Design & Engineering Services

Office of the Future
Phase II Report
The 25% Solution

ET 08.01 *Final Report*

Prepared for:
The Office of the Future Consortium:
Design and Engineering Services, Southern California Edison; Pacific Gas & Electric; Sempra Energy; Sacramento Municipal Utility District; Consolidated Edison; National Grid; NSTAR; BC Hydro; U.S. Department of Energy

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Disclaimer

ABBREVIATIONS AND ACRONYMS

AEC	Annual Energy Consumption
AIA	American Institute of Architects
AMI	Advanced Metering Infrastructure
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASID	American Society of Interior Designers
BC	British Columbia
BOMA	Building Owners and Managers Association
BTU	British Thermal Unit
CBECS	Commercial Buildings Energy Consumption Survey
CBSA	Commercial Building Stock Assessment
CEC	California Energy Commission
CEUS	California Commercial End-Use Survey
CFL	Compact Fluorescent Lamp
CI	Commercial Interiors
CLD	Current Limiting Device
CLS	Commercial Lighting Solutions
CMH	Ceramic Metal Halide
CPUC	California Public Utilities Commission
DDCV	Dual Duct Constant Volume HVAC System
DEER	Database for Energy Efficient Resources
DOE	Department of Energy
DR	Demand Response
DSM	Demand Side Management

DX	Direct Expansion
EA	Energy and Atmosphere
EB	Existing Buildings
EPA	Environmental Protection Agency
EPD	Electric Power Density
EUI	Energy Use Index
HVAC	Heating, Ventilating and Air Conditioning
IBM	IBM Corporation
IFMA	International Facility Managers Association
LBNL	Lawrence Berkeley National Laboratory
LEED	Leadership in Energy and Environmental Design
LPD	Lighting Power Density
M&V	Measurement and Verification
ME	Miscellaneous Equipment
NBI	New Buildings Institute
OE	Office Equipment
OTF	Office of the Future
PAG	Project Advisory Group
PECI	Portland Energy Conservation, Inc.
PNNL	Pacific Northwest National Laboratory
PR	Performance Review
ROI	Return on Investment
RTU	Roof-top Packaged Units
SPB	Simple Payback
TI	Tenant Improvement
UPS	Uninterruptible Power Supply

WE	Water Efficiency

CONTENTS

TABLES

EXECUTIVE SUMMARY

The 25% Solution developed by the Office of the Future Consortium (OTF Consortium) strives to reduce the site electrical energy use in office spaces by 25% or more, using Title 24-2005[1] as a baseline for minimum performance in California and ASHRAE 90.1-2004[2] as the minimum baseline for the rest of the country. While the 25% Solution is structured primarily to affect the Tenant Improvement (TI) process - where new or existing office spaces are customized for use by a specific tenant - it is important to keep in mind that these solutions are also viable for any new construction or retrofit project.

The 25% Solution reduces the energy used by lighting, plug loads and HVAC systems by means of a comprehensive "systems" approach that also improves lighting quality and air conditioning/heating performance. The 25% Solution provides electric utility energy efficiency programs with the necessary technology and system performance information to create incentive programs that will motivate property owners/managers, tenants, design professionals and contractors to create a more responsive and responsible office environment - one that better serves tenant needs while reducing energy costs, enhancing property values and delivering a reduced carbon footprint.

Some aspects of energy use, such as office equipment or "plug loads," are strictly under the control of the occupant/tenant. Other functions may be shared. For example, while a tenant may change a thermostat setting to increase cooling, the chiller efficiency and operation are under the control of the owner. The 25% Solution program is oriented to serve the occupant/tenant spaces and does not address items such as central system efficiencies, exterior lighting, elevators and central corridors, which typically are controlled only by the owner.

Measure packages were developed and engineering calculations performed to develop power densities and schedules representing the effect of measures. These schedules were incorporated into the analysis of large and small office prototypes. A decision was made to use "vetted" prototypes already in use for utility program development, so the large and small office prototypes selected were adapted from the Database for Energy Efficient Resources (DEER, 2004-05, version 2.01), a California Energy Commission (CEC) and California Public Utilities Commission (CPUC) sponsored database designed to provide well-documented estimates of energy and peak demand savings values, measure costs and effective useful life (EUL) all with one data source. The prototypes were modeled in four climate zones and five vintages, using the DOE 2.2-45m Building Energy Simulation Computer Program to determine measure impacts and analyze the interactive effect of these measures with the energy performance of HVAC systems. The results of this analysis, shown in Table 1, indicated that the lighting and plug load measures on a stand-alone basis combined to provide nearly 25% site electrical savings in all models.

The modeling determined both source energy and site total net energy savings. Source energy savings was calculated using a simplified ratio of 10,239 BTU/kWh rather than the more complex Time Dependent (TDV) method. The TDV method was considered too specific and complex for this model that was intended to vet the 25% Solution across a multiple areas of the country.

TABLE 1. RANGES OF TENANT ELECTRIC MODELED SITE AND SOURCE ENERGY SAVINGS FOR EQUIPMENT AND LIGHTING MEASURES ONLY

CITY	BUILDING SIZE	TENANT SITE ELECTRIC ENERGY SAVINGS FROM MODEL (%)	TENANT ELECTRIC SAVINGS RANGE (kWh/ft²/yr)	NET TOTAL SOURCE ENERGY SAVINGS FROM MODEL (%)
Boston	Small	24 - 28	2.7 – 2.8	15 - 17
	Large	22 - 28	2.8 – 2.9	15 - 20
Los Angeles	Small	24 - 27	2.9 – 2.9	23 - 26
	Large	18 - 25	2.8 – 2.8	14 - 21
San Francisco (Bay Area)	Small	26 – 29	2.8 – 3.0	22 - 25
	Large	20 – 27	2.8 – 3.0	15 - 22
Lake Tahoe (Mountains)	Small	23 - 26	2.7 – 2.7	16 - 19
	Large	22 – 26	2.8 – 2.8	15 - 19

Interactive effects, particularly the impact upon gas used for heating, generated a wide range of results that reduced total savings, on a source basis, below the 25% target. This impact is moderate in Los Angeles and San Francisco, California, but substantial in Boston, Massachusetts, and Lake Tahoe, California.

To offset these interactive effects, additional measures are suggested in this report to increase HVAC performance and boost expected electrical and total energy savings. These measures include a Performance Review of HVAC and lighting operation and several options for advanced metering. Incorporating these measures would expand the boundaries of an Office of the Future program beyond tenant space to consider some whole-building systems. However, including these additional low-cost HVAC measures and feedback to tenants and owners can assure electricity savings from lighting and plug load equipment are fully realized and provide greater total savings.

Other measures are focused upon changing office real estate business practices and behavior to ensure the persistence of energy savings and develop a mindset of continuous improvement regarding office energy use. Energy savings for these measures were not estimated due to a lack of performance data, but these strategies are extremely likely to both increase total savings and improve savings persistence. They will be included in pilot efforts to determine the comprehensive savings possible with program elements that influence tenant behavior.

The solutions available through the OTF Consortium are designed to fit in a platform which, from the customer's perspective, will be simple, flexible and stable over time. Tenants and owner/managers will be able to create performance packages that work for them. For example, there are three primary lighting design options for each type of office space, three major office equipment energy reduction strategies and two options for tenant and whole building metering, HVAC performance review and miscellaneous workstation equipment. Tenants can simply choose from a chart the options which work for their situation; the savings for the total package will still be in the 25% range. In addition to "hardware" measures, the program includes multiple options to sustain and improve savings over time, such as procurement strategies or participation in green building programs, again with multiple options for customer participation. Tenants and owners who implement the 25% solution will receive simply-structured incentives to design efficient lighting, install plug load measures per the options packages, undergo a simple "Low Cost/No Cost" performance review, and

install/participate in other elements of the package. A sample chart of solution options/packages for the 25% Solution is shown in Appendix C.

The 25% Solution is the initial offering developed by the Office of the Future Consortium, based on improved integration of readily available technologies and a basic set of best practices related to design and operations. Pilot programs are being planned for 2009 to document savings through field measurement and finalize package elements and marketing strategy. Packages capable of greater savings levels (50% to 100%) are planned for later development, with the research and development agenda for the 50% Solution package planned for 2009-2010.

Office of the Future

Mission Statement

As public policies to address global warming and rising energy costs are strengthened, new ways to deliver energy efficiency programs are needed. The Office of the Future Collaborative (OTFC) strives to uncover a strategy for efficiency in commercial office buildings that incorporates integrated design strategies and proven technologies, innovative leasing arrangements and an enhanced partnership between the interested parties to create a new standard for programmatic goals.

