![nbi | new buildings institute]

Commercial Plug Load Energy Use Policy

What's in Place, Pending and Possible

Final Report
March 2013

Prepared by:

Jim Edelson and Mark Lyles
New Buildings Institute

Edmund G. Brown Jr.
Governor

Prepared for:

California Energy Commission
Public Interest Energy Research (PIER) Program
Evidence-based Design and Operations

Table of Contents

INTRODUCTION

The purpose of this paper is to examine the issues related to the energy use category in commercial buildings commonly referred to as Plug Loads. It is prepared as part of the New Buildings Institute (NBI) California Energy Commission Public Interest Energy Research (PIER) program on *Evidence-based Design and Operations*.

Plug loads are frequently characterized as comprising energy consumption that arises from the use of devices connected to electrical receptacles (things that plug into the wall outlets). Plug loads are an increasing use of energy in buildings, especially when considered as a percentage of total energy consumption. As building systems such as lighting and HVAC have become more efficient, and the envelope has become more thermally effective, plug load devices have grown in type and magnitude, even though individual devices may have become more efficient. This is believed to be one of the main reasons that, although major building systems such as lighting and HVAC have become much more efficient, building energy use intensity has not decreased over the three most recent decades of CBECS[1] surveys (1983-2003).

Source: Energy Information Administration, Commercial Buildings Energy Consumption Survey.
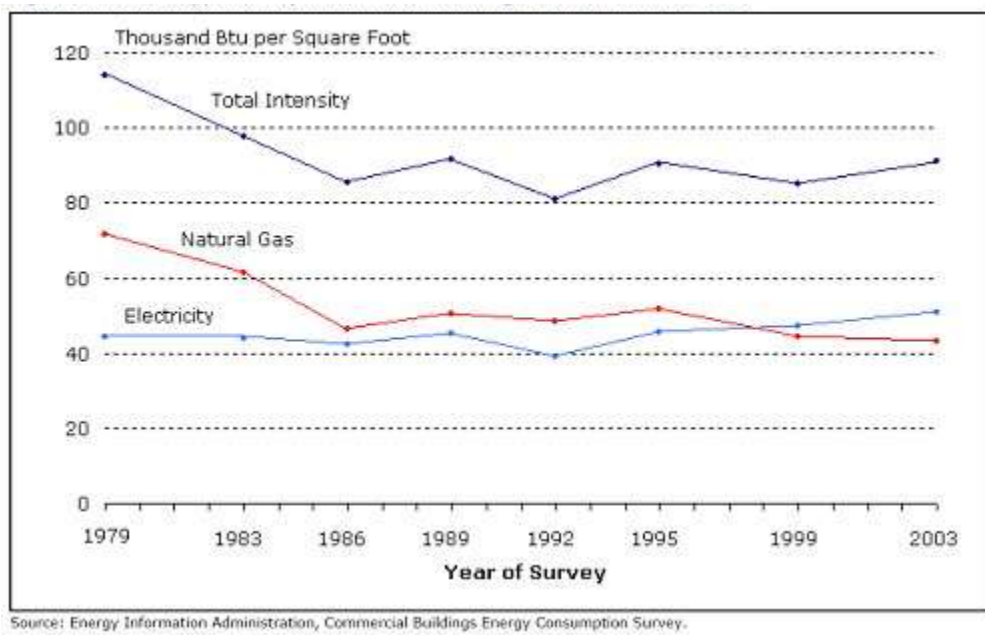
With a path in codes and programs headed toward Zero Net Energy (ZNE), plug loads have become a matter of increasing concern, both as a technological challenge and a policy driver.

