Data Center Growth Challenges Implementation Programs

Tarek Salameh, DNV GL

ABSTRACT

Between 2005 and 2010, data center energy use increased by 36 percent. By 2010, data centers consumed approximately 2 percent of total electricity used in the U.S. With increased global demand for personal electronics and the trend toward cloud computing, the need for more data center space will increase. As a result, many programs are targeting data centers as a relatively untouched sector with a large energy savings potential.

During the course of our work over the past several years evaluating new construction data center projects for implementation programs, we have identified a number of challenges that are unique to this sector. For program implementers, this may mean adjusting measurement methods or using new tools. For example:

- Baseline Determination – Using ASHRAE 90.1, Power Utilization Effectiveness (PUE), and other sources.
- Analysis Tools – Standard analysis tools may not be suited for data center spaces.
- Load Growth Rate – Many data centers do not reach full IT loads for a number of years.
- Product Development Times – Keeping up with technology advances.

In this paper, we will discuss the most important data center challenges we have discovered and provide suggestions for solutions. We will also recommend areas for continued research. While many of the issues identified will apply to a number of program and facility types, the paper focuses on whole building program approaches for stand-alone data centers.

Introduction

Energy-intensive and growing rapidly, data centers offer unique challenges and opportunities for utility-sponsored energy efficiency programs. These facilities present significant potential for energy savings, but they don't fit the usual prescriptive incentive approach. Data centers consume 10 to 50 times the energy per floor space of a typical commercial office building and account for approximately 2 percent of total electricity use in the U.S (EERE 2014). The upward trend in energy use is increasing: data center loads are forecast to grow 10 to 15 percent annually (EERE 2014) due to increasing size and denser computing platforms.

What's driving the need for more data center space? Global demand for personal electronics, exponential growth in mobile applications, an explosion in social media, storage needs for big data and the trend toward cloud computing, to name a few. As a result, data centers are becoming a larger portion of many utility program portfolios.

This paper will discuss barriers unique to data center facilities seeking incentives through new construction whole building-type programs and suggest appropriate program modifications. We will also identify areas where additional research is needed.

What is a Data Center?

The term "data center" is often applied to any building or space containing IT equipment such as servers, computers, and data storage equipment. Under such a broad definition, the term data center could be applied to anything from a server closet to a 100,000-square-foot facility. The EPA's ENERGY STAR® program divides data centers into five different categories, summarized in Table 1. This paper focuses on the challenges presented by utility scale, enterprise, and localized data center types.

Table 1. ENERGY STAR data center classifications

Data Center Type	Description	Area (Square Feet)
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 a 40 MW load. Includes most retail and wholesale co-location data centers.	Greater than 100,000sf
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.	Greater than 5,000sf
Localized	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.	500sf to 5,000sf
Server Room	Often do not have dedicated cooling or power delivery systems or climate conditioning equipment.	200sf to 499sf
Server Closet	The smallest-scale data center.	Less than 200sf

Source: EPA ENERGY STAR program

Data Center Baselines

Many new construction incentive programs utilize a version of ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, as the program baseline energy code. The standard specifies minimum energy efficiency requirements for most common building systems. The primary use of the ASHRAE 90.1 is for code compliance, however; in 2004, a Performance Rating Method (PRM) was added as an informative appendix for use in utility incentive and green building programs such as the US Green Building Council's (USGBC) Leadership in Energy and Environment Design (LEED).

ASHRAE 90.1 is updated every three years to keep pace with changes in the building industry. In 2010, the standard was expanded to cover receptacle and process loads in data centers. The major updates related to data centers primarily focused on Computer Room Air-Conditioner (CRAC) efficiencies and economizer requirements. Previous versions of the standard did not apply to equipment using energy primarily to provide for commercial processes, such as data center cooling.

Utilizing ASHRAE 90.1 2010 or any of the previous versions to establish baseline efficiencies for individual pieces of equipment is fairly straightforward and provides reasonable results as long as the equipment is covered by the standard. While newer versions of ASHRAE 90.1 do contain some data center equipment, older versions contain only equipment commonly used in standard commercial facilities. The main challenge when applying the various versions of ASHRAE 90.1 to data center facilities is how to utilize the PRM process as described in the standard's Informative Appendix G ("Appendix G").