The 25% Solution

The 25% Solution developed by the Office of the Future Consortium strives to reduce the total energy use in office spaces by 25% or more, on a source basis, using Title 24–2005 Building Energy Efficiency Standard as a baseline for minimum performance in California and ASHRAE 90.1-2004 Building Energy Efficiency Standard as the minimum baseline for the rest of the country. The 25% Solution is primarily structured to affect the TI process, where new or existing office spaces are customized for use by a specific tenant, but is also applicable in any new construction or retrofit project.

The 25% Solution reduces the energy used by lighting, plug loads and HVAC systems using a comprehensive “Systems” approach that also improves lighting quality and air conditioning/heating performance. The 25% Solution works for property owners/managers, tenants, design professionals and contractors to create a more responsive and responsible office environment—one that better serves tenant needs while reducing energy costs, enhancing property values and delivering a reduced carbon footprint.

The 25% Solution is the initial offering developed by the Office of the Future Consortium, based on improved integration of readily available technologies and a basic set of best practices related to design and operations. Additional packages capable of greater savings levels (50% to 100%) are planned for later development, with the research and development agenda for a 50% Solution package being created concurrently with the launch of the 25% Solution.

Office of the Future Consortium

The Office of the Future is a consortium of some of the nation’s largest energy utilities and private companies, formed to find new ways to address energy efficiency in the office segment of the commercial buildings market. Led by Southern California Edison (SCE), the Consortium’s other members include:

Pacific Gas and Electric	Trane Company
National Grid	IBM
NSTAR	Microsoft
New Buildings Institute	Sempra Energy

BC Hydro Consolidated Edison

Sacramento Municipal Utility District

Pacific Northwest National Laboratory (funded by U.S. DOE)

California Lighting Technology Center

Potomac Communications Group

The partnership behind the development of the Office of the Future is already very deep and broad, but the consortium expects it to expand substantially in the near future.

PHASE ONE DEVELOPMENT ACTIVITIES

Office of the Future activities began with an energy efficiency research project named "oPod," focused upon improving the energy efficiency and demand response of office buildings. The founding premise of oPod was that it would take more than widgets – incremental improvements in discrete, isolated technology areas – to effect the kinds of change needed to reach new levels of efficiency. oPod's goal, which continues as the foundation of Office of the Future efforts, was to apply a systems approach, leverage existing technologies, expand the useful data pool and ultimately establish a new model for energy efficiency improvements.

oPod scanned a broad spectrum of technologies and energy factors – thermal comfort, lighting systems, building envelope, plug loads – to overlay economic and human factors analysis on traditional engineering and product improvement efforts to ensure that energy improvements are applied in context and consistent with key economic and human factors drivers. The ultimate goal was a series of "technology packages" that leverage mutual benefits, are cost-effective to implement, utilize plug-and-play solutions and, above all, are viewed as bona fide improvements by end users. oPod proposed a series of technology/topic teams to develop hypotheses, identify partners, develop effective metrics and design appropriate research and experiments to build out new models for workable, systemic solutions for energy efficiency in the workplace.

The Operating Team, which has evolved into the Office of the Future Project Advisory Group led by SCE, is charged with coordinating task team efforts and appointing Integrators – individuals focused on sharing information across teams – to facilitate the systems approach.

PHASE TWO ACTIVITIES

The Project Advisory Group (PAG) steered the OTF Consortium to focus on the TI process and develop an initial "plug-and-play" solution set and initiate longer-term research for deeper savings. A target was set to develop the 25% Solution before the end of 2008, ready for rapid piloting and roll out. As the 25% Solution was introduced to the market, parallel efforts would continue to develop 50% and 75% solution sets for later introduction.

SCE contracted with New Buildings Institute (NBI) to lead the development of the 25% Solution and craft the research and development agenda for the 50% Solution. Pacific Northwest National Laboratory (PNNL), with funding from the U.S. Department of Energy (DOE), is leading the development of the integrated lighting solutions portion of the 25% Solution as part of the national Commercial Lighting Solutions (CLS).

NBI incorporated the lighting designs produced by Pacific Northwest National Laboratory (PNNL) and the plug load, HVAC systems review and metering recommendations of the technology/topic teams to create the finished 25% solution. NBI then performed energy

modeling analysis and vetted the proposed measures to verify the delivery of 25% savings in representative commercial office buildings.

This report provides the market strategy, technical strategy and associated program concepts that can be used to develop an initial program offering around the 25% solution. The report briefly outlines the structure of research for the 50% solution to be directed by the PAG and describes the analysis techniques used in vetting the 25% solution.

PHASE THREE - NEXT STEPS

The Project Advisory Group has approved the methodology of the 25% solution and conducted a strategic coalition meeting among commercial office real estate owners and managers, utility personnel, design build firms and engineering firms to present the 25% solution. The outcome of the meeting was approval by the interested parties and a general consensus regarding the economic and implementation issues surrounding the 25% solution.

The Project Advisory Group approved subsequent activity on two fronts: (1) the 25% solution will enter an integration and piloting phase in partnership with some of the participating real estate and design firms and the member utilities; (2) the PAG will establish a detailed roadmap for research and analysis into the 50% solution over the next 18 months.

The timing of the rollout of the 25% solution will depend on the pace of the piloting and implementation process but will be expedited by the PAG when possible to take advantage of the buy-in expressed by the coalition of firms and OTF Consortium members.

The 50% solution research plan will consist of design research and pilot projects in conjunction with the participating firms. The timeline is anticipated as 18 months for completion and release of a 50% solution with pilot project results and energy modeling. The research plan is anticipated to commence January 2009.

THE MARKET: EXISTING OFFICE SPACE

MARKET DESCRIPTION

Offices are the largest market segment in the commercial sector, consisting of 17% of total floor space and buildings and 19% of primary energy consumption. Energy usage has remained relatively flat in existing offices for many years, as advances in energy codes and energy-related technologies are offset by countervailing trends of increased office equipment energy use and increased intensity of space utilization.

Utility and green building efforts are beginning to more effectively address energy efficiency in new commercial construction, but the very large existing office building market has not been addressed in a comprehensive way by utility sponsored energy efficiency efforts. In particular, energy use under the control of tenants has proven difficult to address, as lease terms and relatively short-term occupancies have created financial and responsibility barriers to market transformation.

EXISTING OFFICE BUILDING CHARACTERISTICS

The typical office building is not large, averaging around 15,000 square feet, a figure that is surprisingly consistent across the country and across office building vintages. The average office is most likely to use packaged HVAC units for both heating and cooling and to have a median lifetime of 73 years (2007 Buildings Energy Databook[3]). But discussion of the typical office masks the incredible diversity seen in the office building population.

SUMMARY OFFICE BUILDING CHARACTERISTICS

The 2007 Buildings Energy Databook also notes that office buildings comprise the largest commercial building type as a percentage of total floor space, followed by retail, education and warehouse and storage. Further data on office building lifetimes and sizes are below:

OFFICE FLOOR SPACE

- 17% total commercial floor space
- 17% total commercial buildings
- 19% total primary energy consumed

Existing office buildings are likely to remain in use for a long time. The building lifetimes for both small and large offices are essentially the same.

EXPECTED OFFICE BUILDING LIFETIMES

- Median life: 73 years
- 66% survival: 52 years (2/3 of buildings constructed today will last 52 years)

- 33% survival: 103 years (1/3 of buildings constructed today will last 103 years)

Across the country, the typical office building is of modest size, with the average floor space per building not varying greatly across vintages.

AVERAGE OFFICE BUILDING SIZE (BY VINTAGE)

- 1959 or prior: 12,400 ft^2
- 1960 to 1969: 16,400 ft^2
- 1990 to 2003: 14,200 ft^2
- All: 14,800 ft^2

The installed base of various HVAC system types represents one of the greatest areas of commercial building diversity (Table 2). Office energy efficiency measures, whatever their focus may be, will typically create interactive effects with HVAC systems. The installed HVAC system type and the manner in which it is controlled will help determine whether a particular building is a good candidate for the 25% Solution.

TABLE 2. HVAC SYSTEM TYPES (MILLION FT^2, 1999 AND % OF TOTAL FT^2)

SYSTEM TYPE	MILLION FT^2	% OF TOTAL FT^2
Individual Air Conditioning	1,257	12%
Packaged Units	4,450	43%
Central Variable Air Volume	2,322	23%
Central Fan Coil Units	484	5%
Central Constant Air Volume	1,161	11%
Not Cooled	561	5%
Total	10,235	100%

The diversity of office building characteristics will be seen to have a significant impact upon the energy savings that can be attained from various measures. Because energy is delivered and consumed on a whole building basis, the interactive effects of building components and systems is an unavoidable reality for any effort to understand the benefits to be gained from a standard set of measures applied across a diverse population.

