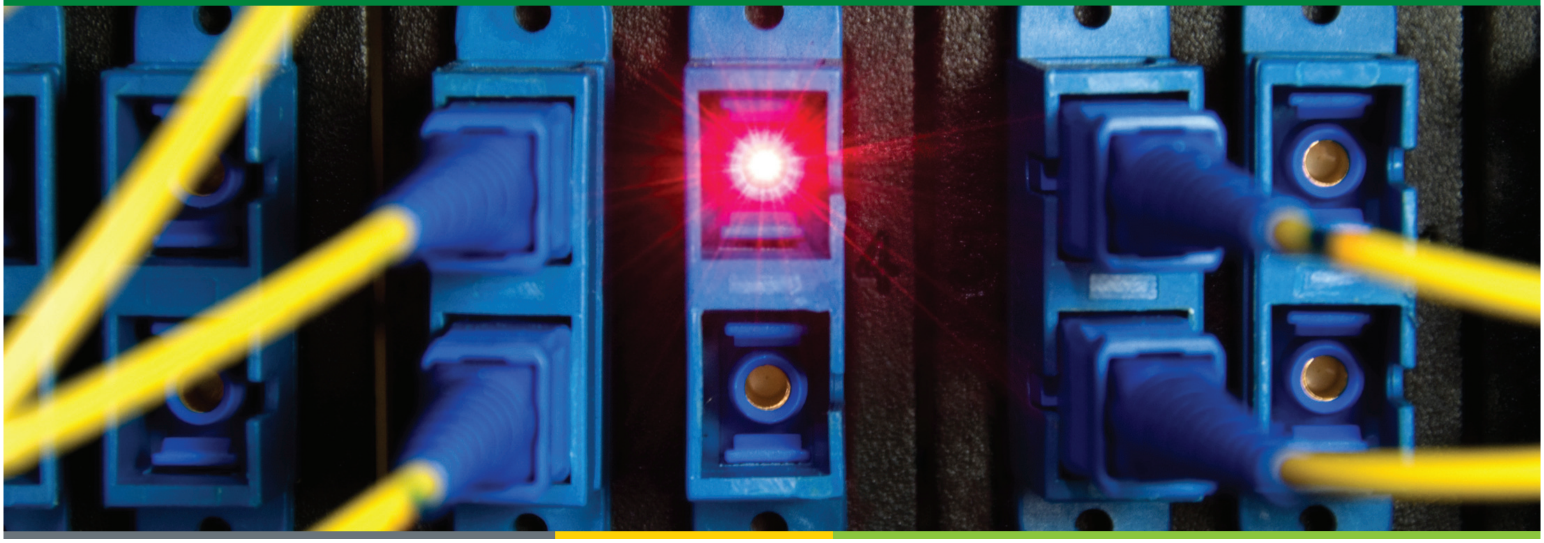
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

INDUSTRIAL TECHNOLOGIES PROGRAM

Information and Communication Technology Portfolio:

Improving Energy Efficiency and Productivity in America's Telecommunication Systems and Data Centers

Contents



INTRODUCTION

Information technology and telecommunications facilities account for approximately 120 billion kilowatt hours of electricity annually—or 3% of all U.S. electricity use. Rapid growth in the U.S. data center industry is projected to require two new large power plants per year just to keep pace with the expected growth in electricity demand from these facilities. Without gains in efficiency, this industry faces increasing costs and greenhouse gas emissions, along with losses in productivity and challenges to electricity service availability and reliability.

The energy used by our nation's vital telecommunications and data centers is growing at an alarming rate. As information and communication technology (ICT) services continue to slowly converge, the data center and telecommunications industries face increasingly similar challenges to manage the power usage of their servers and supporting power and cooling systems. For many companies, the electricity expense from powering ICT systems is greater than that of the actual hardware over the equipment's useful life. In the face of growing global energy demand, volatile energy prices, and constant competition from abroad, innovative homegrown solutions are needed to radically improve the energy efficiency of these systems, which represent the engine driving America's high-tech economy today. Investing in the sector's efficiency today can provide significant energy and cost savings that will yield benefits for many years to come.