> *Plug loads make up a significant piece of energy use that is closely tied to occupant behavior. Plug loads are one of the largest and fastest growing end uses of the commercial sector. Between 2005 and 2030 they are expected to nearly double. The analysis of LEED NC projects in the state of California have plug load fractions that range from 35% to 49% for California LEED rated projects (depending on building use type), and 32% - 45% for "ZNE Capable" California*

---

[1] The U.S. Commercial Building Energy Use Survey (CBECS)

> *LEED buildings. (The Road to ZNE: Mapping Pathways to ZNE Buildings, Heschong, Mahone Group; Dec. 2012)*

Regulatory Background

The plug load energy use in a building primarily occurs after occupancy as users select devices and equipment necessary for their tasks. As a result efforts to limit plug load energy use in construction codes (such as energy codes and electrical codes) have not occurred until very recently. Generally, plug load regulation was limited to requirements on the energy use of the products and appliances themselves, by federal standards and California Title 20 (Title 20). Only recently have construction and energy codes begun regulating aspects of plug loads, such as the switched receptacle requirements in ASHRAE [2] Standard 90.1 (90.1) and the task lighting requirements in California Title 24 (Title 24)

Existing Program and Market Efforts

Because consumer and user behavior plays such a large role in the amount of energy consumed by plug loads, the use of utility program mechanisms, such as product rebates, and voluntary programs, such as EnergyStar, has played a large part in influencing the amount of plug load energy use. But as the plug load portion of building energy use continues to grow and the pressure increases to work toward Zero Net Energy (ZNE) buildings, accelerated and additional approaches are needed to impact all phases related to plug load energy use: the construction phase, consumer choices and operational behaviors.

Utility program energy savings opportunities around miscellaneous unregulated energy uses can be characterized in these categories:

1. **Power Management.** Promote management and control of device power management settings for computers, virtualization of data centers, etc.

2. **Technology Improvements.** Promote and procure more efficient technologies such as improved personal computers, monitors, printers, copiers and servers.

3. **Behavioral Approaches.** Utility programs can incorporate messaging, prompts and feedback displays within their programs. Although the direct savings are more difficult to account for to this specific measure it is an important part of the full plug load savings strategy and should be included along with the two items above.

4. **System Efficacy.** Ensure existing energy efficiency program strategies are effective such as the supply and temperature of heated and cooled air and light distribution so fewer personal space heaters, fans and lamps are needed.

   According to Dan York of ACEE in his article "The Next Generation Programs Reach for High Energy Savings" in the December 2012 edition of The Frontiers of Energy Efficiency:

   In the interim (until further research and program development is competed), programs should continue to target data centers, should continue expanding these offerings to servers outside of data centers, and should consider pilot programs building on the New Buildings Institute Plug-Load Guide.

Plug Loads, Codes, and the Leap to Zero Net Energy Policies

The increasingly stringent energy codes since the first "Energy Crisis" in the 1970s have significantly decreased energy levels in commercial buildings as represented by simulations of building energy use.

---

[2] American Society of Heating, Refrigeration and Air Conditioning Engineers, www.ashrae.org