However, with proper selection and use of office building prototypes it should be possible to predict, with reasonable accuracy, the average results from a program - assuming the characteristics of a given population of buildings have been accurately represented. For this current analysis, large and small office prototypes from the California DEER program have been selected.

OFFICE ENERGY USE

Office energy end uses vary. This study's prototypes assume heating is provided by natural gas and that other uses are met by electricity. Baseline office energy use was discussed at the March 2008 Office of the Future PAG meeting in terms of data gathered for the California Commercial End-Use Survey[4] (CEUS).

Using the CEUS data and looking at electricity use, summarized in Table 3, note that usage density in KWh/ft^2 within large offices is roughly 30% higher than small offices. Office equipment and ventilation are more dominant in large offices compared to small offices. Table

3 also shows the five principal end uses that account for more than 80% of use, of which only 30% is comprised of space cooling and ventilation for small offices compared to 37% for large offices. Lighting and equipment loads comprise about 50% of electrical energy density in both office types.

TABLE 3. CEUS DATABASE —OFFICE KWH/FT^2-YEAR AND TOP FIVE END-USES BY PERCENTAGE

	kWh/ ft^2-yr	Interior Lighting	Cooling	Office Equipment	Ventilation	Exterior Lighting	Total
Small Office	13.7	29%	20%	17%	10%	7%	83%
Large Office	17.7	25%	20%	20%	17%	3%	85%

Comparing end use usage density on a total energy basis, in kBTU/ft^2, for small and large offices in Table 4 and Table 5, respectively, indicates these relationships shifting. Large offices on a total energy basis use nearly 50% more energy than small offices. Heating becomes more dominant in large office offices than small offices. This will become important when considering measures that reduce sensible heating through electrical measures. This also indicates larger offices utilizing more built-up VAV systems that may use gas for VAV reheat.

TABLE 4. CEUS DATABASE — SMALL OFFICE KBTU/FT2-YEAR AND TOP FIVE END-USES BY PERCENTAGE

	Total kBTU/ ft2-yr	Interior Lighting	Heating	Cooling	Office Equipment	Ventilation	Total
Small Office	55.21	24%	17%	16%	14%	8%	79%

TABLE 5 . CEUS DATABASE — LARGE OFFICE KBTU/FT2-YEAR AND TOP FIVE END-USES BY PERCENTAGE

	Total kBTU/ ft2-yr	Heating	Interior Lighting	Cooling	Office Equipment	Ventilation	Total
Large Office	82.31	23%	18%	15%	15%	13%	84%

The fraction of end use density that serves HVAC functions is significant in all three tables. The data shows that in electrical energy density the HVAC contribution is close to 50% for both types but on a total energy basis the HVAC contribution grows to 51% for large offices compared to 41% for small offices and is driven by ventilation and heating. Complete CEUS information is available at http://www.energy.ca.gov/ceus/.

MARKET AND SERVICE STRATEGY

The largest areas of energy use in office buildings are interior lighting, plug loads (computers, office equipment, etc.), ventilation to ensure adequate fresh air, and heating and cooling. Heating has generally been considered more important in colder climates and smaller office buildings, but depending upon a building's vintage and the design of its HVAC system, reheat—the need to first cool air for delivery to critical zones and then to reheat it before final delivery—can generate as much (or more) heating load on HVAC systems as climatic conditions. Elements of the HVAC system may serve the entire building, but some subsystems and components are specific to office space areas and/or tenant control.

While certain energy end-uses, such as plug loads, are strictly under the control of the occupant/tenant, other functions may be shared: for example, a tenant may change a thermostat setting to increase cooling, but the chiller efficiency and operation are under the control of the owner. The 25% Solution program is oriented to serve the occupant/tenant spaces and does not address items such as central system efficiencies, exterior lighting, elevators and central corridors, which typically are specifically controlled only by the owner.

TARGET MARKET: TENANT IMPROVEMENT PROCESS

The 25% Solution is designed to influence decisions made in the tenant improvement process, with some additional elements to improve/sustain savings over time. During the TI process, office space is typically vacant, space is reconfigured, decisions are made regarding lighting fixture selection and design, and the HVAC system may need to be modified in response to changes in space use or loads. The TI process occurs in both existing buildings and new construction/renovation, although opportunities during initial new construction/renovation TI's may more easily address opportunities such as HVAC distribution and control. TI's are regular events in the leased space market (commercial real estate), and similar processes are used in corporate and government office space to refresh the space and to accommodate changes in use over time.

The TI process creates an opportunity to change significant energy-related elements of buildings while both the tenant and owner (or owner's representative) are actively engaged in negotiation of changes to the office space and financial terms of the lease. Owners will typically provide a "TI allowance" to fund TI's. This allowance is negotiable, based on market conditions, lease terms, and/or plans for general property improvements or market repositioning. It is incorporated into the lease agreement and repaid by the tenant over the lease term. Tenants can and frequently do contribute additional funding to the TI process, either in cash, increased rent or longer lease terms, to ensure that the space is suitable for their needs. In general, there is both a financial negotiation and space design process in play, creating opportunities to achieve deeper energy savings while addressing how costs can be shared and benefits can best be attained by both owner and tenant, with minimal construction-related disruption to the occupants.

The entire package of 25% Solution measures will be supported as a "plug-and-play" system that can readily be implemented during (and following) the TI and is directly usable in an extremely broad array of office spaces. Anticipated electrical energy savings are robust, about

25% beyond typical office energy use (after adjustments are made for a code lighting baseline); for spaces with older lighting systems, the savings relative to the pre-TI space could be substantially higher. Demand control is included as part of the package, enabling office spaces to participate in utility demand reduction programs, reducing electricity charges even more.

MARKET MODEL/BUSINESS CASE

The core of the 25% Solution is to modify the TI process with information and incentives, influencing both tenant and owner decisions. Tenants and owners have very different perspectives on the business benefits of the 25% Solution, but a strong business case can be built for both parties, as well as the design and construction firm that would complete the TI.

PROPERTY OWNERS/MANAGERS

For Property Owners/Managers, the 25% Solution will:

- Enable the manager to incorporate additional energy-related improvements into the TI package to better meet tenant needs and expectations. This will become increasingly important as high profile tenants gravitate to newer, greener buildings and more tenants want the benefits of green buildings.
- Differentiate their property or their management style, by offering more highly efficient, higher performing buildings as vacancy rates increase in a more competitive market.
- Secure financial incentives to reduce the costs of needed upgrades.
- Provide advice from a third party regarding the most appropriate places to spend capital and maintenance dollars to save energy.
- Improve internal rates of return and increase asset value. Early market research[5] indicates that green and energy efficient properties lease more rapidly, may enable higher rents and have higher asset values.
- Reduce operating costs (for utility bills paid by the owner) thereby improving margins. (Realized energy bill reductions may be substantially greater than 25% when measured from typical operating conditions rather than an energy code baseline.)
- Improve the market appeal of their properties through enhanced lighting design and state-of-the-art control technology.
- Reduce comfort complaints, thereby increasing tenant satisfaction and the likelihood of tenant retention and reducing the costs of resolving complaints.
- Support or enable participation in Energy Star, LEED-EB, LEED-CI or other recognition programs.
- Assist in taking advantage of additional utility programs to further reduce costs.

TENANTS

For Tenants, working with the 25% Solution will:

- Provide financial assistance to secure a higher level of office space upgrades, specifically including a better lighting design and a review of HVAC performance issues.

- Support employee comfort, satisfaction, retention, health and productivity.
- Support corporate commitments to carbon reduction and energy efficiency.
- Increase control over their operating costs and comfort conditions.
- Reduce wasted energy, saving energy costs directly if paid by the tenant.
- Support participation in LEED-CI or other energy/environment recognition program.
- Enable participation in demand control programs, further reducing energy costs.
- Provide advice from a third party regarding the best places to save energy in their daily office operations.
- Secure training and/or informational metering services to help maintain or improve energy performance over time.

DESIGN AND CONSTRUCTION

For Design and Construction Firms, working with the 25% Solution will:

- Demonstrate a high level of professionalism and competency in their field by being associated with a nationally developed and recognized program.
- Increase revenues per square foot, which may be vitally important in an economy experiencing a downturn in construction.
- Enable learning of new skills, both at the employee and firm level.
- Create new business partnerships.

