ENERGY STAR

UNDERSTANDING AND DESIGNING ENERGY-EFFICIENCY PROGRAMS FOR DATA CENTERS

The U.S. Environmental Protection Agency (EPA) is providing this guide to help inform energy efficiency program administrators about opportunities to save energy in data centers, and to share emerging practices for program design and implementation based on the experiences of recent data center programs.

WHY DATA CENTERS?

Data centers consume up to 50 times the electricity of standard office space.[1] In 2010, between 1.7% and 2.2% of the total electricity use in the United States was consumed by data centers. United States data center electricity use nearly doubled between 2000 and 2005, and increased by approximately 36% between 2005 and 2010. Despite some recent efficiency gains, data centers remain a significant and growing energy end use.[2] Industry analysts expect data center energy consumption to continue to grow at a rate of more than 9% per year through 2020 (from a base of 200 trillion end-use BTUs in 2008 to 600 trillion end-use BTUs in 2020).[3]

Utilities and other energy-efficiency program administrators can play a significant role in helping customers reduce data center operating costs, while also reducing energy demand.

DELIVERING SOLUTIONS FOR DATA CENTERS

Information technology (IT) is intrinsic to our economy, society, and culture. For most enterprises, IT provides crucial support for financial operations, data storage and analysis, and all levels of management.

Data centers consume a significant amount of energy per square foot, even when the physical space they occupy is small. In addition to operating at very high energy intensities, data centers operate 24 hours per day, 365 days per year. This high load factor presents an important target for energy-efficiency programs.

The U.S. Department of Energy (DOE) estimates that for every 1 watt of energy used to directly operate a computer, as much as two additional watts are used by the data center to support that computer. However, the DOE has found that energy-efficient data centers are capable of reducing that consumption by up to 80%.[4]

While data center energy-efficiency programs are relatively new, early pioneers are realizing significant savings. *Duke Energy* and several utilities in *Wisconsin* manage data center programs that achieved an average energy savings of 396 MWh per project during their 2009 to 2012 program cycles. During that time, they processed, paid, and claimed energy savings for 174 applications, ranging in savings from under 250 MWh to greater than 3,000 MWh.[5]

This guide will:

- Characterize the data center market;
- Highlight energy-efficiency program opportunities in data centers;
- Provide an overview of data center programs throughout the country;
- Discuss the market structure and resulting challenges, and suggest solutions to overcome those challenges;
- Summarize appropriate program models and measures;
- Explain program planning strategies and evaluation, measurement, and verification (EM&V) best practices that can mitigate program implementation barriers; and
- Suggest implementation strategies for data center programs.

[1] Based on data center energy use information submitted to the ENERGY STAR Buildings program in EPA's measurement and tracking tool, ENERGY STAR Portfolio Manager.

[2] Source: Koomey, Jonathan G., Ph.D., Stanford University, Analytics Press, and The New York Times. Growth in Data Center Electricity Use 2005 to 2010. August 1, 2011.

[3] Source: Choi Granade, Hannah, J. Creyts, A. Derkach, P. Farese, S. Nyquist, and K. Ostrowski. McKinsey Global Energy and Materials. Unlocking Energy Efficiency in the U.S. Economy. July 2009. Pp. 68.

[4] Source: U.S. Department of Energy. Energy 101: Energy Efficient Data Centers. May 31, 2011. Available online: http://www.youtube.com/watch?v=xGSdf2uLtlo.

[5] In 2009-2012, the Wisconsin Energy Conservation Corporation (WECC) implemented data center efficiency programs for Duke Energy, which services North Carolina, South Carolina, Ohio, and several utilities in Wisconsin. Source: WECC, personal communications. April 2012.

UNDERSTANDING DATA CENTER CUSTOMERS

In most traditional data centers, IT equipment, which includes servers, data storage equipment, and communications gear, is housed in racks that are often placed on a raised floor system. Computer room air conditioners (CRACs) deliver cool air through the under-floor plenum via grate tiles in the floor.

Data centers differ from other IT infrastructure in that they commonly have dedicated cooling systems and power delivery and conditioning systems that require a high degree of reliability. Power delivery equipment can include:

- Uninterruptible power supplies (UPSs) that provide backup power using batteries or flywheels;
- Power delivery units and distribution transformers; and
- Backup generators.

Virtually all commercial and industrial (C&I) customers have some level of IT infrastructure, and larger C&I customers typically operate data centers. Table 1 provides information about different data center types.

Table 1. Data Center Classifications

Data Center Type	Description	Square Footage	Facilities (2009 U.S. estimation)	Total Servers (2009 U.S. estimation)	Average Servers per Location
Utility Scale	Generally measured by the size of the facility's total load (in MW), or the amount of power available to the IT equipment. Usually larger than 10 MW, and commonly built with 40 MW load. This category includes most retail and wholesale co-location data centers.*	>100,000	7,006	3,604,678	515
Enterprise	Typically operated by large corporations and institutions. Generally occupy spaces in the low tens of thousands of square feet (10,000 square feet can support approximately 1 MW of IT equipment load, with almost another 1 MW needed for cooling and power delivery systems).	>5,000			
Localized	These facilities may serve only the local, specific needs of a call center or office operation (for example), with general, large-scale IT services provided by a data center in another location.	500-5,000	73,987	3,977,187	54
Server Room**	These data centers often do not have dedicated cooling or power delivery systems or climate conditioning equipment.	200-499	1,170,399	3,057,834	3
Server Closet**	Smallest-scale data center.	<200	1,345,741	2,135,538	2

Source: Bailey, Michelle et al. IDC Special Study. *Data Center of the Future*. Filing Information: April 2006, IDC #06C4799.