This matches the policy objectives of the U.S. Department of Energy (DOE) and several states, including California. As shown in Figure 1 below, the standards required are a reduction of 40% of energy use compared with the standards in place in 1975.
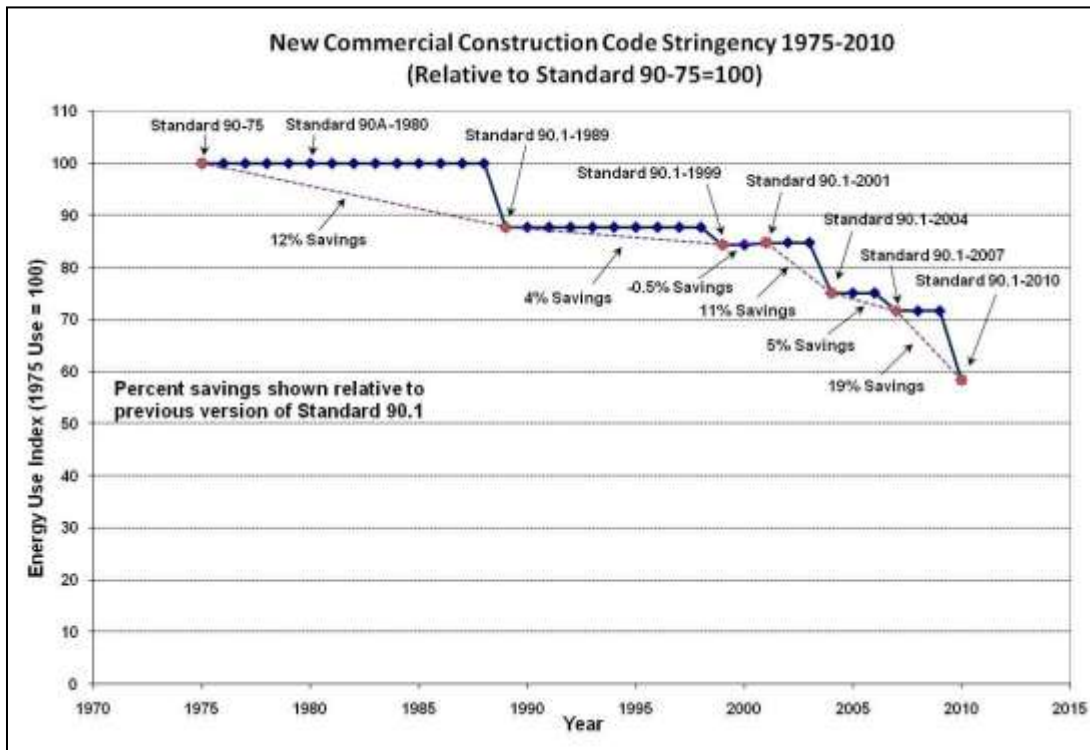

Figure 1: New Commercial Construction Code Stringency 1975-2010 Relative to 1975 Energy Use of '100'

However, these energy reduction achievements measure something referred to as "regulated loads" in energy codes. 'Regulated loads' is a self-referential term directly reflecting whatever is delineated by the Scope section of that particular energy code. However, in many ways the term regulated loads has become synonymous with those energy loads regulated by model codes, such as ASHRAE 90.1, the International Energy Construction Codes (IECC), and state codes, such as Title 24.

In the most recent energy code determination done for the U.S. Department of Energy, the nationally weighted energy savings for Standard 90.1-2010 over Standard 90.2-2004 was 33% for the "regulated loads" , but only 26% when plug and process loads were included *(Liu, et al; Achieving the 30% Goal: Energy and Cost Savings Analysis of ASHRAE Standard 90.1-2010).* This further demonstrates that over time a larger portion of the savings sought in public policy is falling from the current scopes of energy codes and that a keener focus must be placed on plug loads in working toward ZNE goals.