MARKETING STRATEGY/PARTNERSHIPS

It is difficult for an energy efficiency program to even discover when a lease transaction/TI process is beginning. Therefore, core marketing for the program will be conducted through partnership programs with property owners/managers, designers active in the TI market, larger tenants/owner-occupiers and existing utility relationships with key customers in the office market. Some more general advertising and public relations efforts will be provided to the general business community to increase awareness.

The 25% Solution is both a national program and a program directly supported by participating utilities at the local level. At the national level, the program will pursue national accounts (large commercial real estate companies, real estate developers, design-build firms, large design firms) and will work with key trade associations, such as Building Owners and Managers Association (BOMA), International Facility Managers Association (IFMA), American Institute of Architects (AIA), American Society Interior Designers (ASID), American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) and others to market the program to their memberships through presentations and articles. These efforts will be coordinated with local level partnerships and associations with local/regional chapters.

Participation in the 25% Solution will help facilitate achievement within other, well-established recognition programs. These programs are:

- *Energy Star Buildings* recognizes the top 25% of commercial buildings in measured energy performance.
- *LEED-EB (Existing Buildings)* includes the measured energy performance of commercial buildings on a whole building basis.

- *LEED-CI (Commercial Interiors)* extends LEED recognition to the tenant level, both in new and existing buildings.
- *BOMA Energy Challenge* builds on the Energy Star methodology to improve the performance of the existing portfolio of buildings of their members.

25% TECHNICAL SOLUTION

The 25% Solution is comprised of a package of categorical measures and design that provide an integrated solution to reduce energy in office spaces. The general areas of the 25% solution are:

- High Quality Lighting Design
- Efficient Plug Load Measures
- HVAC Performance Review
- Advanced Metering
- Demand Response Thermostats (where applicable)

The 25% Solution is designed to be a low-impact, high efficiency, easily implemented integrated solution coupled with tenant and owner education to ensure savings persistence.

HIGH-QUALITY, ENERGY-EFFICIENT LIGHTING DESIGN

Energy and demand can be reduced through a combination of lighting technologies, luminaire selection, lighting layout and controls. The lighting packages aspects developed for the 25% Solution feature energy efficiency and offer advanced control features to adjust to personal preferences, daylight availability, vacancy in workspace, and demand control. Recommended designs enhance lighting quality and provide options for personal control, which have been linked to increased visual comfort, satisfaction, health and productivity.

The lighting packages proposed for the 25% Solution are still under detailed development, although general characteristics are sufficiently defined to support the analysis and conclusions in this report. The lighting packages are being developed by PNNL as part of the Commercial Lighting Solutions (CLS) project, funded by the U.S. Department of Energy. Office of the Future is leveraging the DOE CLS project to take advantage of an infrastructure that delivers integrated design solutions through an interactive web-based tool, so as to support wide-scale implementation. Most of the development work of a set of a parallel retail lighting packages has been completed, and can be reviewed at http://www1.eere.energy.gov/buildings/lighting-solutions.html. Detailed office lighting designs have been developed, and stakeholder review and input to the designs will occur in the second and third quarters of 2009. Once the designs have been revised based on this input, the designs will be integrated into the web tool.

The goal of the CLS project is to reduce energy use in lighting by 30% relative to ASHRAE/IESNA Standard 90.1-2004. The proposed solutions will include lighting power density (LPD) reductions beyond code (e.g., Std. 90.1-2004), but much of the savings is anticipated to come from improved control strategies. Energy savings from lighting have historically resulted primarily from component retrofits in existing fixtures. Energy-efficiency technology options in lighting have achieved significant market penetration and thus offer diminishing returns. Deeper savings can be achieved through more complex solutions that do not solely focus on one element of technology, i.e., integration of all elements of the system considering the interactions and relationships of lamps, ballasts, fixtures, lighting design, daylighting, and lighting controls. The use of a synergistic combination of strategies can provide optimum energy savings as well as lighting quality.

The CLS web tool will allow users to select different types of spaces in offices (private office, open office, conference rooms, and corridors), and then select one of several predetermined lighting solutions for each type of space. The web tool will produce a design and lighting specification that can be directly implemented for the project, as well as a lighting energy savings estimate. Office TI projects that employ professional lighting designers can base elements of their design on one of the predetermined templates, or create alternative designs with similar LPDs and control strategies that can meet their energy reduction goals.

The DOE CLS program provides a multi-faceted strategy to provide the needed "how to" guidance in support of programs that are reaching far beyond codes and standards. The program provides scalable lighting energy-efficiency solutions using high-performance products, daylighting, and lighting controls. For each space type, design options have been created that offer options in terms of overall lighting strategy. Control recommendations are layered to improve energy savings and react to the presence of daylighting, occupancy of a space, and/or personal dimming, depending on the choices made. The designs have been developed by a national team of leading lighting designers to both reduce energy use and to create a high-quality office lighting environment based on the most recent research results. Details of systems and choices used to support the OTF modeling analysis are found in Appendix A.

The CLS packages are delivered to the market via a web tool that guides end users through a decision process to help them make the best choices for their needs. The web tool guides, analyzes, delivers, and measures. The use of the Internet bridges the gap between theory and action because it allows for a dynamic decision process, flexibility of use by the end user and allows the content to develop in a continuous improvement process. Using the website as the portal for delivery also allows for marketing and outreach, education and training of the end user, interaction to help provide direction to the most relevant solutions, and – importantly - the ability to measure energy savings against a baseline. The web tool allows for all of the technical information to be easily downloaded at the end of the selection process. Office of the Future sponsors benefit by having actionable solutions for customers and energy analysis sufficient to create programs designed around kWh rather than LPD or component-based rebates.

The web tool includes the following elements: (1) front page information and orientation; (2) user and project registration; (3) input screens to provide project info about building type, square footage, operations, baseline code, and more; (4) a decision-tree process to guide user selections using design vignettes, controls strategies, lighting equipment specifications, calculation examples, and implementation guidance; (5) energy calculations to show savings in kW and kWh; (6) a summary page with a link to download documentation based on user choices; and (7) links to utility and energy-efficiency programs where appropriate for rebates and incentives.

The lighting elements of the 25% Solution will provide an improvement to the office environmental conditions by improving lighting quality and occupant comfort. In addition to the positive impact on workers for tenants, these improvements can also impact the value of the real-estate portfolio by increasing property asset values and leasing. As a result of these significant indirect or non-energy benefits, these improvements can have a positive impact on customer relationships.

EFFICIENT PLUG LOAD MEASURES

Plug loads are simply devices that are plugged into electrical outlets. Primary uses include computers and peripheral equipment (speakers, monitors), office equipment (copiers), kitchen

equipment, vending machines, and a wide variety of other devices from cell phone chargers to personal space heaters.

Plug load efficiency measures either:

- Reduce the energy consumption of active equipment;
- Switch off inactive equipment; or
- Eliminates extraneous equipment.

This report categorizes office plug loads into two general categories:

- *Office Equipment (OE):* defined as computers, printers, faxes, phones, copiers, and other plugged in pieces of equipment used in the course of business.
- *Miscellaneous Equipment (ME):* Desktop speakers, vending machines, chargers, kitchen equipment, electronic display items, desktop radios, etc.

This categorization is adopted from work by Lawrence Berkeley National Lab (LBNL)[6,7].The following summary of measure descriptions shown in Table 6 were modeled as part of the 25% Solution modeling evaluation. The following descriptions, savings, and cost data were drawn from various sources.[8,9,10,11,12,13,14,15,16]

TABLE 6. SUMMARY OF DIRECT PLUG LOAD MEASURES IN THE 25% SOLUTION BY EQUIPMENT TYPE

EQUIPMENT TYPE	MEASURE NUMBER	MEASURE	TYPICALLY REPORTED ANNUAL SAVINGS (KWH)	COST PER UNIT ($)
Desktop Computer and Monitor	OE 1	Power Management	225	20 - 25
Workstation Miscellaneous Equipment	ME 1	Occupancy Power Strip (preferably hard-wired as part of electrical system or outlets controlled by master timer)	200	90
Laser printer	OE 2	Power Management or Night Timer	500	20 - 25
Copier	OE 2	Power Management or Night Timer	600	20 - 25
Fax	OE 2	Power Management or Night Timer	50	20 - 25
MFD, other	OE 2	Power Management or Night Timer	N/A	20 - 25
Vending Machine	ME 2	Vending Miser	1600	179
Coffee Maker	ME 3	Night Timer	112	20 - 25
Small Refrigerator	ME 4	Upgrade	Var.	Var.

OE 1: Install Networked Power Management Software and Configure Workstations

Network control of desktop and monitor settings by a central IT administrator helps ensure all desktops have sleep and hibernate settings properly set. Many states have programs that provide rebates for software to control network management settings. Savings are reported to be reliable and cost effective.