* Retail and co-location data centers provide rental space to multiple tenants and are only responsible for managing their tenants' IT equipment. Wholesale co-location providers develop new data centers, which then lease these facilities on a long-term basis to single tenants who take over the responsibility of operating and maintaining the entire facility, including the cooling and power delivery systems. *Seattle City Light* is starting to see more interest from co-location providers.[6]

** Server rooms and server closets are not considered data centers in the ENERGY STAR Buildings Program.

Different data center types require different efficiency program approaches:

- Operators of *utility-scale data centers* are typically very sophisticated and may implement many energy-efficiency measures on their own—particularly when building new facilities or upgrading IT equipment. Consequently, freeridership concerns are important to recognize and manage, and incentives may need to be limited to highly innovative measures or those measures with higher payback periods. For example, customers that operate utility-scale data centers, such as the technology, communications, financial services, and government sectors, most likely do not need incentives rewarding them for server virtualization upgrades.
- *Enterprise data centers* represent an excellent opportunity for energy-efficiency retrofits, and energy-efficiency programs have had an impact on this market. At this time, there are few freeridership concerns. As a result, this segment is an important target market for efficiency program managers. Enterprise data centers are used by both commercial and noncommercial entities across widely diverse business sectors.
- *Localized data centers, server rooms, and server closets* pose difficulties for utility programs because the market is disaggregated and the savings per project are small. However, they are considered an untapped market. The Natural Resources Defense Council believes that program implementers can increase energy efficiency opportunities for small server rooms and closets with education and evaluation tools, and extend education programs with on-site efficiency evaluations. These tools and services could, subsequently, support a select package of incentive programs to encourage energy efficiency upgrades in this market. Program strategies that minimize administrative costs need to be considered.[7]

[6] Some market actors believe that this response from co-location providers was caused by pressure from their customers to become more efficient in order to avoid spending a lot of money and resources to power and cool their data center.

[7] Source: Bramfitt, Mark and P. Delforge. Natural Resources Defense Council. Utility Energy Efficiency Program Design: Server Room Assessments and Retrofits. April 2012. Available online: http://docs.nrdc.org/energy/files/ene_12041101a.pdf.

OPPORTUNITIES FOR IMPROVING DATA CENTER EFFICIENCY

Data center IT managers have varied motivations when considering facility improvements. These include reducing the ownership cost of IT operations, which have become so high that they threaten to take capital from other investments and projects;[8] and addressing existing or upcoming capacity shortfalls, such as a lack of cooling capacity for additional equipment or a lack of power delivery and conditioning capacity.

IT managers know that adding more power or cooling capacity to an existing building is challenging, time-consuming, and costly. As a result, energy-efficiency measures that help reclaim capacity and IT measures that improve utilization rates and decrease power load can be very attractive. Fortunately, data centers have abundant opportunities for improving efficiency, depending on existing conditions. Potential improvements include the following:

- Cooling system efficiency can be improved with premium-efficiency equipment, such as chillers, pumps, fans, cooling towers, and ultrasonic humidifiers, as well as through the use of variable frequency drives, installation of air- or water-side economizers, and improved air flow management.
- Power delivery and conditioning capacity can be improved with the use of ENERGY STAR-certified UPSs and premium-efficiency distribution transformers and direct current power systems.
- IT equipment efficiency can be improved by upgrading to an ENERGY STAR-qualified or other premium efficiency product, virtualizing and consolidating servers and data storage equipment,[9] and by employing other data storage measures.

Table 2 summarizes measures that utility-funded energy-efficiency programs commonly target. Not all efficiency measures and technologies are applicable to every data center type and, as is discussed in subsequent sections, program design and delivery strategies vary by market and data center type.

Table 2. Measures Commonly Targeted by Energy-Efficiency Programs[1]

Utility Programs	Virtualization	ENERGY STAR Server	Massive Array of Idle Disks	Uninterruptible Power Supply[2]	Chillers/ Cooling Towers	Thermal Energy Storage	Storage Consolidation	Airflow	Variable Frequency Drive	Air-Side Economizer	Water-Side Economizer	Pumps/Motors	HVAC/ CRAC	DC Power
Arizona Public Service Company (APS)	C	C		C	C/P			C	P	P	C	P	P	
Austin Energy	C		C	C	C	C			P			P	C/P	
AVISTA Utilities					C				P			P	C/P	
British Colombia Hydro (BC Hydro)	C	C		C	C		C	C	C	C	C	C	C	C
Commonwealth Edison	C			C	C		C	C	C	C	C	P	C	
Duke Energy (NC, SC, OH)	C			C	C/P	C	C	C	C/P	C	C	P	P	C
Efficiency Vermont	C	C		C					P	C	C	P	P	
Energy Trust of Oregon	P			C	C			C		C	C		C/P	
Focus on Energy (WI)	C/P	C		C	P	C	C	C	P	C	C		P	C
Idaho Power									P			P	P	
Nevada Power									P				P	
New York State Energy Research and Development Authority (NYSERDA)	C			C	C		C	C	C/P	C	C	C/P	C/P	C
Pacific Gas & Electric Company (PG&E)	C	C		C	C		C	C	P	C	C	P	P	C
Puget Sound Energy (PSE)	C			C					C			C	C	
Sacrament Municipal Utility District (SMUD)	C				C/P			C	C/P	C	C	P	C/P	
Salt River Project					P				P				P	
San Diego Gas & Electric (SDG&E)	C								P		P	P		
Seattle City Light	P	C/P	C	C	C		C	C	P	C	C	C	C	C
Silicon Valley Power	C				C			C	P	C	C	P	P	
Snohomish County Public Utility District					C				C			C	C	
Southern California Edison (SCE)	C			C	C	C	C	C	C	C	C	C	C	

Source: Utility websites and personal communications with utility energy efficiency program managers and industry groups, April 2012.

Note:

[1]"C" indicates a customized measure, and "P" indicates a prescriptive measure. Some programs also incentivize the removal of existing servers through a customized approach. (Data current as of April 2012).

[2] Uninterruptible Power Supplies (UPS) became eligible for ENERGY STAR certification as of August 1, 2012.

[8] Source: Kaplan, James M., W. Forrest, and N. Kindler. McKinsey & Company. Revolutionizing Data Center Energy Efficiency. July 2008.

[9] A virtual server is software implementation of a server that executes programs like a real server. Virtualization is a method for operating multiple independent servers on a single physical server. Instead of operating many servers at low utilization, virtualization combines the processing power onto fewer servers that operate with higher energy utilization.

UNDERSTANDING AND ADDRESSING KEY MARKET BARRIERS

Effective program design requires understanding market barriers that prevent greater investment in energy efficiency and developing strategies to overcome those barriers. Common barriers in the data center market include:

- ***Lack of knowledge and risk aversion:*** IT managers demand very high reliability for power and cooling systems. As a result, they may be wary of projects that could affect that reliability, and/or they may have misperceptions about the tradeoff between energy efficiency and performance.
- ***Disincentive for trade allies:*** Trade allies sometimes have a disincentive to encourage efficient measures. For example, server virtualization and consolidation may reduce future sales of servers.
- ***Higher first cost and split incentives:*** In many cases, efficient equipment and related services cost more to purchase. This barrier is often compounded when the IT manager purchasing the equipment is not responsible for paying data center operating costs (i.e., the electricity bill is paid by another party).