Fortunately, the arbitrary distinction between regulated and unregulated loads has changed to be more inclusive within 90.1 itself. The scope in the most recent version of Standard 90.1-2010 was expanded to include "*new equipment or building systems specifically indentified in the standard that are part of industrial or manufacturing processes.*" This growing inclusiveness has also occurred between the base codes, such as 90.1 and the IECC, and the 'green codes', such as ASHRAE's 189.1, and the International Green Construction Codes (IgCC), as documented later in this paper.
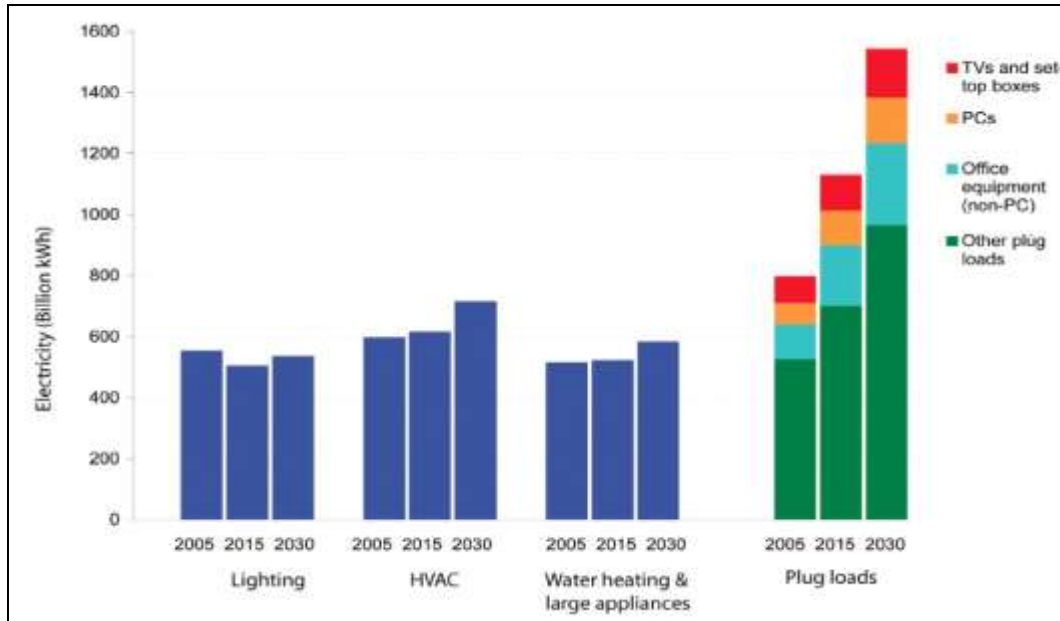
Figure 2: Change in Energy Use by System

Source: Graph created by Ecova with data from EIA 2008 Annual Energy Outlook

Thus even though the "regulated loads" should be decreasing according to Figure 1 above, the actual total building Energy Use Index (EUIs)[3] is behaving more like and becoming the dominant load growth area in the country. This is illustrated in another way in Figure 2, where growth in the direction and magnitude of plug loads has continued to grow much more quickly relative to other loads. And as further illustrated in Figure 2 above on the projections for 2030, the trends in plug loads will make it much more difficult to achieve ZNE buildings even if traditional lighting, HVAC and water heating are reduced to near zero energy.

> *As the more permanent subcomponents of a building continue to improve in efficiency (envelope, HVAC, and lighting), the remaining plug loads are becoming a larger and larger portion of the overall load. In this "stress test" of Zero Net Energy design objectives, reducing the plug loads often proved critical to meeting the overall energy use targets. That is also the experience of most architects and engineers working on Zero Net Energy projects.*
> *(The Technical Feasibility of Zero Net Energy Buildings in California, Arup; Dec., 2012)*

The following section presents energy codes and other policies for plug load efficiency improvements within a framework of direct/indirect distinction, rather than the regulated load designation. Using the direct/indirect distinction is conducive to comparing policy choices and framing specific recommendations.

---

[3] EUIs are the amount of energy use per square foot per year expressed in British Thermal Units (BTUs)/sf/yr and provide a benchmark reference for the comparison of energy use across like types of buildings.

POLICY APPROACHES

In the last couple of years we have seen a number of policies put forth that seek to more closely regulate plug loads and other 'unregulated loads' not addressed by energy codes in commercial building. While energy codes certainly are a major factor in setting minimum requirements and ensuring energy savings, there are several other policy approaches discussed in this section that can enable plug load efficiency gains. Each approach is described and examples provided to illustrate where the approach is applied or being considered.

Energy Codes and Standards

Energy codes are the most direct policy tool for addressing and reducing plug loads in commercial buildings. There are several direct approaches used by the three major code bodies in the U.S. (ASHRAE 2010, IgCC and Title 24) and a number of indirect approaches that seek to increase the visibility of plug loads within a building. A summary of the application of these plug load regulatory mechanisms in current codes can be found in Table 1 at the end of this section.