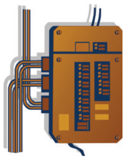
The U.S. Department of Energy's (DOE) Industrial Technologies Program (ITP) is teaming with industrial partners, national laboratories, and members of academia to provide crucial financing to support the development of new technologies that can dramatically improve energy efficiency and productivity in the nation's ICT industry. With emphasis on novel technologies that can be commercialized within the next three to five years and on field experiments for near-commercial-ready emerging technologies, the teams share the costs and risks of cutting-edge ICT research designed to increase energy efficiency, reduce carbon pollution, and revolutionize this vital domestic industry.

Through the American Recovery and Reinvestment Act (also known as the Recovery Act), ITP is investing $47 million to help fund 14 projects across the country that will yield technologies capable of drastically improving the energy efficiency of America's ICT sector. Private industry is providing more than $70 million in matching funds for these projects, resulting in a collective project value of more than $115 million. Each project promises meaningful reductions in energy consumed by ICT systems.

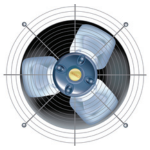
> "By reducing energy use and energy costs for the information technology and telecommunications industries, this funding will help create jobs and ensure the sector remains competitive."
>
> Steven Chu,
> U.S. Secretary of Energy

Projects span three subject areas but may include aspects of more than one area. These subject areas are as follows:

- **Equipment and Software:** Projects focus on the core components of a data or telecommunications center, such as servers and networking devices, and software, to optimize equipment energy use.



- **Power Supply Chain:** Projects develop technologies to minimize the power loss and heat generation that occurs as electricity moves through the ever-growing number of server-based information technology and communications systems.



- **Cooling:** Efforts seek to develop ways of cooling the equipment used in ICT systems more effectively and efficiently, using less power than current methods.

With Recovery Act funding, ITP supports early-stage, laboratory-scale concept definition studies, research and development, and field experiment projects that explore new technologies with the potential to dramatically improve energy efficiency in the ICT sector.

The topic areas and 14 projects are explored in greater detail in the pages that follow.

List of Projects in the Information and Communication Technology Portfolio

	Concept Definition Studies	Research and Development Projects	Field Experiment Projects
Equipment and Software	Energy Efficiency of Data Networks through Rate Adaptation (Alcatel-Lucent Bell Laboratories)	SeaMicro Volume Server Power Reduction (SeaMicro Incorporated)	A Measurement–Management Technology for Improving Energy Efficiency in Data Centers and Telecommunication Facilities (IBM Thomas J. Watson Research Center)
	Power Minimization Techniques for Networked Data Centers (California Institute of Technology)		
Power Supply Chain	Dynamic Energy Consumption Management of Routing Telecom and Data Centers through Real-Time Optimal Control (BAE Systems)	Integrated DC-DC Conversion for Energy-Efficient Multicore Microprocessors (Columbia University)	Data Center Transformation from "Always On" to "Always Available" (Power Assure, Inc.)
		Adaptive Environmentally Contained Power and Cooling IT Infrastructure for the Data Center (Hewlett-Packard Company)	
		High-Efficiency, Wideband Three-Phase Rectifiers and Adaptive Rectifier Management for Telecom Central Office and Large Data Center Applications (Lineage Power)	
Cooling		Advanced Refrigerant-based Cooling Technologies for Information and Communications Infrastructure (Alcatel-Lucent Bell Laboratories)	Yahoo! Compute Coop Next Generation Passive Cooling Design for Data Centers (Yahoo! Inc.)
		Economizer-Based Data Center Liquid Cooling with Advanced Metal Interfaces (IBM Thomas J. Watson Research Center)	Federspiel Controls' Data Center Energy Efficient Cooling Control System (Federspiel Controls Inc.)
		Development of a Very Dense Liquid Cooled Compute Platform (Edison Materials Technology Center)	

CONCEPT DEFINITION STUDIES

Concept definition studies use early-stage research, laboratory-scale experiments, data generation and analysis, and other exploratory methods to define and advance technical concepts or answer a specific technical question. The evaluations focus on specific ICT technologies that offer the potential for major energy, carbon, and economic benefits. Results of the research must translate end-user needs into preliminary technical specifications and clearly define the technology's market while illustrating a path forward to introduce the new technology into the marketplace. Studies include the application of algorithms to enable more efficient energy management, load-balancing technologies, and others.