ME 1: Install Occupancy Controlled Power Strip at Workstations

The occupancy sensor controlled power strip is a measure that is widely known and has provided verified savings. Two well known products[a] are the Isole and the Smart Strip. It is recommended that a hard-wired version of the measure be used when possible where the device is incorporated into the workstation supply service outlet.

OE 2: Install Power Management for Other Office Equipment or Install Nighttime Shut-off Timer for Other Office Equipment

Some other miscellaneous office equipment continues to use phantom power when plugged in. Nighttime shut-off timers installed on these discretionary appliances or their power strips will eliminate all off-hours loads. Networked office equipment can be also included in the power management strategy and controlled by the IT administrator to achieve the desired shutdowns.

ME 2: Install Vending Miser Control on Refrigerated Vending Machines

The Vending Miser[b] uses occupancy sensing and advanced algorithms to switch refrigerated vending machines off. Many utilities have programs that provide incentives for the installation of vending misers. (Note that Vending machine efficiency is covered, in California, by Title 20)

ME 3: Install Nighttime Shut-off Timers on Coffee Makers and Water Coolers

Water coolers and coffee stations are not considered high AEC devices but do exist in most commercial office prototypes. Heating and cooling of water requires high power and both devices are frequently left on outside of normal operating schedules. A simple programmable night timer for each item will ensure no off-hours operation.

ME 4: Replace Old and Inefficient Office Refrigerators in Office Kitchen

Replace inefficient refrigerators.

PERFORMANCE REVIEW

The 25% Solution includes a service to review the performance of Lighting and HVAC systems and tune their performance, if needed, to assure that the systems are functioning properly. This can save energy, as demonstrated in *Energy Savings* below, as well as reduce comfort complaints.

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[a] Isole® offered by WattStopper and the Smart Strip are both off-the-shelf products that are incentive by utilities such as PG&E. Energy savings data was provided by WattStopper for this project in addition to published evaluations. Anecdotal evidence indicates that if not hard-wired the power strips may be removed and taken home by office personnel.

[b] The VendingMiser® manufactured by USA Technologies has also been offered as a core feature of many utility programs and has been evaluated and shown to produce savings. It uses occupancy sensors and adaptive algorithms on patron behavior patterns to ensure power is supplied only when needed. http://www.usatech.com/energy_management/energy_vm.php

A Performance Review (PR) is a systematic process of identifying energy inefficiencies in existing systems that can be cost-effectively corrected, and to restore or improve the system's original level of energy efficient operation. This process covers what are commonly referred to as "low-cost, no-cost" measures addressing the following areas:

- Controls
- Heat Exchange Equipment
- Core Heating and Cooling Equipment
- Staff

A listing of the measures recommended for inclusion, employing a condensed version of the EPA Retro-Commissioning process, are detailed in Appendix B.

Performance Reviews and building tune ups have the potential to deliver significant electricity and gas savings but, with the exception of tenant spaces served by dedicated HVAC systems, will require review of HVAC systems that are shared among tenants (or serve the entire building). As valuable as these strategies may be to generate and ensure the persistence of savings, they may cross the boundaries of a tenant space improvement solution set in larger, multi-tenanted buildings.

The PR has a different recommended procedure for each of two fundamentally different HVAC scenarios. All buildings that enter the program will consist of the owner and at least one tenant. In cases where there is a single tenant for the entire building (or the tenant has a dedicated HVAC system or systems) the tenant will have greater freedom and leverage over what may be done during the PR. In large office buildings more likely to have built-up systems and multiple tenants served by central systems there are fewer options. The recommended PR procedures in the appendix reflect the differences between these two common situations.

The PR is integrated with the advanced metering (described below) and provides a powerful combination to ensure thorough analysis and persistence of savings. The PR will also serve to assist in the integration of the Demand Response Thermostat in situations where both DR and an advanced programmable thermostat are recommended as upgrades.

ADVANCED METERING

Verification of performance and the ability to sustain persistence of savings are very valuable and can be enhanced by metering strategies. An interval data meter with remote data capabilities—a system that meters energy data at intervals of one hour or less and relays it to a remote database—serves several needs that will result in a more successful, more cost-effective program.

- Evaluations[c] have shown that retro-commissioning programs are more effective when monitoring at whole building levels is incorporated. ("Bulls-Eye Commissioning: Using Interval Data as a Diagnostic Tool.") The initial and final conditions can be seen explicitly and a new performance baseline created.
- In existing office spaces with less than whole building occupancy it is difficult to identify a performance baseline. Interval metering options can provide a basis for reviewing performance over time.
- The building owner or tenant can use the interval data to periodically evaluate the operation of major building systems and identify maintenance needs.

[c] Most notably: Price, W and R. Hart, "Bulls-Eye Commissioning: Using Interval Data as a Diagnostic Tool.", Eugene Water and Electric Board, Eugene, OR.

- Night and weekend operating schedules can be readily verified and monitored.
- Metering data can be leveraged using performance benchmarks and indicators to ensure optimal operation.
- Interval data will provide the utility with M&V evaluation data. Meter installation will eliminate after-the fact data recovery costs, which can be significant on a per square foot basis.

Advanced Metering Infrastructure (AMI) programs are underway in many utility service territories[d] that permit owner's access to the interval data at the utility meter or permit the upgrade of the meter to a pulse output meter with data collection. For utilities that are not committing to AMI or wish to avoid the pulse output upgrade, the building should be outfitted with an advanced metering system from a third-party vendor

Where AMI programs are not available, but whole building information is desired, an advanced third-party interval meter can provide these functions at an approximate cost of $2,500 installed (main building and tenant sub-meter). Bulk purchase, by either an individual utility or a nationwide OTF program, would result in a significant reduction in costs.

Alternatively utility costs for a meter upgrade range from $200 – 1300 depending on the utility[17]. An electrical meter upgrade provided for the building combined with a third-party data acquisition system, as typified by the examples in Table 7, may provide a lowest cost solution for the measure. Table 7 also provides installed costs estimates.

TABLE 7. SOME VENDORS OF THIRD-PARTY METERING SYSTEMS

EXAMPLE PRODUCT	VENDOR	COMMENTS	EST. INSTALLED COST ($)
AcquaLite	Obvius	Complete system + Internet	2000
Class 3000	E-Mon	Meter + software	1300
HOBO U30	Onset	Complete system – Cellular	2000
Energy Tracker	Energy Tracker, LLC	Meter only + Custom software	1200

In certain buildings the tenant space that is undergoing the TI process will comprise the entire building's leased space. In these situations the tenant may utilize the interval meter data for feedback regarding energy savings practices. In large buildings with multiple tenants the tenant space undergoing the TI will not be able to use the advanced interval data. Ideally these tenant spaces are revenue sub-metered but revenue sub-metering is not always possible.

The OTF Consortium recommends installation of a non-revenue sub-meter ("check meter") and energy display device in the TI package of the participating tenant space when wiring configurations permit isolation of tenant loads. At a minimum the device will display power at the electrical distribution panel that serves the tenant space.

In a commercial office study by the Carbon Trust[18] in the United Kingdom, simply metering the office identified 10% potential savings, with 3% implemented by tenants on their own. With the addition of utility advice, savings of 15% were identified, with 7.5% of the identified measures implemented.

[d] The Smart Metering Projects Map is a Google® map is a useful reference showing smart metering initiatives in the U.S including details of technology used, dates, and volumes. This map is maintained by the Energy Retail Association in London, England, UK. http://www.energy-retail.org.uk/

This display, coupled with tenant education and the assignment of an office advocate responsible for office energy management, will help assure measure persistence. Table 8 describes an example system with a low price point that would be suitable as a display. Research shows that peer pressure improves energy efficient behavior. Further, using the non-revenue meter tenants can:

- Verify that all equipment and lights are off when exiting
- Set goals for future performance improvements
- Ensure adherence to corporate miscellaneous equipment policies

TABLE 8. ENERGY DISPLAY DEVICE AND CHECK METER PRODUCTS

PRODUCT	VENDOR	COMMENTS	EST. INSTALLED COST ($)
Efergy	Efergy Technologies Limited www.efergy.com	Displays and logs energy and power for 1,2 or 3 phase	< 200

DEMAND RESPONSE THERMOSTAT

The 25% Solution includes a new generation of thermostats that can 1) control temperature more closely, reducing temperature swings, 2) are easily programmable, to better match occupancy schedules, 3) are demand control enabled, so that tenants can participate in demand reduction programs. Demand response (DR) thermostats have been demonstrated as effective in areas with demand constraints, but also offer web-based programmability that may provide additional savings to the owner/tenant and the utility.