Controlled Plugs (direct approach)

This approach requires that a minimum amount of receptacles in a building be on an independent circuit capable of being switched off through the use of a controller. In all cases these controlled receptacles are required to be easily distinguishable by occupants from the other, non-controlled receptacles within the building. The three major codes or standards – ASHRAE, IgCC (within the IECC), and Title 24 – have some requirements that fall under this approach:

- *ASHRAE 90.1 2010*: At least 50% of all receptacles in private and open offices and in computer classrooms need to be automatically controlled by time clock, occupant sensor or other system that is capable of indicating that the area is unoccupied.

- *IgCC 2012*: Buildings used for office and educational purposes are required to provide receptacles that are controlled by occupant sensors or time switches that are evenly distributed throughout each space. In addition this code requires that computer office equipment and AV systems be plugged into these controlled receptacles.

- *Title 24 2013[4]*: At least one controlled receptacle is to be installed within six feet of each uncontrolled receptacle in all buildings. Hotels and motels are required to have at least half of the receptacles in each guest room be controlled.

Appliance Standards (direct approach)

Appliance standards provide a critical *direct* approach to ensuring manufacturers are meeting specific performance requirements. These efficiency requirements are set forth in the National Appliance Energy Conservation Act (NAECA), Energy Policy Act (EPAct) and the Energy Independence and Security Act (EISA). In California appliances need to meet the minimum efficiency requirements of Title 20. In California the requirements under Title 20 address only larger appliances and 'white goods' that might be found in some non-residential (commercial) buildings such as refrigerators.

Wiring & Metering Approaches (indirect approach)

One of the most significant challenges when it comes to addressing and reducing plug loads is that energy use related to plug loads is strongly associated with building occupants and their behavior

---

[4] The Title 24 2013 Standard is scheduled to go into effect January 1, 2014.

patterns. A secondary policy approach is to put measures in place that increase the accessibility and visibility of plug load energy usage to commercial building occupants. The following energy codes and standards feature requirements, based on use thresholds, for the wiring and metering of circuits associated with plug load energy use:

- *ASHRAE 189.1 2011*: All buildings with connected plug and process loads that exceed 50 kVA are required to include subsystem measurement devices with remote capability that measure energy consumption data and communicate it to a data acquisition system.

- *ASHRAE 90.1 2010 (Addendum BN)*: All new commercial buildings larger than 25,000 square feet shall include separately metered receptacle circuits. This data is to be reported regularly to the tenants of each tenant space. This requirement does not apply to hotels, motels and restaurants.

- *IgCC 2012*: Energy sub-metering of plug loads is required for all buildings 25,000 square feet or larger.

- *Title 24 2013*: There are four different energy thresholds with varying levels of disaggregation requirements for plug load circuits. All commercial buildings with a plug load service between 50 and 250 kVA need to aggregate plug loads separately from other loads in the building. Buildings with a plug load service exceeding 250 kVA need to separate plug loads by floor, type or area. In addition, groups of plug loads exceeding 25 kVA in an area smaller than 5,000 square feet must also be on a separate circuit.

- *Oregon Reach Code*: The distribution of all convenience receptacles needs to be isolated from other load types in the building.

Task Lighting Approach

Task lighting serves an important role in many commercial environments, providing additional illumination for building occupants on an as-needed basis. When accounted for in a larger lighting design, task lighting can be an effective way to reduce overall space lighting energy use by putting the lumens at the work surface. Because task lights are most commonly plugged into convenience receptacles they fall into the plug load category and therefore are difficult to "touch" from a policy perspective. Title 24 2013 requires all portable lighting systems be accounted for in the lighting power density (LPD) space limit but provides a budget of .3 watts per square foot for task lighting. The Energy Code of Canada also requires that "supplemental interior lighting provided by movable or plug-in luminaires" be accounted for when determining compliance with installed lighting power limits.