Energy Efficiency of Data Networks through Rate Adaptation

Most telecommunications infrastructure is not designed to manage power requirements according to real-time network traffic needs. Improved scientific understanding of rate adaptation in packet-switched network equipment such as routers and Ethernet switches can mitigate this problem by making energy consumption proportional to actual data traffic. This project focuses on algorithms and protocols that can be implemented in software or firmware to exploit current and expected hardware capabilities that control energy use. Such algorithms could be applied to a broad spectrum of network equipment, resulting in decreased power requirements and corresponding reductions in incremental computing costs.

Project Partners

Alcatel-Lucent Bell Laboratories
Murray Hill, NJ

Dynamic Energy Consumption Management of Routing Telecom and Data Centers through Real-Time Optimal Control

The real-time optimal control (RTOC) algorithm model minimizes overall facility power consumption by efficiently apportioning service requests to available data or telecommunication center hardware. The algorithm will balance server response requirements and server utilization so that data center power consumption will be minimized. Utilizing existing industry-standard protocols, the model and algorithm minimize energy consumption based on network traffic and energy-management information from network and computing devices, such as mainframes and servers. The algorithm can detect server-related activity at the network switch level and adjust server power states and infrastructure and cooling systems, appropriately. Reducing wasted energy during low utilization periods through the implementation of the RTOC algorithm could decrease data center power consumption by an estimated 50%.

Project Partners

BAE Systems
Manassas, VA

Dr. I.M. Ross and Associates
Monterey, CA

Cisco Systems
Research Triangle Park, NC; and San Jose, CA

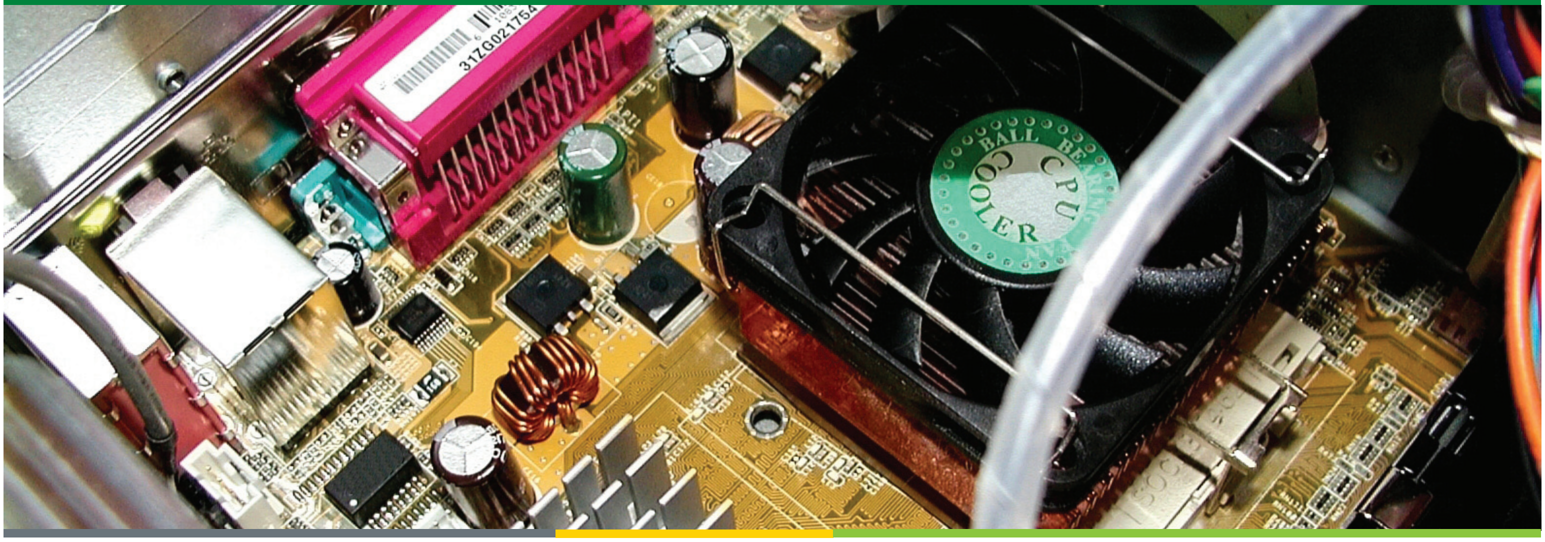
Power Minimization Techniques for Networked Data Centers