In addition to these market barriers, program administrators face challenges in ensuring that their investment in data center efficiency generates energy savings beyond what would occur naturally in this marketplace. The following sections provide further detail about the key barriers listed above and strategies for addressing them.

Educating the Marketplace

A smoothly running data center is essential to business operations, and many IT managers are averse to taking risks and cautious about implementing changes. A recent study found that data center downtime (when a system is unavailable) costs companies over $5,000 per minute.[10] Risk aversion can manifest in several ways, including:

- Building in more power redundancy than necessary (which drives the utilization of power delivery and conditioning equipment well below 50%);
- Overcooling the data center (e.g., setting the temperature too low, setting the air volume too high); and
- Resisting technological solutions that can improve utilization (e.g., virtualization, thin provisioning, data storage measures).

For all of these examples, energy-efficiency measures can be employed without reducing reliability, and in some cases, can improve reliability or help recapture capacity. For example:

- Removing non-critical equipment from power conditioning systems minimizes potential points of failure and reduces the energy overhead of these systems.
- Overcooling is a burden on cooling equipment and could lead to premature failure.
- Some new software solutions, such as virtualization, feature the ability to move IT workloads to other servers, providing more operational flexibility to balance equipment load and respond to system failures.

Implementing a comprehensive data center training program can increase the information that IT managers have at their disposal and help address hesitation to making energy-efficiency improvements caused by risk aversion. These trainings typically focus on the many energy-efficiency measures and technologies available for these facilities, are often organized by end use (e.g., cooling, power delivery and conditioning, IT measures), and are popular with both vendors and customers.

Internal Training

Educating the following internal parties gives them the tools to properly identify energy-saving opportunities for data center managers:

- *Account representatives and call center specialists* manage all aspects of the commercial customer relationships, and represent a critical channel for marketing energy-efficiency programs.
- *Project managers and engineers* support account representatives and should have a comprehensive technical understanding of efficiency measures, rebate processing, and administration.

In 2010, *Consolidated Edison* of New York held a two-hour training program for account managers, during which they provided an overview of leading energy-efficiency measures for data centers and desktop IT equipment.

External Training

Utilities in California, the Pacific Northwest, Ohio, North Carolina, South Carolina, and Wisconsin have demonstrated that education programs focused on data center and IT equipment energy efficiency are popular with customers and vendors.

- *SMUD* has held an annual Business Computing showcase for the past five years, featuring a seven-hour training course and a show area for up to 30 vendors.
- *Pacific Gas and Electric Company (PG&E)* has been holding two data center training courses each year since 2005, and notes there has been increasing attendance by IT professionals, along with the usual participation by facility managers and members of the design and engineering community. *PG&E* later began offering one general program course and a targeted training course (i.e., data center design, evaluation tools, and retrofit opportunities) annually.
- *Duke Energy* and *utilities in Wisconsin* have held five all-day Data Center Efficiency Summits since 2010. Over 350 customer representatives have attended.

[10] Source: Emerson Network Power. Understanding the Cost of Data Center Downtime: An Analysis of the Financial Impact on Infrastructure Vulnerability. 2011. Available online: http://emersonnetworkpower.com/en-US/Brands/Liebert/Documents/White%20Papers/data-center-uptime_24661-R05-11.pdf

Successful trainings include:

- An industry overview of market trends and challenges;
- Descriptions of available efficiency programs and services. For example, an airflow management strategy class would describe eight to ten measures that improve airflow, and would cite customer case studies and describe a utility retro-commissioning program; and
- A call to action message asking participants to consider implementing measures and participating in efficiency programs.[11]

In addition, most data center operators have little context of how their facility's energy use compares to their peers' data center energy use. EPA's measurement and tracking tool, ENERGY STAR Portfolio Manager, can help data center operators assess their facility's energy performance by providing an easy to understand score between 1 and 100. Understanding energy performance can capture the attention of not only the operator, but also other business executives that make investment decisions. Data centers that perform in the top quartile are eligible to apply for ENERGY STAR certification.[12] Also, the ENERGY STAR Low Carbon IT Champion campaign recognizes organizations that reduce the energy costs of their data centers. Education about assessing energy use and recognizing energy-saving opportunities can help motivate data center operators.

PG&E, Sacramento Municipal Utility District (SMUD), Seattle City Light, and *Southern California Edison (SCE)* have promoted the use of ENERGY STAR Portfolio Manager and participation in the Low Carbon IT Champion campaign through customer education programs.

Engaging Trade Allies

Within the data center industry, there are numerous trade allies that could influence their customers' decisions about more efficient options, thereby helping program managers deliver efficient data center programs. The first three groups of trade allies listed below focus on IT engagements (including equipment and software solutions); the second three are important partners for facility improvements:

1. **Value-Added Resellers (VARs):** Sell IT equipment and services, often providing integrated solutions to customers (including project planning, equipment specification, and software integration). VARs are crucial in the sale of premium-efficiency equipment and for solutions such as server virtualization and consolidation.
2. **System Integrators:** Offer the same services as VARs, but can also offer customized equipment and, in some cases, their own branded IT equipment.
3. **IT Equipment Manufacturers:** The largest firms offer premium-efficiency equipment (including ENERGY STAR-rated equipment) and often sell directly to customers.
4. **Design and Engineering Firms:** Design new data centers and/or make significant modifications to existing facilities.
5. **Electrical and Cooling System Contractors and Maintenance Firms:** Can recommend retrofits and/or upgrades to existing systems.
6. **Data Center Cooling Equipment Manufacturers:** Market leaders provide technical support for both new installations and retrofits.

Trade allies often have an established relationship with their customers and are relied upon for technical advice. Unfortunately, not all IT vendors promote efficiency with their customers due to a lack of knowledge or, in some cases, a disincentive to promote efficient options that would reduce sales. This disincentive can be mitigated to some extent by the following strategies:

- Structuring incentives to reward vendor participation. For example, upstream incentives to manufacturers or vendors can align their interests directly with energy-efficiency programs. This concept is covered in more detail in the Designing Program Incentives section.
- Using incentives that are geared towards certain efficiency behavior. Some utility programs incent the removal of inefficient servers rather than the purchase of new servers to encourage server virtualization and consolidation.
- Offering energy-efficiency assessments to customers using internal staff or contracted consultants. Utilities that choose this program approach (e.g., *PG&E* and *SCE*) typically offer free assessments if customers commit to implementing recommended measures that meet a specified financial return criteria. Assessments performed by consultants have the advantage of providing independent analyses that customers can then use to seek bids from multiple vendors, thus engaging the trade ally community.
- Offering subsidies for energy assessments provided by trade allies. Utilities that choose this approach typically offer to pay half of the costs for energy assessments that meet established criteria. Vendors often use the assessment process as a sales tool.