Outcome-based Codes Approach

A code approach that relies less on addressing the building in the construction phase but more in the operational phase is frequently referred to as an Outcome-Based Codes (OBC). Outcome-based codes rely on the demonstration of the building meeting some target for energy consumption, usually based on at least 12 months of measured energy use data. The targets can be set by building energy simulations or derived from surveys such as CBECS or CEUS.

Though this code approach is only now in the pilot phase in Seattle, Washington, and Vancouver, British Columbia, it offers excellent potential for coping with the most significant issues around plug loads – their variability among buildings and inability to be regulated in the construction phase. While several hurdles need to be addressed for outcome-based codes, chief among them the question of enforcement mechanisms available long after the building has been occupied, OBCs offers significant promise in the medium- to long-term to address energy consumption by plug loads.

Modeled Approaches

Computer modeling is typically used to comply with energy codes. In the energy modeling programs plug loads are treated the same in the code baseline building and the proposed building. This means plug loads do not directly impact the building's energy use calculation relative to the code baseline, but they do have an impact on factors that could influence the load placed on other systems in the building, such as the HVAC system, that do figure in the code compliance calculation.

Reach (or Stretch) Code Approaches

Several cities and states, including California, have adopted mechanisms that require an energy saving level beyond the base energy code. California's CalGreen has been adopted by over 100 jurisdictions, and similar actions are underway in Massachusetts and Oregon. At this point, none of the requirements for plug loads in these codes exceed those in ASHRAE 90.1-2010 or Title 24, but the Reach Codes, where available, provide a mechanism for implementing plug code requirements on less than, or in advance of, a full statewide mandatory basis.

Table 1: Policy Approach Matrix

	Switched Outlets	Wiring/Metering	Task Lighting	Energy Star	*Relevant Jurisdiction(s)*
Title 24 2013	X	X	X		*California*
ASHRAE 2010	X	X		X	*Maryland*
IgCC 2012	X	X		X	*Rhode Island[5]*
Oregon Reach Code		X			*Oregon*
ASHRAE 189.1 2011		X		X	*Army Corp of Engineers[6]*
National Energy Code of Canada			X		

Cross-Cutting and Behavioral Approaches

When discussing successful policy approaches to reducing plug load energy use it is important to look at what can be done beyond the receptacle level and address the devices that are plugged into those receptacles and the building occupants using those devices. Steps have been taken to address power consumption at the device level, especially related to servers and computer use. The "behavioral" piece is possibly the biggest wildcard when it comes to reducing plug loads in commercial buildings. Recent research through Ecova and NBI on Plug Load Savings Assessment details the office equipment device-level energy use and metered savings from a variety of field applied software, hardware and behavioral approaches[7].

Occupant Engagement Approaches

---

[5] Adopted for Public Buildings only.

[6] Proposed.

[7] The Plug Load Savings Assessment Report is available at www.newbuildings.org/PIER-research.

Engaging building occupants in an effort to reduce energy use can be an effective policy approach to achieving low plug load energy use, as proven by a number of recently developed behavior programs that have been implemented in the workplace[8]. For such a program to be effective it is critical to have buy-in from upper management, assemble a committed team and directly engage employees through a variety of social engagement and communication tools. Below are a number of examples of occupant engagement programs that have demonstrated reduced energy use:

- BC Hydro's "Conservation Action!" program

- U.S. House of Representatives "Green the Capitol"

- The Empire State Building's "Tenant Energy Management Program"

- Investa Property Group's "EcoSpace" Initiative

A second occupant-orientated approach that can result in reduced plug loads is the use of "Green Leases" by commercial real estate services firms. According to a recent California report, "Investing in high performing efficient technologies will not make a significant difference if the equipment is not used and calibrated properly"[9]. These can include purchasing agreements for efficient equipment and incentives for improved performance.