Algorithms to optimize energy consumption under any given load pattern are being developed for volume servers, the most commonly used server types in data centers. Researchers are focusing on three synergistic technologies that: (a) optimize the scheduling and speed scaling at individual servers, (b) minimize delay in the delivery of computation results, and (c) achieve load balance across multiple servers in one or more data centers, based on electricity costs and user locations. More effective load balancing enhances individual server performance and optimizes computation and results delivery.

Project Partners

California Institute of Technology
Pasadena, CA

Cornell University
Ithaca, NY



RESEARCH AND DEVELOPMENT PROJECTS

Research and development projects can range from testing prototype technologies or processes and modeling or simulating performance to conducting scale-up engineering studies. Each project at this stage includes partners capable of manufacturing the proposed technology, delivering the technology to the market, and serving as an end user of the proposed technology. Projects include, among others, efforts to design liquid-cooling platforms, develop power voltage converters, and create more efficient rectifiers.

Development of a Very Dense Liquid Cooled Compute Platform

A prototype of a 100% liquid-cooling, ultra-high-density computing platform using off-the-shelf commodity components and high-volume manufacturing techniques is being developed to cool information technology systems more efficiently than traditional forced air flow techniques. A two-CPU compute module and a rack-mounted shelf with built-in cooling, rack plumbing, and pumped refrigerant platform connected to a cold water system is coupled with a standard data center cooling system to create a more efficient cooling infrastructure. The liquid-cooling system is expected to achieve energy savings of at least 15% compared to conventional air-cooled data centers and an estimated Power Usage Effectiveness[1] (PUE) of 1.19 versus today's typical PUE of 1.7 or higher.

Project Partners

Edison Materials Technology Center
Dayton, OH

Clustered Systems Company, Inc.
Menlo Park, CA

Emerson – Cooligy
Mountain View, CA

SLAC National Accelerator Laboratory
Menlo Park, CA

Intel Corporation
Santa Clara, CA

California Energy Commission
Sacramento, CA

Advanced Refrigerant-based Cooling Technologies for Information and Communications Infrastructure

Advanced Refrigerant-based Cooling Technologies for Information and Communication infrastructure (ARCTIC) is a refrigerant-based, liquid-cooling technology that dramatically enhances the management of server heat, and requires less energy than traditional computer room air conditioning (CRAC) units. A heat exchanger is mounted directly on the back of the equipment rack and cold air rushes through the shelf to carry away waste heat while a fluid-handling system pumps refrigerant through the heat exchangers to provide cooling. Researchers anticipate that ARCTIC can be up to 90% more efficient than conventional CRAC units, and can even lower space requirements by enabling greater equipment densities.

Project Partners

Alcatel-Lucent Bell Laboratories
Murray Hill, NJ

Modine Manufacturing Company
Racine, WI

US Hose Corporation
Romeoville, IL

[1] Power Usage Effectiveness is equal to total facility power used divided by IT equipment power used.