> "Trade allies are essential to the success of energy efficiency programs due to their customer relationships and their marketing and sales efforts. It is crucial for the trade ally community to incorporate efficiency and program resources into their messaging. Investing time and resources to help trade allies succeed with energy efficiency marketing and selling will improve the cost effectiveness …"
>
> – Geoff Overland, WECC

Engaging trade allies in data center efficiency programs is important to successful program implementation. A variety of strategies can be used to identify potential trade allies, such as:

- Working with utility customers to generate leads by asking for contractor and supplier referrals, thereby fostering utility-customer relationships.

[11] A call to action message might focus on key drivers to implementing energy-efficiency measures, such as realizing cost savings, maximizing the use of existing capacity (and avoiding future capital outlay for new capacity), and maintaining IT competitiveness.

[12] As of April 2012, 22 data centers had qualified for ENERGY STAR certification.

- Pursuing productive outreach opportunities including regional data center conferences, such as Data Center Dynamics.

Once trade allies are identified, the following outreach and educational activities can lead to their active support of utility energy-efficiency programs and services:

- Inviting vendors to customer education and training sessions.
- Creating efficiency program marketing materials that can be co-branded with the trade allies' information.
- Encouraging vendors to invite efficiency program managers to deliver presentations at their customer outreach events.

Overcoming Split Incentives

Financial barriers related to the cost of efficient products and services are often exacerbated by split incentives created when the decision maker responsible for authorizing an energy-efficiency project does not receive direct benefits from the project. In data centers, the most common split incentive is between the IT manager and the facility manager. The split incentive can occur because, in some instances:

- The IT manager, responsible for selecting and deploying IT equipment in a data center, typically makes financial decisions based on available capital budget, and is not responsible for power use or its associated costs.
- The facility manager, responsible for the power delivery, cooling systems, and related utility bills, primarily manages the operating budget and often cannot influence how the capital budget is spent.

Generally, in organizations where this dynamic is present, the IT manager seeks to stretch the capital budget as far as possible, often by buying less efficient, lower cost IT equipment. This eventually leads to a cooling system or power delivery capacity shortfall, which must be rectified by the facility manager. The facility manager must overcome this capacity shortfall with limited capital funding, as well as absorb the ongoing operational cost increases.

Outreach, education, and incentive programs should be designed with the understanding that data center efficiency measures cannot be implemented without the full commitment of both the IT and the facility manager. As such, marketing and outreach efforts should be targeted to both local IT and facility trade associations, and program opportunities should be discussed when the facility and IT managers are both present.[13] After learning about the large incentives available for data centers, facility and IT managers can collaborate on efficiency program activities and share incentive dollars. Incentive design strategies are discussed in the following section.

In addition, for data centers located in leased buildings, the property owner, leasing agent, and management firm may need to be included in the decision-making process, along with the IT and facility managers. Tenants are often hesitant to make capital improvements to a facility that they do not own, and in some cases, energy costs accrue to the building owner rather than the tenant.

Designing Program Incentives

Well-designed incentives can address key barriers in a given target market by improving project cost-effectiveness and addressing split incentive barriers. Incentives designed using input from customers and trade allies are far more likely to be effective than those designed in the abstract. This should be complemented by continuing regular feedback and market observation to allow program designers and operators to update the program as market conditions change. Financial incentives can be combined with nonfinancial incentives, such as information and/or technical services, to maximize results.[14] The following subsections describe incentive strategies and their applicability to measures commonly targeted by programs.

Prescriptive Incentives

A prescriptive incentive (also referred to as a deemed incentive) is commonly applied to measures that offer reliable savings on a per-unit basis, regardless of installation practice. Only a handful of measures in the data center are commonly promoted using prescriptive incentives. Yet, prescriptive incentives can be an important market entry strategy for developing relationships with trade allies and for engaging customers seeking straightforward savings opportunities.

Efficiency programs have successfully developed prescriptive rebate programs for desktop computing and data center IT equipment. These rebates are based on energy savings generated by premium-efficiency power supplies and, in some cases, by power management capabilities. In addition, prescriptive rebates in other sectors for specific end-use technologies (e.g., variable speed drives (VSDs), HVAC, pumps and motors) could be marketed to data center operators.

Network PC power management, and server virtualization and consolidation measures have been successful in the past,[15] but there are high freeridership concerns in customer segments where IT is a core business function. For data centers with a distributed infrastructure (server rooms, server closets, and localized data centers), server virtualization has about a 40% market penetration.[16] As a result, a combination of technical assistance and an easy-to-access incentive program may be the best program delivery mechanism.

Depending on the incremental costs and incremental savings associated with an efficient product, the incentive can be targeted downstream to the purchaser, midstream to the supplier, or upstream to the manufacturer. If an incentive only represents 1% or 2% of the total measure price, it may be more effective to engage the marketplace with midstream, or upstream incentives: that is, to introduce an efficiency incentive into the

[13] One program manager illustrates the long-standing disconnect between IT and facilities departments with an anecdote: a facility manager's swipe card was not programmed to let him enter the data center.

[14] National Action Plan for Energy Efficiency. Customer Incentives for Energy Efficiency Through Program Offerings. Prepared by William Prindle, ICF International, Inc. February 2010. pp.12. Available online: http://www.epa.gov/cleanenergy/documents/suca/program_incentives.pdf.

[15] There are concerns about freeridership for server virtualization and consolidation projects because of high market saturation. However, freeridership claims associated with large businesses should be carefully examined because industry sources indicate that market penetration hovers around 40%. As a result, opportunities remain within that market, and incentives for virtualization can convince an organization to apply virtualization to high-value business functions.

[16] Source: Virtualization Industry Quarterly Survey: http://www.v-index.com/full-report.html. August 2012.

production, stocking, and promotion of efficient IT equipment. Successful midstream and upstream programs typically involve the collaboration of multiple efficiency programs for a larger customer base in order to attract vendor participation, and possibly manufacturer interest (e.g., leading server manufacturers sell directly to customers). Manufacturers have historically been interested in changing production lines only if there is a sizable market for energy-efficient models.