Tenant spaces with appropriate HVAC configurations—where individual thermostats control unitary equipment large enough to provide cost effective demand savings—should be outfitted with DR capable thermostats and offered participation in the utility DR program.

The cost/benefit relationship of DR thermostats depends on many factors. A California study[19] placed a load requirement of approximately six tons of air conditioning per thermostat control point to achieve cost-effectiveness. This figure was derived using program and equipment costs specific to the utility, region, and payment structure.

Any DR thermostat installed should be of the two-way pager or other stand-alone communicating variety. The cost of backhaul communications will likely reduce the cost effectiveness of other solutions. Table 9 shows data taken from vendor websites and published program evaluations regarding the utilities using demand control thermostats.

TABLE 9. DEMAND RESPONSE THERMOSTAT PRODUCTS

PRODUCT	VENDOR	UTILITIES USING PRODUCT[e]	EST. INSTALLED COST ($)
SuperStat	Comverge	Austin, LGE	~ 320 [12]
ComfortChoice	Carrier	SCE, LIPA, SDG&E, ConEd	N/A
ExpressStat	Cannon Technologies	Duke, KCPL, IPL, LGE, XCel	N/A
UtilityPRO	Honeywell	BGE	N/A

[e] Louisville Gas and Electric (LGE), Southern California Edison (SCE), Long Island Power Authority (LIPA), San Diego Gas and Electric (SDG&E), Consolidated Edison (ConEd), Duke Energy, Kansas City Power and Light (KCPL), Indiana Power and Light (IPL), Xcel Energy, Baltimore Gas and Electric (BGE)

ENERGY SAVINGS

Projections of energy savings attainable from the 25% Solution were developed through a combination of engineering calculations and simulation modeling applied to a large office and a small office building prototype described below. A decision was made to use "vetted" prototypes already in use for utility program development so the large and small office prototypes selected have were adapted from the Database for Energy Efficient Resources (DEER) (2004-05, version 2.01), a California Energy Commission (CEC) and California Public Utilities Commission (CPUC) sponsored database designed to provide well-documented estimates of energy and peak demand savings values, measure costs, and effective useful life (EUL) all with one data source. DEER has been designated by the CPUC as its source for deemed and impact costs for program planning. A user's guide and the data can be found at http://eega.cpuc.ca.gov/deer/.

Building upon characteristics of the prototype offices[20], engineering calculations established typical hourly load profiles for lighting and plug loads, both to establish baselines and to simulate the performance of the 25% Solution measures. Plug load profiles were incorporated into hourly simulations using DOE 2.2-45m. Preliminary modeling runs were performed for four climate zones[f]:

- Los Angeles, California
- San Francisco (Bay Area), California
- Lake Tahoe (Mountains), California
- Boston, Massachusetts

This analysis also considered differing building characteristics (as defined by DEER 2004-5 v2.1), by vintage (building age):

- Pre-1978
- 1978-1991
- 1991-2001
- 2001-2005
- Post-2005

The modeling process for the 25% solution modeled only the directly installable measures of the 25% Solution including the lighting and plug load measures. Performance review, advanced metering, demand response, and education measures that are recommended as part of the 25% Solution were not modeled. The estimates of savings attributed to these actions are discussed categorically below.

[f] All California weather files were TMY2 files from California Climate Zones, Revision 2, 1992, Supplied by the California Energy Commission. Header identifications: Los Angeles (CZ06RV2 WYEC2); Bay Area, CA (CZ03V2 WYEC2); Mountains, CA (CZ16RV2 WYEC2). Boston TMY2 file from www.doe2.com; identification name (bostonma.bin)

The modeling determined both source energy and site total net energy savings. Source energy savings was calculated using a simplified ratio of 10,239 BTU/kWh rather than the more complex Time Dependent (TDV) method. The TDV method was considered too specific and complex for this model that was indented to vet the 25% Solution across a wide area.

OFFICE PROTOTYPE CHARACTERISTICS

The small office prototype is a 2-story 10,000 square foot building served by package single-zone gas furnace/Direct Expansion (DX) cooling units. The primary differences, by vintage, are overall insulation level, duct insulation/leakage and economizer controls. The Pre-1978 vintage does not have an economizer cycle.

The large office prototype is a 10-story 175,000 square foot building served by three variable air volume (VAV) air systems serving multiple zones with fan-less VAV boxes and hot water reheat (gas fired boiler). The primary differences by vintage are the VAV supply air temperature control, envelop insulation levels, windows, duct insulation/leakage, and economizer controls.

> Note: The pre-1978 building is modeled as a constant volume system with reheat (CVRH) with no economizer cycle.

Refer to Appendix F and the DEER website, www.deerresources.com, for detailed information.

SIGNIFICANT MODELING ASSUMPTIONS

Assumptions for the 25% Solution model were made as conservatively as possible to ensure that savings were not over-predicted. The most significant are:

1. **Lighting and equipment densities for the baseline were assumed to be at ASHRAE 90.1-2004 levels in all building vintages.**

   The use of ASHRAE-2004 densities in the baseline assured that the savings would be predicted for any building including those where lighting may have been retrofit in the past. Compare the lighting and equipment power densities shown in Table 10 in the original DEER model vs. the OTF baseline.

TABLE 10. SUMMARY OF OTF BASELINE VS. DEER BASELINE FOR ENERGY DENSITY OF LIGHTS AND EQUIPMENT IN COMMERCIAL OFFICE

	Lighting Energy Density (kWh/ft^2)				Equipment Power Density(kWh/ft^2)			
	Small Office		Large Office		Small Office		Large Office	
Vintage	OTF	DEER	OTF	DEER	OTF	DEER	OTF	DEER
Pre- 1978	3.0	5.9	3.6	7.6	4.1	6.1	4.1	6.1
1978-1991	3.0	4.8	3.6	6.2	4.1	5.8	4.1	5.8
1991-2001	3.0	3.8	3.6	4.9	4.1	5.6	4.1	5.6
2001-2005	3.0	3.5	3.6	4.4	4.1	5.3	4.1	5.3
Post 2005	3.0	3.2	3.6	4.1	4.1	5.1	4.1	5.1

This assumption results in very conservative estimates for savings as result of direct tenant measures. As shown in Table 10 the OTF consortium applied the design tool developed by PNNL to the DEER prototype to find the OTF lighting energy density. This resulted in different densities for the large and small prototype. The modeling process for equipment energy densities used an internal process to calibrate the

energy density using the equipment schedules of the DEER model and a power density from published literature. The resulting assumed pre-measure energy density is significantly lower than the DEER assumptions.

2. **The modeling software assumes that all HVAC systems work as designed**. Obviously this is not the case for the great majority of buildings, but it provides a common baseline assumption. In the field this assumption is not valid, though the extent of which it is not valid is not presented. The modeling of the post-measure performance assumes a Performance Review has occurred and thus accurately represents performance. This assumption results in conservative savings estimates for Performance Review completion.

3. **The model assumes the California DEER model building characteristics and design is appropriate for typical Boston, MA commercial office buildings**. Buildings and HVAC systems in Boston may not exactly reflect the building methods used in California, resulting in a building that is unprepared for the much more severe winter climate.

4. The model assumes that the savings for the participation of a single tenant office in the large office prototype will be a proportional fraction of the savings when measures are modeled as a whole building program.

5. The OTF Consortium considers the boiler modeled in the DEER prototype as severely oversized and the corresponding part-load conditions create inefficient reheat and reduce net savings.

SAVINGS RESULTS – TENANT OFFICE MEASURE MODELING

The complete results for initial baseline and final savings are available in Appendix F. The results looked at five different vintages of building for each size and climate zone and thus the summary results are presented in Table 11 as a range of electrical and net site energy savings percentage and an electrical energy per square foot. Table 11 also reports the project annual demand peak reduction in demand intensity.

Heating in both prototypes is provided by gas fired equipment, either boiler or furnace. The heating energy increase reported in Table 11 is reflected in the net total energy savings[g], on a site basis and source basis shown in Table 12.

[g] Site energy savings is calculated by making 1 kWh electrical savings equal to 3414 BTU and calculating the net savings. Source energy uses 10,239 BTU/kWh as a simplified source energy calculation.