Appendix G provides detailed guidelines to establish baseline building system types and operational criteria to be used in a computer simulation for comparison with the proposed building design. When applied to standard commercial facilities such as office buildings, Appendix G guidelines result in reasonable baseline building specifications. However, attempting to follow these same guidelines for data centers produces poor results, with the following commonly encountered issues.

- **Unrealistic baseline HVAC system type selection.** The standard was developed for commercial facilities providing ventilation for occupant comfort and not process loads. HVAC system type selection is based primarily on building area and height. Data center HVAC system selection should be based on internally driven IT loads.
- **Data center air delivery system types are not offered as a baseline option**. Supply air for data centers is typically provided through an under-floor air distribution system via Computer Room Air Conditioners (CRAC) or Computer Room Air Handlers (CRAH). Baseline data centers using Appendix G are often forced to use Variable Air Volume (VAV) systems common to commercial buildings instead of CRAC or CRAH units more typical for data centers
- **Appendix G does not address redundancy.** Redundancy can play an important role in facility energy use and should be factored into baseline building requirements.
- **IT infrastructure and process loads are unregulated and treated as a receptacle load.** IT infrastructure and process loads are frequently treated as a pass-through, ignoring any system efficiency improvements.
- **Operational specifications are based on standard commercial facilities**. Appendix G provides guidelines on minimum flow rates, temperature deltas, etc., that are based on commercial building operation.

Fortunately, ASHRAE has recognized the shortcomings in using ASHRAE 90.1 for data centers and is in the process of developing *ASHRAE 90.4P Energy Standard for Data Centers and Telecommunications Buildings*. The standard was proposed in 2012 and was available for public review in draft form at the end of 2013.

However, until *ASHRAE 90.4P* is released, the industry is still without a standard baseline document. In the interim, implementation programs should seek out a different data center baseline source or create their own. A number of California utilities recognized the need for a baseline document specific to data centers and commissioned the *Energy Efficiency Baselines for Data Centers* report (Integral Group 2013).

One alternative baseline option for data centers is the Power Utilization Effectiveness (PUE) (The Green Grid 2012) of the data center. The PUE is the industry standard measure of efficiency of a data center and will likely play a large role in ASHRAE 90.4P. When developing baseline PUE values, it is important to provide values specific to the data center type or class and climate, as well as any other criteria that impact the building energy use and is outside the control of the design team. Additionally, if the program allows for a systems approach, partial PUE baseline values will need to be developed.

Using a PUE baseline significantly decreases the effort required to develop the baseline data center energy profile. But energy savings estimates will still be necessary to inform design decisions, so a PUE baseline does not eliminate the need to calculate the energy use of the proposed design. Additionally, measuring PUE after the building is constructed can be difficult for data centers in mixed-use buildings and for data centers with slow load growth rates, which is discussed in more detail in the "IT Load Growth" section below.

It should also be noted that none of the baseline codes or procedures discussed in this paper addresses the energy use of data center IT systems. IT systems account for the vast majority of data center energy use and should certainly not be ignored when discussing data center energy efficiency. Due to the variation in IT equipment design and capabilities as well as the fast equipment refresh rates, it is unlikely that a single energy code will be able to address both the energy efficiency of data center infrastructure and IT systems. Programs such as the EPA's ENERGY STAR Enterprise Server and the ECOVA 80 Plus programs attempt to fill the void.

Analysis Tools

Regardless of the baseline used, there will be, at a minimum, the need to estimate the energy use of the proposed building design. To model data center energy use, analysts often employ many of the building energy modeling software programs that are used for standard commercial buildings, such as eQUEST, EnergyPlus, Trane Trace, and Carrier HAP. In many cases, these modeling software programs can accurately estimate data center energy use, but modeling data center energy use presents a number of unique challenges that typically require the use of supplemental or alternative calculation methods.