> "Utilities can benefit from collaborating and partnering with other utilities. Combining forces allows sets of utilities to enter the space quickly representing a larger market. This could lead to additional opportunities with customers, vendors, and manufacturers."
>
> – Lee Cooper, PG&E

Midstream and upstream incentives can be used to help overcome the disincentive that vendors may have to promoting efficiency. Both *PG&E* and *Seattle City Light* have indicated that upstream incentives can influence distributors to sell a more efficient product by increasing those products' profit margins. Upstream rebates can be offered for thin client, ENERGY STAR-qualified servers, storage, and networking technologies.

Customized Incentives

The lack of measures appropriate for prescriptive incentives leads to a reliance on more costly customized or performance-based program models, which can be more complicated for vendors and customers due to additional program rules and requirements. This incentive structure may require:

- Qualified technical support for project verification,
- Application qualification processes that require engineering estimates of energy savings and expected project costs prior to project initiation (pre-installation), and
- Application approval that requires review of the calculations.

Consequently, data center program portfolios tend to have higher administration costs than other market sector-targeted programs. Despite this, these programs are cost-effective (at a level similar to industrial sector programs), and they deliver some of the best results of any sector-directed program. In addition, data center projects deliver high peak energy demand and usage savings. Customized incentives are particularly important for data center cooling measures.

The following measures are generally cost-effective and suitable for customized incentives:

- Water-side economizers
- Server removal
- Control systems for CRACs and air handlers
- Replacement of infrared humidifiers with adiabatic units[17]
- Conversion of cooling systems from fixed volume to variable volume by installing VSDs for fans and associated control systems (using a customized approach, substantiated by field measurements, may result in much higher verified energy savings compared to a prescriptive incentive approach)
- Airflow management measures (measures that prevent supply and return air from mixing, including containment systems)

While many data center energy-efficiency measures can be evaluated using calculation methodologies, some (notably those related to airflow isolation measures) will benefit from accurate energy-savings values via field measurements and monitoring.

One advantage of data centers' very high load factor and low seasonal variation in energy use is that pre- and post-measurements to determine energy savings can be accomplished in short timeframes (a week or two of monitoring before and after project implementation is usually sufficient). Efficiency programs requiring post-measurement of on-site energy use to more accurately quantify savings may wish to consider using simple standard spreadsheet-based calculation models for evaluating some measures.

Retro-Commissioning Based Incentives

Retro-commissioning (RCx), or tune-up services, represents a new program area for utilities. These programs typically feature a facility audit that recommends no- and low-cost efficiency measures and provides financial incentives for measures that are implemented by the customer or a contractor. Some programs feature pre- and post-measurement of actual savings. Retro-commissioning has become more important as equipment-efficiency opportunities have become more difficult to capture and less cost-effective. RCx services can directly generate cost-effective energy savings, and can also serve as a gateway service by establishing a utility/customer relationship that can lead to more substantial retrofit projects.

> Retro-commissioning, or RCx, opportunities depend on data center size. Permanent monitoring and control systems can be installed to measure actual efficiency gains, but this is generally only cost-effective for data centers larger than 10,000 square feet. For such facilities, customers should be encouraged to consider installing a monitoring and control system, not only to measure energy savings from airflow management upgrades, but also to ensure the persistence of energy savings. An RCx service addressing smaller data centers can use temporary metering and monitoring equipment to measure pre- and post-conditions, entering data into a calculation model that predicts and calculates energy savings. *PG&E* pioneered an RCx program in 2008 targeting smaller data centers.

[17] Adiabatic humidification raises humidity without adding heat, and includes ultrasonic, fogger, and mister technologies.

For data centers with dedicated cooling infrastructures (excluding most server rooms or closets), ample opportunity exists for addressing poor airflow conditions, which can dramatically improve cooling system efficiencies. As a side benefit, often of paramount concern to the data center operator, improved airflow can recapture cooling system capacity, allowing the addition of more IT equipment over time.

Some low- or no-cost airflow management improvement and cooling system retrofits—separately or in combination—reduce energy use and improve cooling system effectiveness. These improve airflow delivery by:

- Removing obstructions from under-floor plenums
- Blocking airflow to ancillary equipment (such as power delivery units and distribution transformers)
- Blocking airflow through cable outlets
- Installing blanking panels in all IT equipment racks
- Rebalancing airflow by moving grate tiles
- Reorienting IT racks in a hot aisle/cold aisle configuration
- Ducting return air

Please Note: Fire Suppression Safety

In order to comply with fire safety recommendations and codes, customers may have to take additional installation or protection steps when pursuing airflow management strategies.

For example, hot aisle/cold aisle containment structures may be required to have separate "in-aisle" fire protection systems because their components (e.g., enclosed ceilings, plastic curtains) can:

- Shield the hot aisle from data center's regular fire suppression; and
- Prevent smoke from reaching detection systems.

Current and local codes may require certain construction materials or patterns.

These measures allow data center operators to:

- Raise supply air temperatures to an optimum level so that cooling is effectively provided to all IT equipment (typically when equipment does not receive sufficient cooling, the response is to lower the supply temperature rather than improve airflow delivery).
- Avoid supply and return air mixing, which results in lower return air temperatures. This is important because cooling units have a rated capacity based on the difference in supply and return air temperatures (generally, capacity is listed at a 20-degrees Fahrenheit delta). If the difference in temperatures falls below the specification, the unit provides a de-rated cooling capacity.
- De-commission a portion of their cooling units, which are operating at their full capacity. This is one reason that airflow management measures can be so valuable: they not only improve energy efficiency, but they often reclaim cooling capacity that was unavailable due to poor operating conditions.

Table 3 summarizes classes of energy-efficiency measures and indicates which retrofit program approach typically applies. By balancing program elements (offering prescriptive incentives and retro-commissioning services, for example), energy savings can be generated in a shorter timeframe and improve the performance of the entire program portfolio.

PROGRAM PLANNING AND ROLL OUT

Understanding market potential and the market penetration of data center efficiency measures provides valuable insights into how a program should be delivered and what incentive levels would be cost-effective and successfully affect the market.

Establishing Market Potential and Projecting Program Targets

The data center program planning process should include a baseline market assessment of the energy savings potential for data centers. This baseline will allow program managers to set realistic savings goals and design programs that are well-suited for the target market in their service area. Baseline assessments for data center programs typically capture the information outlined in the following subsections.