Integrated DC-DC Conversion for Energy-Efficient Multicore Microprocessors

Applying novel materials and designs to on-chip, direct-current-to-direct-current (DC-DC) voltage converters allows for greater control of power distribution and reduces the demand for power supplied to the processor chips. The use of passive magnetic devices improves the design of on-chip power management and energy delivery by allowing high-density, on-chip storage. On-chip inductor structures use magnetic materials to achieve significantly improved power densities and energy efficiency.

Project Partners

Columbia University
New York, NY

Cornell University
Ithaca, NY

IBM Thomas J. Watson Research Center
Yorktown Heights, NY

Adaptive Environmentally Contained Power and Cooling IT Infrastructure for the Data Center

A complete end-to-end power and cooling solution that can be utilized for large- and medium-size data centers as well as telecommunication facilities is being developed. This includes power designs that increase power efficiency by utilizing alternating and direct currents, minimize cooling by providing optimal air flow to cool information technology (IT) equipment, and provide a high level of heat removal via a closed loop cooling system. By building a fully enclosed IT rack system that provides for optimal power and cooling—using high-voltage alternating current and chilled water as primary inputs to the system—researchers seek to achieve a near-40% reduction over more conventional data center solutions in the amount of energy needed to support a 100-kilowatt IT load.

Project Partners

Hewlett-Packard Company
Houston, TX

Eaton Corporation
Cleveland, OH

Economizer-Based Data Center Liquid Cooling with Advanced Metal Interfaces

Two complementary technologies using ambient-cooled liquid are being developed to advance cooling technology and provide a cost-effective solution for commercial data center systems. A Liquid Metal Thermal Interface improves the thermal conduction paths from high power server components to the data center's ambient cooling system, and a Dual Enclosure Liquid Cooling system uses direct cooling from the outside ambient environment. These two technologies can eliminate the use of the energy intensive data center refrigeration chiller plant and several other cooling components, potentially reducing energy used to cool equipment to as little as 5% of total data center energy. Ultimately, these technologies enable computer devices to operate with significantly lower cooling energy using the ambient environment.

Project Partners

IBM Thomas J. Watson Research Center
Yorktown Heights, NY

High-Efficiency, Wideband Three-Phase Rectifiers and Adaptive Rectifier Management for Telecom Central Office and Large Data Center Applications

This project has two distinct parts. One is the development and testing of a new, more efficient power rectifier capable of operating at high efficiency during any electric use range. The advanced rectifier under development is expected to reduce the need for power and cooling while increasing the efficiency of power conversion. The other part is the development of software to keep conventional, existing rectifiers operating at their highest possible efficiency. To do this, the software places certain rectifiers into a standby mode so that the remaining rectifiers can operate at peak efficiency. Rectifiers, which are responsible for converting AC electricity (supplied by electric utilities) to DC electricity (required to operate equipment used in data and telecommunications centers), contribute to the 25% of energy consumed in data and telecommunications centers for power management.

Project Partners

Lineage Power
Plano, TX

Verizon
New York, NY

SeaMicro Volume Server Power Reduction

This technology advances volume server architecture to produce a server that eliminates 90% of conventional server components. The new server, based on a systems architecture pioneered by Lawrence Berkeley National Laboratory, replaces sophisticated, power hungry chips found in conventional servers with hundreds of ultra-low-energy chips along with input/output (I/O) "virtualization" technology that removes all non-CPU/memory components without hindering performance. This technology shrinks the motherboard from the size of a pizza box to the size of a credit card and uses one-quarter of the power and space of today's best-in-class volume server. Work is then distributed over an array of hundreds of these low-power chips via hardware- and software-based load-balancing technology.

Project Partners

SeaMicro Incorporated
Santa Clara, CA

FIELD EXPERIMENT PROJECTS

Field Experiment projects provide “commercial facility” operating data and enable initial validation of the technology through field evaluation. At this stage, evaluations of the technology’s energy performance ensure that the emerging technology improves energy efficiency without compromising data center or telecommunication reliability. Experimental host sites must be early adopters of the technologies and the technologies should result in a reduction of the data or telecommunication center’s energy intensity by at least 25 percent.