Some of the building components in a data center have been specifically designed for use in a data center, most notably in the HVAC and IT support systems. In some cases, these systems are similar enough to common commercial building systems that they can be incorporated into the energy model. For instance, many data center chilled water plants are identical to plants in commercial buildings and can easily be modeled using common energy modeling software.

In other instances, the modeling software may lack the functionality to accurately model the data center, requiring the analyst to use supplemental calculations. For example, IT systems such as Uninterruptable Power Supplies (UPS) typically cannot be directly modeled in commonly available simulations software, but can easily be included as a process or receptacle load. To properly account for UPS energy use and internal loads, analysts will have to perform supplemental calculations to generate all of the necessary software inputs.

Some modeling software programs are not capable of modeling certain data center systems, such as under-floor cooling and integrated water-side economizers. Analysts should understand the baseline and proposed data center building systems and select a software program that has the required capability. In some cases, the data center building systems may include a level of complexity that cannot be accurately modeled using any of the available building modeling software programs, requiring the analyst to use alternative analyses tools that often take the form of custom spreadsheet calculations.

DNV GL developed the following guidelines to help analysts avoid many of the common pitfalls associated with using commercial energy modeling software for data center facilities.

Select Appropriate Software/Analysis

Select a software program or analysis method that is capable of accurately modeling all data center systems.

Avoid Using Modeling Software Default Values

Default values are based on commercial building systems, not data centers, and can lead to inaccuracies in modeling.

Capture Energy Savings in IT Support Systems

It is common to model IT support systems as pass through process. Supplemental calculations should be used to show baseline and proposed system energy use.

Obtain IT Process Load Utilization Estimates

Data center IT loads are dynamic and rarely operate a full power levels. Some data centers see nearly constant utilization rates and others see seasonal, monthly, or daily variations. The analyst should work with facility operators to come up with reasonable estimates in lieu of actual performance data.

Understand the Impact of IT Load

Understand what the IT load growth rate will be and how the facility's energy use differs at lower loads. This topic is discussed in more detail in the following section.

To improve the accuracy of data center energy analysis, detailed data center energy modeling and analysis guidelines are needed, similar to the guidelines that have been developed for commercial building analysis. The *Commercial Building Energy Modeling Guidelines and Procedures* (COMNET 2010) provide some high level guidance, but not the level of detail that is critical. Standard guidelines and procedures will help analysts produce accurate and consistent energy savings that can stand up to program measurement and verification standards.

There is also a need to incorporate data center technologies and operations into existing energy simulation software. Analysts are often forced to use inappropriate components or supplemental calculations to model data center equipment, leading to a more error-prone and complicated analysis. Incorporating items such as data center-specific HVAC systems (CRAC, in-row cooling, etc.) and IT infrastructure equipment (UPS, PDU, etc.) would significantly improve the analyst's ability to accurately predict the energy use of complex data center facilities.

IT Load Growth

Data center mechanical and electrical systems are designed around the maximum potential data center IT loads, or the design IT loads. The IT load installed in most data centers at the time of post-construction is typically far lower than the design IT load. IT load is added to the data center over time until the installed IT load reaches the design IT load. During the IT load build-out, the facility's mechanical and electrical systems are drastically oversized, impacting the facility energy performance and causing significant challenges to implementation programs.

COMNET's *Commercial Building Energy Modeling Guidelines and Procedures* provides a rule of thumb for the post-construction installed IT load of 50 percent of the design IT load. In our experience, values can be as low as 10 percent. Facilities operating at reduced IT loads will both use less energy and perform less efficiently than the same building operating at design IT loads, as can be seen in Figure 1. The impact of both of these characteristics should be carefully understood prior to establishing savings and incentive values.