Proportional Estimation of Energy Use for the Data Center Market

Data centers of all types account for approximately 1.6% of national energy sales.[18] This proportion can be applied to a utility load to establish a market assessment baseline. Utilities that primarily serve rural areas might decrease this estimate; those that serve highly urbanized areas might increase the estimate.

Cataloguing Data Centers within Service Territory

Utilities should consider adjusting the load estimate based on direct knowledge of enterprise and utility-scale data centers. The number of utility-scale and enterprise data centers (defined previously) can be used as a proxy to validate the energy use estimate. Industry analysts report that approximately 40% of data center load is attributable to these two classes. A utility can validate a program's assessment with a reasonable estimate of this load, approximating 40% of the estimated load with the proportional approach. Planners should catalogue:

- All customer loads in excess of 10 MW, and which of those are utility-scale data centers; and
- Customer loads between 1 MW and 10 MW, and which of those are enterprise data centers.

It is important to recognize that any assessment of market potential is an estimation; *British Columbia Hydro's (BC Hydro's)* data center program, which had low adoption rates during initial implementation, found that data center customers were smaller and fewer than they had expected.

[18] Source: Masanet, Eric R.(2012). Estimating the Energy Use and Efficiency Potential of U.S. Data Centers. Lawrence Berkeley National Laboratory, Paper LBNL-5168E. Retrieved from: http://escholarship.org/uc/item/1475d9h0

Table 3. Illustrative Program Treatment for Data Center Measures

Measure		Program Model		
Measure or Technology	**Description**	**Prescriptive Incentive**	**Customized Incentive**	**Performance/RCx**
		Data Center Cooling Systems		
Premium Efficiency Equipment	Premium efficiency chillers, pumps, fans, cooling towers, and other components; ultrasonic humidifiers.	Can use programs established for other markets (e.g., commercial offices), but will likely underestimate savings.	Preferred for retrofits to capture savings from high load factor use of equipment.	
Variable Speed Fans	Variable speed fans on computer room air conditioners/ handlers.	Can use programs established for other markets (e.g., commercial offices), but will likely underestimate savings.	Preferred for retrofits to capture savings from high load factor use of equipment.	
Cooling System Controls	Upgrading controls, integrating controls of multiple cooling units, or installing metering and monitoring to improve control of system.		Generally must be undertaken with suitable airflow management upgrades and/or variable speed fans.	
Air-side and Water-side Economizers	Use of outside air or water-side cooling when environmental conditions are favorable.		Water-side retrofits are very attractive; air-side retrofits are more difficult.	
Airflow Management Upgrades	A set of no- and low-cost measures that ensure the proper delivery and return of cooling air, limiting mixing.			Ideal approach, with pre- and post-measurement of supply and return temperatures and calculation of achieved savings.
		Power Delivery and Conditioning		
ENERGY STAR certified UPS and Premium Efficiency Distribution Transformers	Specification of premium-efficiency equipment.		Easily handled using standard calculation model; note that loading of equipment is crucial.	
Direct Current Power Systems	Use of high-voltage, direct current power delivery and conditioning schemes.			
Self Generation	Use of fuel cells, solar PV, or other generation.	Generally treated as a prescriptive incentive.		
		Premium Efficiency IT Equipment		
Premium-Efficiency IT Equipment	Specification of premium-efficiency power supplies in IT equipment, including ENERGY STAR-certified equipment.	Applicable as a downstream, midstream, or upstream program.		
Virtualization and Consolidation	Software that allows for higher utilization of computing (server) and data storage equipment.	Can be delivered as a prescriptive rebate.	Most often handled using a standard calculation model.	
Data Storage Measures	Premium-efficiency equipment (power supplies), solid-state storage, thin provisioning, compression, de-duplication.		Some measures can be accurately assessed using calculation models (other technologies do not have predictable savings).	

Estimating Potential Program Performance

Program implementers can develop a well-documented market baseline for the data center segment. The following should be considered when establishing baselines:

- Impending changes in technology that improve energy efficiency:
- Estimates of freeridership and spillover based on results from data center program evaluations; and
- Changes in existing and upcoming standards. For example, in 2013, the State of California will adopt new construction standards for data centers that include requirements for free cooling systems, which will obviate those measures from utility new construction incentive programs in California. Similarly, the EPA's ENERGY STAR program will adopt new criteria for classes of IT equipment, which may lead to changes in market conditions over time.

Retrofit opportunities in existing data centers can often capture savings in the range of 25% to 50%, depending on the age of the data center and the operator's willingness to make significant upgrades. For example, eBay's 139,000 square-foot data center in

Phoenix (of which 65,000 square feet is white space) houses all of eBay's business units.[19] This facility, built in 2004, has been the target of numerous energy-efficiency upgrades.

A new construction project might yield energy savings of 10% of the typical baseline design by implementing power delivery and conditioning measures, specifying premium efficiency cooling equipment, and fully isolating airflow.

Once savings claims are established, it is important to prepare work papers for prescriptive rebate measures (e.g., server virtualization and consolidation, premium-efficiency servers) and prepare standard calculation models for selected customized measures. These work papers and models should be submitted to regulators for approval.

Table 4 and Table 5 outline the costs and benefits associated with two retrofit measures that eBay instituted in its Phoenix facility: ultrasonic humidification and VSDs. The tables show the two measures' simple paybacks (costs divided by annual energy savings), with and without incentives offered by Arizona Public Service (APS) Company. The incentives allowed for reasonable payback periods, which enabled eBay to pursue these retrofits. In general, data centers, even utility-scale data centers, need a one-year payback or less on retrofit measures to move forward with projects.

Table 4. Ultrasonic Humidification Payback

	Power Draw (kW)	Hours of Use*	Number of Units	Energy Use (kWh)
Steam Humidifier	30.3	4,380	6	796,284
Ultrasonic Humidifier	0.67	4,380	8	23,477
Energy savings (kWh)				772,807
Energy savings ($) at 6.5 cents per kWh				$50,232
Costs (labor and ultrasonic humidifier purchases)				$94,270
Payback (years)				1.9
Potential incentive at 11 cents per kWh				$85,009
Actual incentive limited to 75% of costs				$70,703
Payback (years) with incentive				0.5

* This calculation is based on humidifiers operating half of the time. Other data centers may have much lower average hours-of-use and need to adjust their savings accordingly.