Federspiel Controls’ Data Center Energy Efficient Cooling Control System

The goal of this project is to prove that the intelligent supervisory control and wireless mesh network sensing system evaluated at the California Franchise Tax Board can scale to a wide range of localized, mid-tier, and enterprise data centers. The system integrates variable frequency drive (VFD) blowers, perforated tiles, and a network of wireless mesh sensors and controllers that provide feedback into an artificial intelligence engine that automatically and constantly determines which cooling units to operate. This intelligent cooling system, if scalable, can reduce cooling energy use by 60% and improve Power Usage Effectiveness (PUE) to 1.25, a significant improvement over the 1.7 or higher PUE rating for most data centers.

Project Partners

Federspiel Controls Inc.
El Cerrito, CA

California Department of General Services
Sacramento, CA

Polargy Inc.
Sunnyvale, CA

Air Treatment Corporation
Alameda, CA

Metropolitan Construction, Inc.
San Francisco, CA

A Measurement–Management Technology for Improving Energy Efficiency in Data Centers and Telecommunication Facilities

Measurement-Management Technology (MMT) 2.0, a precommercial product that offers on-demand, comprehensive facility assessment data in real-time, is being evaluated for its ability to support the management of component power. The MMT software provides real-time data on temperature, humidity, power distribution, and corrosion rates. In addition, the software can control a facility’s energy efficiency by optimizing outside air cooling, reducing fan speeds within the air-conditioning units (ACUs), and increasing ACU utilization. Project participants estimate that use of MMT 2.0 can potentially improve a data center’s Power Usage Effectiveness from 1.7 to 1.35 and facilitate productivity gains.

Project Partners

IBM Thomas J. Watson Research Center
Yorktown Heights, NY

IBM Corporation
Research Triangle Park, NC and Rochester, MN

AT&T
Dallas, TX

Georgia Institute of Technology
Atlanta, GA

Vette Corporation
Portsmouth, NH

Data Center Transformation from "Always On" to "Always Available"

This project seeks to validate management software and supporting hardware which is integrated into various data center components to manage the power-state of large quantities of servers. The software continually analyzes the demand for information and calculates how many servers are needed to support the demand level at any given time along with a safety buffer to protect the application from unexpected surges in demand. By automatically capping, throttling and dynamically turning on and off servers as processing demand increases or decreases, this technology helps avoid the up to 70% power waste that data centers incur. In addition, the system is designed to scale to support from fewer than a thousand servers up to tens of thousands of servers.

Project Partners

Power Assure, Inc.
Santa Clara, CA

Palo Alto Research Center Incorporated (PARC)
Palo Alto, CA

Yahoo! Compute Coop Next Generation Passive Cooling Design for Data Centers

Researchers are engineering and evaluating a new energy-saving data center focused on using outside air to provide data center equipment cooling. Based on the patent-pending "Yahoo! Compute Coop" (YCC) technology, the center design imitates a chicken coop in which hot air rises through a cupola in the roof and cool air is drawn in through the side of the building, which is strategically placed to take advantage of prevailing winds. The integrated building design—including the building's shape and orientation, as well as the alignment of servers within the building—enables the data center to rely exclusively on outside ambient air for cooling 99% of the year. By ensuring that the majority of power used by the facility is allocated to useful computing work rather than cooling infrastructure, the YCC design virtually eliminates cooling energy use.

Project Partners

Yahoo! Inc.
Sunnyvale, CA; and Lockport, NY

The Industrial Technologies Program (ITP) is the lead government program working to increase the energy efficiency of U.S. industry—which accounts for about one-third of U.S. energy use. In partnership with industry, ITP helps research, develop, and deploy innovative technologies that companies can use to improve their energy productivity, reduce carbon emissions, and gain a competitive edge.

DOE/EE-0390

March 2011

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