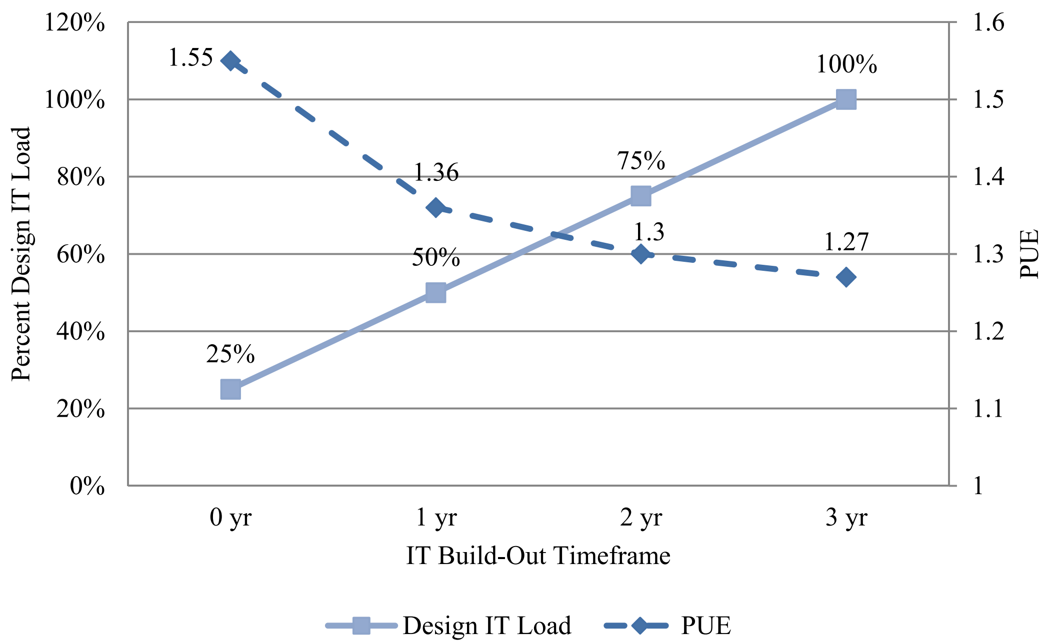

Figure 1. Example IT build-out schedule and influence on Power Utilization Effectiveness (PUE). *Source*: DNV GL, PUE based on Sheehan, 2013.

Many new construction programs base the energy savings on the building's operation, based on the internal loads present at the time of incentive payment. For most commercial facilities, the internal loads are at or near design internal loads shortly after building completion, so the impact to energy savings is negligible. However, for data centers the difference between installed IT loads and design IT loads can be significant. If we assume the efficiency and utilization of the data center are not affected by the IT load, a data center operating at 50 percent design IT load will use roughly half the energy of a facility operating at 100 percent design IT loads. If we base the savings and incentive on the performance the baseline and proposed building operating at 50 percent of the design IT load, we will provide only half the incentive and claim half of the savings that would otherwise be awarded to a data center operating at design IT loads. This is not beneficial for either the implementation program or the data center owner, as neither gets the full credit for the facility, while claiming the energy savings based on design IT loads would certainly overstate the energy savings for the IT build-out period.

For facilities with fast IT build-out periods, this issue can easily be addressed by delaying project completion until the installed IT load reaches the design IT load. Since many data centers take years to build-out the IT loads or do not have control of the IT build-out time frame, this method often does not solve the problem.

Phasing incentive payments based on the IT load over the IT build-out timeframe is another option that avoids both under- or over-claiming savings and does not delay incentive payments to the building owner. Phased incentives typically provide partial incentive payments over the course of the IT build-out at predefined milestones. These milestones are often based on the installed IT loads or predetermined dates. The partial incentive payments are based on the estimated energy savings evaluated at the IT load installed at the time of payment.

While a phased incentive payment process avoids some of the issues associated with commercial new construction incentive determination process, it is not trouble-free. Phased incentive payments require the utility to provide incentives over long time periods, often more than five years. Many utilities cannot commit to holding funds for such long times, adding uncertainty and reducing program effectiveness. Additionally, data centers are dynamic facilities and are likely to change (often significantly) during the IT build-out period.

A phased incentive payment process requires the energy savings to be calculated at each milestone, which can be difficult, depending on the program baseline and analysis method. Data centers operating at IT loads well below the design IT loads will see significant decreases in energy efficiency. If the program uses a specification-based baseline code, similar to ASHRAE 90.1, the inefficiencies will be apparent in both the baseline and proposed building's energy use. When using a PUE based baseline, the analysis becomes a bit more challenging since the data center's performance at low IT loads can easily exceed baseline PUE values based on operation at design IT loads, as can be seen in Scenario 3 in Figure 3.