Table 5. Variable Speed Drive (VSD) Payback

	Power (HP)	Efficiency	Hours of Use	Number of Units	Energy Use (kWh)
Constant Speed	10	90%	8,760	83	6,026,685
Variable Speed	10	95%	8,760	83	1,663,675
Energy savings (kWh)					4,363,010
Energy savings ($) at 6.5 cents per kWh					$283,596
VSD equipment costs					$341,960
Harmonic transformer costs					$338,984
VSD installation costs					$69,056
Payback (years)					2.6
Potential incentive at 11 cents per kWh					$479,931
Actual incentive limited to 50% of costs or $300,000					$300,000
Payback (years) with incentive					1.6

Program Tracking

A program tracking system is important for measuring program progress and tracking energy savings. As with other commercial programs, program administrators have found that, in addition to customer information, it is helpful to track the data listed in Table 6 for each installed measure.

EM&V Planning

Data center operations feature several unique characteristics that complicate verification of claimed energy savings and program attribution. Prior to launching a program, program managers can recognize, understand, and prepare for these complexities by meeting with evaluators to plan the program and performance expectations, thereby reducing risks associated with freeridership, load growth, and short equipment production cycles. Other strategies for mitigating risk include discouraging program participation by utility-scale data center operators (for most measures), establishing defensible energy-efficiency baseline standards, and collecting information from customers to document program influence.

In addition, utility program managers should consider reviewing the latest evaluations that offer analyses of data center programs. Few of these evaluations have been conducted, because few mature data center programs exist.[20] Three evaluations of early programs had the following conclusions:

- Given market potential, evaluators believe that utility managers may have difficulty growing data center programs quickly enough to meet demand.
- The split incentive challenge is particularly acute for the data center market and associated decision makers, especially in co-location facilities.[21]

Addressing Program Implementation Challenges

Understanding market conditions and program implementation challenges is important for effective program planning and for developing a reasonable forecast of energy savings. The major challenges for data center program administrators are the technical complexity, long lead times, and product production cycles associated with data centers, as well as the risk of freeridership.

[19] This includes server applications for the eBay services, analytical databases and storage devices for internal analysis, and routers/switches to direct traffic to the applicable system arrays. In addition, telecom gear will be required to interconnect to a fiber optic backbone.

[20] This data is as of May 2012. Mature programs are defined as those that have been deployed for multiple program cycles.

[21] Seattle City Light reported seeing more interest from co-location providers.

Table 6. Typical Program Tracking Data

Measure-Level Information	Power Consumption Information	Energy Savings Information
■ Measure Type ■ Measure Brand Name ■ Measure Model Number ■ Measure Description ■ Measure Capacity ■ Percent of Load on Measure ■ Quantity of Measure ■ Level of Incentive ■ Installation Date	■ Power Draw of Installed Equipment ■ Power Draw of Typical Equipment Installed at Time of Purchase ■ Power Draw of Old Equipment	■ Energy Savings ■ Summer Demand Savings ■ Winter Demand Savings ■ Years of Useful Life Remaining on Old Equipment ■ Years of Useful Life for Installed Equipment

- **Technical Complexity:** All energy-using elements of data center operations are technically complex, because they use special-purpose equipment with a key goal of ensuring reliability. Generally, identifying energy-efficiency opportunities and accurately characterizing savings is best suited for engineering and technical experts who specialize in data center facilities and IT equipment. Program managers should evaluate whether their traditional technical services team has sufficient data center expertise to support the evaluation of cooling, power delivery, and conditioning systems and, if so, whether using their staff in this capacity is effective. Some examples of how this issue has been addressed include:
  - The process evaluation of *PG&E's* 2006 – 2008 High-Tech Program recommended that *PG&E* expand its efforts to educate customers and utility account managers about IT energy-efficiency measures and technologies for data centers. The evaluation noted that *PG&E* had difficulties performing comprehensive energy audits for data centers, and that its technical support activities instead focused on specific measures.
  - If a utility cannot rely on in-house expertise, it should select qualified technical service contractors who are familiar with specific data centers technologies (e.g., cooling and power systems) and limit each of these contractors to evaluating the specific systems within their area of expertise.[22] The evaluation of *Silicon Valley Power's* Fiscal Year 2008-2009 program recommended that the utility work with local consultants and engineers to identify opportunities.
  - Another method of providing technical support services is to contract with an energy service provider (ESP). ESPs can implement portions of the program, such as technical reviews, engineering support, and turnkey implementation services. For comprehensive program delivery, ESPs generally consider either a cost-based service contract or a performance-based arrangement that makes payments for energy-efficiency accomplishments.

> As part of a regulatory requirement to provide a portion of its energy-efficiency program portfolio through independent contractors, *SCE* selected an energy service provider (ESP) to run a data center retrofit service.
>
> The ESP performs marketing and outreach activities in partnership with *SCE* account representatives, provides technical assessments of customer facilities, and manages the incentive application process for customers.

> "It is advantageous for utilities to partner with ESPs that have traction and success in the data center market. Relationships with industry trade allies, engaging in customer-specific data center technical situations, and accelerating the program time-to-market are valuable examples that ESPs can offer utilities looking to enter the IT and data center efficiency segment."
>
> – Geoff Overland, WECC

- **Long Lead Times:** Data center deployments often take a longer time to complete than other types of energy-efficiency engagements. All projects, whether related to IT equipment or its supporting infrastructure, require careful planning and execution. A data center often takes two years or more to build, and end-to-end project cycles (from planning to commissioning and operation) are typically five years or longer. For projects that aim to recapture capacity (such as airflow management upgrades) or increase utilization rates (such as virtualization and consolidation of servers), savings can also be masked over short periods by growth in IT workloads. In simple terms, reclaimed capacity will often be allocated or used up quickly by new equipment. Customized incentive retrofit and new construction projects have long periods between application approval and project completion. This extended implementation period can complicate program planning; utility incentive funds for retrofit projects may not be paid (and the accomplishments cannot be accrued) in the program year they were committed. A program approach that captures a time-dependent energy savings stream, based on projected load growth, may solve this dilemma, although no known new construction programs have this feature. Most importantly, efficiency program evaluators should be informed of the long project lead times associated with this market.
- **Production Cycles:** Data centers are not static environments. Servers and many other types of IT equipment have production cycles of about a year, due to frequent technological upgrades. These product cycles are unlike product categories such as

[22] Technical service contractors that typically conduct commercial HVAC audits may not be able to assess complex data center cooling systems..