TABLE 11. SUMMARY OF INTERACTIVE BUILDING MODEL SAVINGS FOR EQUIPMENT AND LIGHTING MEASURES IN TENANT SPACE

CITY	BUILDING SIZE (SMALL OR LARGE)	ELECTRICAL ENERGY SAVINGS RANGE FROM MODEL (%)	ELECTRICAL SAVINGS RANGE (kWH/FT^2/YR)	HEATING ENERGY INCREASE RANGE (kBTU/FT^2/YR)	AVERAGE ANNUAL PEAK DEMAND REDUCTION (W/FT^2)
Boston	Small	24 - 28	2.7 – 2.8	5.5 – 6.0	0.9
	Large	22 - 28	2.8 – 2.9	5.2 – 5.6	0.8
Los Angeles	Small	24 - 27	2.9 – 2.9	0.9 – 1.5	1.0
	Large	18 - 25	2.8 – 2.8	2.7 – 5.1	0.8
San Francisco (Bay Area)	Small	26 – 29	2.8 – 3.0	2.6 – 3.4	0.9
	Large	20 – 27	2.8 – 3.0	2.9 – 4.3	0.8
Lake Tahoe (Mountains)	Small	23 - 26	2.7 – 2.7	4.3 – 5.5	0.8
	Large	22 – 26	2.8 – 2.8	4.0 – 5.2	0.8

The lowest savings occurred in the pre-1978 vintage in the large office prototype where the HVAC system is Constant Volume with Electric Reheat and no economizer cycle. This type of system is notoriously inefficient and the program should consider not allowing buildings with this system to participate. Results from this system type are not included in either Table 11 or Table 12.

The results in Table 12 demonstrated to the OTF Consortium that there is a need to address the heating and cooling systems of the target building via a Performance Review (the effects of which were not included in the model). Decreased lighting and plug loads result in decreased need for air-conditioning in the summer but an increased need for heating in the winter thus colder climates, like Boston, have lower net site total energy savings ratio. Addressing the Performance deficiencies of the HVAC system should improve this ratio.

Table 12 demsonstrates that on a source basis, using the assumptions in footnote g, the net energy savings is between 14% and 25% depending on climate zone and size. This again supports the need to provide a Performance Review to improve the net savings.

TABLE 12. SUMMARY OF INTERACTIVE BUILDING MODEL NET SITE ENERGY SAVINGS AND NET SOURCE ENERGY SAVINGS[G]

CITY	BUILDING SIZE (S OR L)	NET SITE TOTAL ENERGY SAVINGS FROM MODEL (%)	NET SOURCE TOTAL ENERGY SAVINGS FROM MODEL (%)
Boston	Small	5 - 6	15 - 17
	Large	7 - 10	15 - 20
Los Angeles	Small	20 - 23	23 - 26
	Large	8 - 15	14 - 21
San Francisco (Bay Area)	Small	14 – 18	22 - 25
	Large	8 - 15	15 - 22
Lake Tahoe (Mountains)	Small	6 - 10	16 - 19
	Large	7 - 11	15 - 19

Detail of Initial and Final Energy Use Intensity for Lighting and Equipment

The lighting model power densities are summarized in Table 13 below. The column "Design Approach" uses a shorthand name to describe some principal configurations described in Appendix A:

- "Recessed" refers to a design based on a curved lensed (2x4) troffer.
- "Suspended" refers to suspended linear fluorescent (direct/indirect) pendants and
- "Intelligent 1" and "Intelligent 2" describe various approaches to intelligent controls and sensor application.
- "Code/Baseline" refers to the baseline requirements for the prototype buildings.

Each design approach was modeled with power density and schedule and the resulting lighting-only electrical energy density reductions are also displayed below. Details regarding the components and strategies of the lighting design approaches are located in Appendix A. Lighting design approaches in Appendix A were applied to the space breakouts for the prototype offices[21] to establish power density and schedule.

Table 13. OTF Lighting Measure Summary

	Design Approach	Annual Energy Use kWh/ft²-yr	Annual Energy Use % below base	Lighting Power Density W/ft²	Lighting Power Density % below base
Small Office	Code/Baseline	2.681	-	0.91	-
	Recessed	1.823	32	0.80	12
	Suspended	1.821	32	0.82	10
	Intelligent 1	1.704	36	0.73	20
Large Office	Code/Baseline	3.196	-	0.91	-
	Recessed	2.598	19	0.83	9
	Suspended	2.161	32	0.75	18
	Intelligent 1	1.911	40	0.72	22
	Intelligent 2	1.969	38	0.76	17

Office and miscellaneous equipment measures were modeled as power density and schedule changes for each space type (e.g. corridor, open office, private office). The total nominal power density change is shown in Table 14 along with the resulting energy density for both initial baseline and final post-measure conditions. The nominal power density change is only on the order of 13% reflecting the modest impact of the measures' ability to reduce the cumulative demand density of all the controlled equipment which occurs during busy weekday hours. Note that the energy basis change is 43% which is line with published case studies where a package of equipment measures similar to the 25% Solution package were installed[22]. This is a result of the measures' ability to produce greater demand density reductions in off-hour periods and the total integrated energy savings effect of those reductions.

TABLE 14. OTF EQUIPMENT MEASURE SUMMARY FOR SMALL AND LARGE OFFICE

	Design Approach	Annual Energy Use kWh/ft²-yr	Annual Energy Use % below base	Equip. Power Density W/ft²	Equip. Power Density % below base
Equipment Measures	Base	4.11	-	1.05	-
	OTF	2.34	43.1	0.91	13.2

SAVINGS RESULTS – WHOLE BUILDING PERFORMANCE REVIEW

ESTIMATING HVAC PERFORMANCE REVIEW COSTS AND BENEFITS

The variety of HVAC system and control types in existing buildings, and the potential range of equipment condition and operating efficiency, has lead The OTF Consortium to review studies of retrocommissioning impacts to arrive at a reasonable cost/benefit for the PR approach. The focus of the PR is on identification, diagnosis and repair of system flaws, i.e., low-cost, no-cost items as opposed to upgrades or enhancements, so simple payback (SPB) is the metric of choice, because it directly ties the cost of implementation with its associated savings and provides an return on investment (ROI) indicator (ROI = 1/SPB).

The relevant findings of three studies are summarized below:

2007 California Retrocommissioning Market Characterization, PECI and Summit Building Engineering, (2007)[23]. Based on the collective retrocommissioning experience to date, office sector retrocommissioning estimates are 7.1% electric savings and 5.1% gas savings at a cost of $0.38/ft^2 (investigation and implementation) for a SPB of 2.2 years (ROI = 45%). Non-energy benefits are not included in the analysis.

How Monitoring-Based Commissioning Contributes to Energy Efficiency for Commercial Buildings, Karl Brown et al (2007)[24]. This study focuses on identification, diagnosis and repair, the development of a baseline for performance, and the ability to verify and track persistence of savings. Estimates for monitoring-based commissioning of higher education buildings) delivered median site savings of 10%, with a SPB of 2.5 years (ROI = 40%). Non-energy benefits are not included in the analysis.

The Cost-effectiveness of Commercial-Buildings Commissioning—A Meta-Analysis of Energy and Non-Energy Impacts in Existing Buildings and New Construction in the United States, Mills et al (2004)[25]. This meta analysis of commissioning aggregated data from a number of previous studies from around the United States. The estimates for commissioning-delivered, median site savings are 15% of total energy annually with a SPB of 1.0 year (ROI = 100%). Non-energy benefits are not included in the analysis.

Based on these and previous studies, it is expected that the Performance Review will provide savings of 5% to 10% of total building energy at a cost of $0.10 to $0.25 per square foot and a simple payback of less than 2.0 years.

INTERVAL METERING, TENANT CHECK METER, AND DEMAND RESPONSE THERMOSTAT

Many multi-tenant buildings do not have utility revenue meters related to the rental space. Energy costs may be prorated across tenants by square footage, or included in the base rent cost. Technical aspects related to this measure have been discussed in the *25% Technical*

Solution section of this report. However, the behavioral aspect of metering and monitoring energy use is arguably more important than understanding the technologies available to generate and analyze usage data.

There is substantial evidence in the residential sector that providing simple, easily understood and accessible energy information to residents results in energy savings, typically in the 10–15% range[26]. This is true for multi-family buildings that switch from master metered to separate utility metering[27], and in single-family dwellings where the billing does not change, but better quality feedback is provided (daily and hourly, quality graphic presentation, on the kitchen counter)[28].

There is no comparable body of literature of commercial sub-metering or check metering (non-revenue grade) studies. There are sufficient differences between residential and commercial situations to make extrapolation from residential studies dangerous. For example, households usually have some clarity about who is responsible for paying the bill, and who is empowered to adjust operational conditions in the house to reduce energy use. In business settings, the bill may be sent to the accounting department with offices in a different state, and responsibility for some types of activities (adjusting thermostat settings, purchasing more energy efficient equipment) may be unclear or removed from the occupant's control. That is, the people who see the better feedback may not have sufficient authority to act on the information.