To simplify the process, programs may consider pro-rating the savings and incentive at design conditions based on the IT load installed at each milestone. This makes the savings and incentive calculations at each milestone straightforward and predictable. While this method is simpler, it likely does not accurately represent the true annual energy savings during the IT build-out period.

To illustrate the differences between the various approaches considered in this paper, the annual energy savings were estimated for a facility with the IT build-out schedule in Figure 1. It was assumed the data center has a design IT load of 1,000 kW and a utilization of 80 percent. The annual energy savings are displayed in Figure 2 for the following four scenarios:

- Scenario 1—Annual savings calculated at design IT.
- Scenario 2—Annual savings calculated at initial IT loads.
- Scenario 3—Annual savings re-calculated each year based on actual PUE and constant PUE baseline.
- Scenario 4—Annual savings re-calculated each year based on simulated baseline and proposed building energy use.

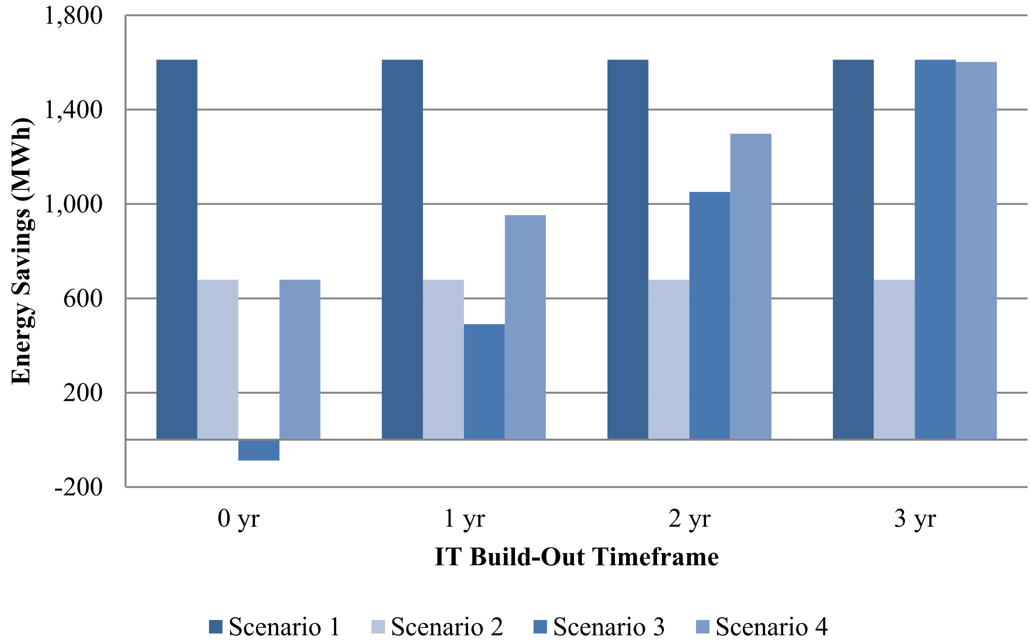

Figure 2. IT build-out energy savings estimations. *Source:* DNV GL.

The extended IT build-out periods common to many data centers make it challenging to fit data center projects into existing commercial new construction whole building incentive programs, often resulting in poor realization rates or insignificant incentives and low customer satisfaction. While this paper offers a few suggestions, such as phased payments or waiting until full IT build-out, no solution is perfect and no one design will fit the program and regulatory requirements of every utility program. What this paper hopefully demonstrates is the need to modify program policies for data centers or risk low participation and poor realization rates.

Accelerated Product Development Times

Data centers and data center technology development times are significantly faster than commercial building technology development. Data centers are dynamic facilities that are in an almost constant state of renewal to keep pace with the industry. To stay relevant and avoid free-ridership, implementation program staff must keep pace with this rapid transformation.