HVAC equipment, food service equipment, and residential appliances, which generally advance only over multiyear timeframes. Technological advances can cause data center equipment to become antiquated with relative frequency. This phenomenon suggests that IT equipment incentives should reward customers who purchase premium-efficiency equipment that compares to currently available standard models, rather than to their existing installed equipment.

- **Freeridership:** Industry leaders (often utility-scale data centers) are more likely to undertake energy-efficiency projects (particularly in new construction) in the absence of utility program offerings and involvement. These industry leaders are generally companies from the high technology, communications, financial services, and government sectors. Proper targeting from the onset can help decrease issues surrounding freeridership.
  - Many industry leaders undertake energy-efficiency retrofits absent utility efforts because the most recent technologies and high-operational efficiencies are required to remain competitive. Program designs that set maximum incentive payments, preclude certain rate classes or facility loads, or limit participation by operators of large, sophisticated data centers can mitigate freeridership concerns.
  - Server virtualization may be common practice in utility-scale data centers, but is less common for localized data centers. The evaluation of *BC Hydro's* Data Center Program concluded that customers (i.e., utility-scale data centers) who are committed to pursuing server virtualization will undertake these projects regardless of the additional incentive dollars.

Implementation Strategies

A program development and launch strategy can feature phased deployment, thereby encouraging early accomplishments, while laying the foundation for a broader portfolio. The program delivery roadmap presented in Table 7 focuses on delivering high-value program elements, while building internal expertise and customer and vendor engagement. The elements contained in the Early Stage Program column could be delivered in the program cycle's first year, with Mid-Stage activities added in the second or third years. Advanced Programs require sophisticated program development work, but could be added to address local markets.

Table 7. Sample Data Center Program Implementation Timeline

Activity/Program Element	Planning	Early Stage Program	Mid-Stage Program	Advanced Programs
Assess market baseline	✓			
Prepare work papers for prescriptive rebate measures and submit to regulators for approval	✓			
Hold internal stakeholder training (for account representatives, program managers, etc.)	✓			
Meet with program evaluators to review the design and implementation plan	✓			
Identify potential vendor partners	✓			
Prepare standard calculation models for selected measures	✓			
Identify technical support contractors and issue an RFP for technical support and/or program management and delivery services	✓			
Offer prescriptive rebate program		✓		
Hold customer and vendor training events		✓	✓	
Participate in vendor-sponsored outreach activities		✓	✓	
Conduct energy assessment services		✓	✓	✓
Offer customized incentives for selected measures and technologies		✓		
Expand customized incentive measure eligibility			✓	
Monitor program results		✓	✓	✓
Consider new construction program			✓	✓
Consider offering server room retro-commissioning program			✓	✓
Consider upstream/midstream rebate program for prescriptive measures (e.g., energy-efficient servers)			✓	✓

Keys to Success:

BC Hydro believes the key to their program's success was a committed internal team of program and account managers who worked well with industry stakeholders and who had technical expertise and team building and interpersonal skills.

WECC recommends that utility program managers should focus on one measure, or a small subset of measures, to get the program started. By entering the market with a narrow focus, utilities can avoid risking too much, expedite implementation, and ultimately grow more successfully.

SUMMARY

Energy efficiency programs can achieve sizeable energy savings and advance the adoption of efficient products and practices in data centers. While market barriers exist, they are understood by the industry and can be addressed with proven program designs and effective emerging strategies that focus on key measures and systems. Tapping into data center industry interest in managing costs and recapturing under-utilized infrastructure is an effective way to engage data center management. Energy-efficiency measures can be employed without reducing reliability, and in some cases, can improve reliability, or help recapture capacity. Efficiency program administrators can partner with their customers and the vendor community to deliver cost-effective program results starting with a modest program portfolio that can be extended and expanded based on early success.

RESOURCES

Federal Resources

EPA and DOE offer the following tools and resources to help efficiency programs, customers, and implementers:

- Energystar.gov/products – includes information on qualified office equipment and enterprise servers. Market share information for existing ENERGY STAR qualified products is available at energystar.gov/usd.
- Energystar.gov/datacenters – includes information on guiding principles for measuring energy efficiency in data centers, the ENERGY STAR rating for data centers, and ENERGY STAR product development efforts.
- Energystar.gov/lowcarbonit – includes information on the ENERGY STAR Low Carbon IT campaign, a nationwide effort to assist and recognize organizations for reducing IT energy consumption.
- Energystar.gov/ia/products/power_mgt/downloads/DataCenter-Top12-Brochure-Final.pdf – EPA's Top 12 Ways to Decrease the Energy Consumption of Your Data Center provides more information about energy-efficiency opportunities in data centers.
- www1.eere.energy.gov/manufacturing/datacenters/software.html – includes a Data Center Profiler Software Tool Suite that allows companies to identify and evaluate efficiency opportunities in data centers. DOE also offers training and certification for data center practitioners.

Ratepayer-Funded Programs Promoting Efficient Data Centers

Consortium for Energy Efficiency: Data Center Program Offering Summary Table (2010/2011 Data Center Programs), www.cee1.org/com/dcs/dcs-main.php3

Arizona Public Service: www.aps.com/main/services/SolutionsForBusiness/it.html

Austin Energy: www.austinenergy.com/energy%20Efficiency/Programs/Rebates/Commercial/Commercial%20Energy/dataCenter.htm

Duke Energy: www.duke-energy.com/north-carolina-business/smart-saver/smart-saver-custom-incentive-program.asp

Pacific Gas and Electric Company: www.pge.com/hightech/

Xcel Energy: www.xcelenergy.com/Save_Money_&_Energy/For_Your_Business/Customized_Solutions/Data_Center_Efficiency_-_CO_-_MN

INDUSTRY INITIATIVES AND GROUPS

C-Net: www.cnet-training.com/

Climate Savers Computing Initiative: www.climatesaverscomputing.org/

Consortium for Energy Efficiency (CEE): www.cee1.org/

Datacenter Dynamics: www.datacenterdynamics.com/

The Green Grid: www.thegreengrid.org/

Uptime Institute: www.uptimeinstitute.com/

Evaluation Resources

California Measurement and Advisory Council searchable database: www.calmac.org/search.asp

Consortium for Energy Efficiency Evaluation Clearinghouse: www.cee1.org/search/search.php

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