Cloud Computing

An *Issue Brief* from the Natural Resources Defense Council states, ". . . running a computer application in the cloud is generally more energy and carbon efficient than running it in your server room because cloud commuting can serve more customers at the same time, achieving economies of scale than small and medium size organizations"[10]. The *Brief* also references a report which determined there were a range of possible outcomes and that for efficiencies to be realized by switching to virtualization and cloud computing alternatives best practices would need to be enacted.

Voluntary Appliance Mechanisms

The two most successful and effective policy mechanisms in place for promoting the most efficient appliances, beyond what is required by federal standards, are DOE's EnergyStar rating and TopTen USA. TopTen USA[11] is an independent, nonprofit organization that identifies the most energy-efficient products on the market on a continual basis and serves as a valuable resource for companies and building owners interested in committing to low plug load energy use through purchase of the most energy efficient appliances available.

---

[8] Shui Bin, *Greening Work Styles: An Analysis of Energy Behavior Programs in the Workplace* (Washington DC, American Council for an Energy-Efficient Economy, 2012).

[9] L. Park and S. Ivery, *Greening California's Leased Office Space: Challenges and Opportunities* (California Sustainability Alliance, 2009),.

[10] *Is Cloud Computing Always Greener?, NRDC.org,* October 2012, http://www.nrdc.org/energy/files/cloud-computing-efficiency-IB.pdf.

[11] http://www.toptenusa.org/.

NEXT STEPS FOR CALIFORNIA

Relationships to ZNE Commercial Building Codes

There are two important types of plug load recommendations with regard to meeting ZNE goals for commercial buildings identified in an Arup report titled *The Technical Feasibility of Zero Net Energy Buildings in California* (2012). These recommendations will be broken out in the sections below.

1. **Energy Use Reduction at the Device?** The first recommendation relates to reducing plug loads directly to reduce direct power consumption and to reduce the secondary consumption due to increased cooling requirements in the California climate types.

2. **Plug Load Codes and Targets?** The second type of ZNE recommendation relates to developing building energy targets and moving the targets into codes. Building energy targets necessarily include plug loads, whereas current building codes due not. In addition, energy use targets are an essential component of outcome-based codes if that development is ever to occur.

   The language typically used to express code changes is in terms of percent improvements over the previous standards. This language is counter-intuitive to achieving the ZNE goals. Since we [California Title 24] have only two code cycles to 2020, and another three until 2030 each successive code update must target a greater portion of the regulated energy use of the building than the previous standard. However, the absolute magnitude of savings (TDV, kWh, Therm) may actually be lower in each successive code update. Thus a percent better than previous code language is actually misleading and may lead to confusion at best and opposition at worst. Instead, laying out a clear goal of a code performance target has the advantage of simplicity and ease of comparison to other ZNE metrics. (The Road to ZNE; Pacific Gas and Electric; Dec, 2012)

Recommendation 1: Complete research and implement pilot programs to demonstrate energy use performance targets in codes.

Efficient Task Lighting

The Title 24-2013 approach to task lighting of including a power budget could be enhanced by requiring the most efficient lighting technology available.

Recommendation 2: Set efficacy requirements for all task lighting to ensure that efficient technologies such as Light Emitting Diodes (LEDs) are implemented.

Recommendation 3: Make use of realistic default task lighting values (e.g. per workstation) when submitting project plans for Title 24 lighting power density calculations to facilitate accounting for and reducing task lighting loads.

Optimized Appliances in Title 20

Recommendation 4: Continue to move toward lower power limits as technologically feasible for appliance standards and expand to include electronics that feature standby, sleep and idle modes of operation - particularly for large plug contributors such as computers.