The advent of modular or containerized data centers is one recent example of the quickly changing data center industry. Modular centers present a number of new challenges to implementation programs. Can we use the same baselines that we would use for a brick-and-mortar data center? What modifications will be needed to energy analysis methods PUE calculations?

Whether it's modular data centers or any other technological development, implementation teams must be familiar with the cutting-edge technologies and have the flexibility to modify rules and processes to successfully drive innovation in data center design. Otherwise, programs risk being too slow to capitalize on the opportunity before it is standard practice. In the energy intensive world of data centers, lost opportunities often take the form of large energy savings.

Summary and Discussion

Data centers represent a rapidly growing and energy intensive sector for utility new construction implementation programs. Attempting to use the same rules, processes, and methods for data centers that are used for commercial facilities can result in lost energy savings opportunities, poor realization rates, increased free-ridership, and reduced customer satisfaction. It is important for new construction implementation programs to recognize some of the unique qualities that set data centers apart from commercial facilities, and to modify or design new policies and procedures respectively.

At a minimum, this paper suggests the modifications listed in Figure 3 for a new construction program for data center projects.

Develop Data Center Definition

- Definition should at a minimum distguish between data center and server room/closet.
- Definition should reflect data center activity in utility territory.

Develop or Adopt Data Center Baseline

- Avoid using baseline developed for commercial facilities.
- Baseline should reflect all data center types identified in program definition.

Set up Procedures to Handle Slow IT Load Growth Rates

- Process should be developed with cooperation from evaluator to reduce evaluation risks.

Modify Analysis Methods

- Educate program engineers and staff on proper data center energy savings evaluation methods.
- Develop custom tools where standard software packages fall short.
- Extend education to local design teams and energy analysis firms.

Stay Relevant

- Participate in trades groups and industry conferences.
- Develop relationships with data center equipment manufacturers and suppliers.

Figure 3. Modifications for new construction programs designed for data centers. *Source*: DNV GL.

Data centers present a number of unique challenges to energy efficiency program implementation teams, but the payoff in potential energy savings is significant, and the industry is forecast to continue its rapid growth. With increased awareness and by employing a few of the recommended modifications listed in this paper to existing approaches, utility programs can continue to work to overcome these challenges.

References

ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers). 2013. *ASHRAE Seeking Comments on Proposed Data Center Energy Standard.* https://www.ashrae.org/news/2013/ashrae-seeking-comments-on-proposed-data-center-energy-standard-

ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers). 2004. *Energy Standard for Building Except Low-Rise Residential Buildings. ANSI/ ASHRAE/IESNA Standard 90.1-2004.* Atlanta, GA. American Society of Heating, Refrigerating and Air Conditioning Engineers.

ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers). 2007. *Energy Standard for Building Except Low-Rise Residential Buildings. ANSI/ ASHRAE/IESNA Standard 90.1-2007.* Atlanta, GA. American Society of Heating, Refrigerating and Air Conditioning Engineers.

ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers). 2010. *Energy Standard for Building Except Low-Rise Residential Buildings. ANSI/ ASHRAE/IESNA Standard 90.1-2010.* Atlanta, GA. American Society of Heating, Refrigerating and Air Conditioning Engineers.

COMNET. 2010. *Commercial Buildings Energy Modeling Guidelines and Procedures.* Oceanside, CA. COMNET - Commercial Energy Services Network.

EERE (US DOE Office of Energy Efficiency and Renewable Energy). 2014. *Data Centers and Servers.* http://energy.gov/eere/buildings/data-centers-and-servers

ENERGY STAR®. 2012. *Understanding and Designing Energy-Efficiency Programs for Data Centers.* US Environmental Protection Agency.

Integral Group. 2013. *Statewide Customized New Construction and Customized Retrofit Incentive Programs; Energy Efficiency Baselines for Data Centers.* Oakland, CA. Integral Group.

Sheehan, M. Sam. 2013. *PUE Calculations: The Model and The Myths.* Baltimore, MD. CCG Facilities Integration Incorporated.

The Green Grid. 2012. *PUE: A Comprehensive Examination of the Metric.* The Green Grid.