors

Design Tools and Protocols

- Development of assessment protocols and assessment tools for DOE's Save Energy Now program
- Development of a self-benchmarking protocol
- Action-oriented benchmarking tool, EnergyIQ
- Power Supply and UPS screening tools
- Demonstration Projects
- DC power
- "Air management" improvement
- Air economizer use
- Performance criteria (similar to LEED® type points)
- Spray cooling
- Demonstration of infrared thermography for visualization
- Indoor Environmental Quality
- Failures due to contamination or loss of humidity control

DCJ: How many researchers, scientists and staff are dedicated to research involving data center issues?

LBNL: The following 13 people have worked on data center efficiency and energy analysis issues:

Scientists and engineers

- Bill Tschudi
- Dale Sartor
- Evan Mills
- Steve Greenberg
- Paul Mathew
- Bruce Nordman
- Rich Brown
- Jon Koomey
- Arman Shehabe
- Rupa Ganglia
- Eric Massanett
- Tim Xu

Staff

- Margaret Johnson

In addition, there are staffs involved with our Demand Response Research Center that are exploring opportunities to reduce demand at critical times.

DCJ: Has anyone on your staff worked in a data center previous to conducting research about them? If so what insights were the able to share? If not, how do you inject practical experience?

LBNL: Yes. Prior to joining LBNL, Bill Tschudi headed design offices in Silicon Valley that designed high tech facilities including data centers. LBNL also operates data centers and a super-computing center, and the energy research team has extensively worked within those facilities to help our institution "practice what it preaches". Dale Sartor, the Lab's energy manager at the time, and Steve Greenberg, a facility mechanical engineer, were intimately involved in the design and operation of the National Energy ResearchScientificComputing(NERSC) supercomputer facility <http://www.nersc.gov/>. Many best practices were incorporated in this facility making it one of the most efficient facilities that LBNL has benchmarked. We are also involved with the design of a new supercomputer facility at LBNL with a goal of making it a showcase of energy efficient design. In many projects, LBNL researchers go into the field and work within operating datacenters, e.g. while conducting benchmarking studies and establishing demonstration projects. We often conduct projects

BILL TSCHUDI, STAFF SCIENTIST, LBNL

jointly with people located in the networking and telecom industries. LBNL also participates actively in professional technical committees and engages leading consulting engineers in this field, which further helps to ensure a two-way flow of information and "reality checks" between the lab and the field. LBNL also conducts basic computational research. <http://crd.lbl.gov/>

DCJ: What is LBNL currently working on in data center related research?

LBNL: Yes several of the activities listed in a previous are on-going and additional demonstration projects are planned. LBNL is working with ASHRAE, Green Grid, Silicon Valley Leadership Group, various energy utilities, and other industry organizations in many areas.

DCJ: What trend, product or technology do you see impacting the data center the most in the next five years?

LBNL: The trend towards increased power demands will, in turn, compound the already critical problem of excess heat and reliability. This will drive increased interest in energy efficiency. Moving to liquid cooling will likely have a large impact on energy efficiency as will more efficient power delivery (e.g. DC power). We also believe that energy benchmarking will continue to play an important role in awareness raising and opportunity identification.

EVAN MILLS, STAFF SCIENTIST, LBNL

DCJ: What direction will data center power and cooling technology go in coming years?

LBNL: We will see more use of liquid cooling solutions and more use of "free" cooling through use of water-side or air-side economizers. Like energy intensive industries of the past, data centers may choose to locate near power and cooling sources (e.g. along rivers). Eventually the market may eliminate the "box" approach and find better ways to assemble processors and other computing elements - perhaps a move back to more of a mainframe approach. One supercomputer manufacturer claims that processors and other equipment could be designed to operate at 80 degrees centigrade.... meaning that equipment could operate anywhere without compressor-based cooling.

DCJ: Your group has done research on DC power in the data center and your conclusions indicate more research is required to determine the true ROI of installing this system. In your opinion is DC Power a practical solution in helping to reduce energy costs in the data center today and in the next five years?

LBNL: DC power today is available in several configurations. Some of them are being used now. As energy prices continue to rise (which seems inevitable), the ROIs will only improve. We continue to work with our industry team to attempt to standardize on voltages, develop standard DC connectors (similar to an AC line cord) and implement DC in pilot settings. We will also examine the Total Cost of Ownership for a DC system such as the one demonstrated last year. Like any new technology, costs may be higher initially but in the long run our team expected that a DC system would have a lower first cost because of fewer components. We are seeing great interest in the use of DC including use in Europe and Japan. Eventually it will be adopted here, although perhaps first overseas (as is often the case with energy efficiency innovations).

DCJ: How do you see advances in chip technology impacting the data center?

LBNL: The chip is the big gorilla in the data center so anything that can be done to lower power consumption at the chip level will have a magnifying effect on energy savings. The chip manufacturers are definitely motivated to improving computational ability while reducing energy use. We are confident that there will continue to be new advances in this area perhaps including use of new materials or manufacturing techniques.

DCJ: Do you believe that data center owners will regulate themselves regarding power usage or do you believe that an intervention of the Federal Government will be required?

LBNL: Both EPA and DOE have active market-based (i.e. non-mandatory) data center initiatives that are focused on working in partnership with industry to encourage efficiency improvements. In this market, characterized by change, and many different applications, the best way that progress can be made would be through industry's rapid adoption of new practices and technologies. The Federal Government can help in this regard through research, training, and general dissemination of helpful information. Thus, the "intervention" seems to thus far be in the voluntary domain rather than through regulation.

DCJ: What advice would you give to a data center owner or manager regarding managing power and cooling in the data center?

LBNL: Critically question all rules of thumb and "conventional wisdom" and seek out best practices. Look at decisions with a life cycle view, and always include commissioning in the new design process and retro-commissioning in the retrofit process. With power costs exceeding the cost of the IT equipment and possibly the building over its life it would be wise to do everything possible to reduce power consumption.

For more information and white papers on the Lawrence Berkeley National Lab and its work with data center energy efficiency research please visit them at: http://hightech.lbl.gov/documents/DATA_CENTERS

> editor's note

As a barometer of the rising interest in this subject, the Design Guide to High Performance Data Centers www.datacenterjournal.com/index.php?option=com_whpaper&id=158 on the Data Center Journal's white paper area has had over 500 downloads between December 2007 and January 2008 from readers all over the world noting a global concern.