Appliance and Equipment Purchase Voluntary Programs

Recommendation 5:

> *Continue equipment efficiency incentive programs. Finding new ways to incentivize the outcomes of smart equipment purchasing and operations strategies – tapping into submeter data or disaggregated smart meter data for the Measurement & Verification (M&V) – is another pathway worth exploring. This could provide better return on investment to the IOUs and allow building owners more leeway in collaborating with the IOUs in addressing the plug load reduction challenges. (Such outcome based programs could be challenging to implement in new construction projects where there is not a baseline for M&V.) (The Technical Feasibility of Zero Net Energy Buildings in California, Arup; Dec., 2012)*

Turning Off Idle Equipment

Recommendation 6: Align with the findings from this PIER research in the Savings Assessment Report (Ecova, NBI 2011) and Arup's recommendation in the Technical Feasibility Study for NZE buildings pertaining to Power Management methods for energy reduction of off or idle equipment:

> *Sensors and software are becoming ever more proficient at reducing equipment loads when a piece of equipment is not necessary for occupant use in buildings and homes. The resulting energy savings – a type of automated conservation – are potentially as important as future equipment efficiency gains.*
>
> *Promote and/or regulate the application of control systems in buildings and homes to drive integration with ever more equipment. There are ample opportunities for research in the sector that should bear fruit in short order. Continuing to improve interoperability of the systems as well as installation simplicity is important in making the promise of sensor systems a reality.*
>
> *Further research establishing how a host of sensor applications will affect building equipment schedules within energy models will facilitate future analysis of the systems in the context of a building's overall energy use. (The Technical Feasibility of Zero Net Energy Buildings in California, Arup; Dec., 2012)*

Regulating "The Cloud"

Computer systems should have increasingly effective sleep functions that move them into a low- energy consumption mode when not being utilized but permit both a rapid and remote (for enterprise applications) return to full functionality. The final step in minimizing onsite computing energy is to move computing functions and data storage to a highly efficient "cloud." "Private clouds" may be available for larger operations, and "public clouds" are available to all users. However, further analysis by NRDC and WSP Environment & Energy found that:

> *While cloud computing is generally more energy efficient and has a smaller carbon footprint than on-premise server rooms, not all clouds are created equal: some clouds are greener than others; and an on-premise server room that implements energy efficiency best practices can be a greener alternative than a "brown" cloud. (The Carbon Emissions of Server Computing for Small to Medium-Sized Organizations—A Performance Study of On-Premise vs. The Cloud, 2012)*

The energy efficiency rating of a data center is expressed as "Power Use Effectiveness" (PUE). PUEs have been increasing at a rapid rate. For instance, the *Open Compute Project*[12] was the outcome of the Facebook high performance data center design located in Prineville, Oregon. A significant product of this *Open Compute Project* is a specification for a data center that "maximizes mechanical performance and thermal and electrical efficiency." The National Renewable Energy Laboratory (NREL) has also published its *Best Practices Guide for Energy-Efficient Data Center Design* which includes equipment and component recommendations. These are two examples of possible design requirements for data centers that would ensure that shifting this computing load from server closets to the cloud would result in known efficiency gains.

Recommendation 7: As efficiencies and usability of "cloud computing" increases, and mobile devices become more ubiquitous, every effort should be made to encourage use of the most energy efficient cloud computing resources and minimize the installation and use of onsite equipment commensurately.

SUMMARY OF RECOMMENDATIONS:

1. Develop and set **energy use targets** through existing regulatory (Title 24), possible new pathways (outcome based) and voluntary (Reach, Stretch or Green) codes for commercial buildings.

2. Set minimum efficacy ratings for **task lighting**.

3. Set **default task lighting densities** for compliance with Title 24 lighting power densities.

4. Reduce, where possible, **stand-by power** use limits in Title 20 requirements.

5. Maintain and enhance **appliance efficiency programs** while piloting outcome-based (measured) approaches.

6. Apply **power management strategies** through integrated control systems and behavioral modifications to minimized unnecessary power usage.

7. Encourage migration of onsite computing function to the most **energy efficient cloud-based systems**.

---

[12] http://www.opencompute.org/