However, there are some options available to typical office occupants that can reduce energy use, ranging from banning portable space heaters to making sure that lights and equipment are turned off when not needed. If office occupants had better information about how their behavior impacted energy use, it is likely that a percentage of them would adopt better energy use habits.

A recent report by the Carbon Trust[29] in the UK of 528 Small-Medium Enterprises consisting of all types of commercial businesses indicated a 7.5% savings due to the installation of interval electric meters coupled with advice and customer contact. The use of the interval meter with energy education support described as part of the educational measures will serve to work towards this order of savings.

The use of an interval meter, check meter or display device ensures persistence of savings and attention to energy issues that The OTF Consortium believes will ensure the success and widespread acceptance of the program. Strict electrical savings can be difficult to attribute to these measures since the variation of their application does not lend itself well to using evaluations of past programs to project future results. An initial estimate based on a conservative perspective on the UK study is 3%. The persistence of the savings achieved as a result of this check meter is in doubt and consequently the savings are not a core measure of the 25% solution. There is promise that the savings persistence can be enhanced through coordination with the educational portions of the 25% solution.

SAVINGS SUMMARY AND DISCUSSION

The estimated electrical and net energy savings predicted for the 25% Solution are summarized in Table 15. The tenant lighting and equipment savings are calculated using the modeling process and the other category savings are estimated from literature and evaluations of similar programs as described earlier in this section. No energy savings were estimated for the demand control thermostat. The Whole Building Savings show the net result accounting for interactive effects when lighting and equipment sensible loads are removed from the building. The OTF Consortium determined that the Performance Review and Advanced Metering measures will be important to the achievement of both the electrical and net energy savings goals.

TABLE 15. SUMMARY OF SAVINGS ESTIMATED IN THE 25% SOLUTION

CATEGORY	ELECTRICAL SAVINGS (ROUNDED %) EXCLUDING CV SYSTEM	WHOLE BUILDING SITE ENERGY SAVINGS (ROUNDED %) EXCLUDING CVRH SYSTEM INCLUDING INTERACTIVE EFFECTS	COMMENT
Tenant Lighting and Equipment	18 - 28	5 – 23	Modeled savings estimates
Whole Building Performance Review		5 -10	Literature Review
Advanced Metering		3	Literature Review
Demand Response Thermostat	Not estimated	Not estimated	

These savings estimates represent the conservative assumptions of the modeling process. The savings achieved in an implementation of the program will be verified through the advanced metering installed as part of the program and will likely result in larger than estimated savings. These issues are discussed as part of the modeling assumptions above.

LIGHTING AND EQUIPMENT MEASURE IMPACT ON HVAC ENERGY USE

Analysis of the lighting and equipment measures, on a standalone basis indicate substantial reduction in electrical energy use and power density compared to the baseline prototype assumptions. However, to assess the net savings potential available from the application of these measures, the DOE 2.2-45m model was run to look at the interactive effects upon HVAC systems. This modeling produced data that, when analyzed, led the researchers to a few notable conclusions:

1. The net energy savings in large prototypes with pre-1978 vintage HVAC systems was nearly zero. This indicates that the heating system is so inefficient that the loss of the internal gain due to the lighting and equipment loads must be entirely made up by additional heating and the cooling system is unable to take advantage of the reduce cooling load. The **OTF Consortium recommends that the program preclude buildings utilizing and HVAC system based on a Constant Volume with Reheat (CVRH) design from participating. In addition Variable Air Volume systems in large buildings without fan-powered control and using reheat may also pose a problem for savings.**

2. Electrical savings are sometimes less than 25% and most often net energy savings, even in late vintage buildings, are less than 25%. This accentuates the importance of the Performance Review and advance metering to achieve the 25% target for net energy savings. These numbers also represent the conservative assumptions mentioned above. The **OTF Consortium recommends implementing the full package of measures described above rather than a subset of lighting and equipment only measures.**

CHANGING BUSINESS REAL ESTATE PRACTICES: ENHANCING AND SUSTAINING ENERGY SAVINGS

This section suggests four general strategies that businesses can adopt to enhance and sustain energy savings. Estimated additional savings resulting from these strategies are not estimated, as savings are either 1) not well documented, 2) likely to be variable or uncertain in terms of timing and/or 3) the program mechanism to support the strategy is not precisely described at this time. Nonetheless, these strategies are very likely to have value in terms of energy and demand savings, and further development of selected strategies and evaluation of actual measured savings could result in one or more of these options proving to be quite valuable.

The four strategies are:

- Support for participation in green building programs or EPA Energy Star
- Procurement strategy for office equipment purchase
- Training and support of an energy advocate at the tenant level
- Use of Green Leases

Each strategy is described below at the first level of detail, with consideration for how it could be implemented as a utility program. In general, use of one or more of these strategies to support the more technical program described for the tenant improvement process is recommended to ensure that savings persist.

GREEN BUILDING AND ENERGY STAR PROGRAM PARTICIPATION

There are multiple programs available to tenants and building owners to gain credit for energy efficiency and green building measures. The best known[h] of these are:

- The EPA Energy Star program provides whole building energy benchmarking based on energy bills and recognizes buildings that are in the top quartile of buildings with an Energy Star Building label. For multi-tenanted buildings, securing the Energy Star Buildings label would require some level of participation and support from tenants, as would improving their benchmark score.
- USGBC's LEED-EB (Leadership in Energy and Environmental Design – Existing Building program) looks at a variety of green building and behavior factors to reward a green building label. The program includes use of recycled materials, indoor air quality, water use and energy elements. The LEED-EB program uses the Energy Star benchmarking score for energy performance, so again, whole building performance is the key metric.
- USGBC's LEED-CI (Commercial Interiors) is focused on tenant space improvements rather than whole building. Originally designed for use in newly constructed buildings, it can be applied to existing spaces as well. For energy benchmarking, LEED-CI has a

[h] Information regarding the EPA Portfolio Manager tool can be found at http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager. More information on the USGBC programs for existing buildings, new construction, and commercial interiors can be found at www.usgbc.org. These programs can work with programs like Office of the Future facilitate approval of ratings.

prescriptive list that includes, for example, reducing lighting power density and using Energy Star listed office equipment, rather than the whole building metrics of the other two programs. This program is therefore available on an individual tenant basis while the other two programs are whole building based and would require coordination between the owner and tenant.

Using any of these programs would provide additional motivation to save energy through behavior, operational and capital investment beyond the 25% Solution. Elements of the 25% Solution are sufficiently aligned with LEED-CI in particular to enable interested tenants to earn multiple energy performance points. See Appendix E for additional detail about how the 25% Solution aligns with LEED programs.

RECOMMENDATION

Utilities should assess local market interest in energy benchmarking and green building programs and both encourage participation in such programs (through information and/or incentives) and review program offerings to better align program goals over time. Participation in such programs is very likely to yield additional energy savings, as the owners and/or tenants have additional motivation and additional requirements to fulfill beyond the 25% Solution effort. This option could be combined with the metering strategy or other Enhancing and Sustaining Energy Savings strategies to further support savings.

OFFICE EQUIPMENT PROCUREMENT

Many firms have adopted procurement strategies that reference Energy Star listed equipment. Such a strategy is difficult to implement directly as part of the TI process as most firms replace computers and other equipment on a defined upgrade schedule, when needed to meet changing needs, or when equipment does not function properly. Tenant improvement projects that represent business expansions or new offices may have equipment purchases timed to the moving in process, but this will likely be a minority of opportunities.

Upgrading to Energy Star equipment (or beyond) represent well-defined energy saving opportunities, typically at no or very little cost. Encouraging adoption of a procurement strategy is a relatively simple and very low-cost option for tenants, with very real demand-side savings.

More drastic energy savings purchasing policies may supersede the savings provided by the recommended measures described above and should be encouraged as part of education materials for owner and tenant. These include but are not limited to: thin client office computers[30], dramatically reduced EUI desktop computers[31], and tenant corporate policies that restrict or eliminate office worker miscellaneous equipment.

RECOMMENDATION

Information regarding office equipment procurement policies and benefits should be provided to tenants as part of the 25% Solution to garner additional savings over time. Utilities may want to offer incentives for office equipment that represent additional savings opportunities where such equipment has modest market penetration.

ENERGY ADVOCATE PROGRAM

The Energy Advocate program is a program support concept to work within tenant spaces to provide education and reinforcement of energy efficiency messages on an ongoing basis. The Energy Advocate is a member of the tenant staff, who volunteers to help their peers and the organization that employs them to pay attention to efficiency. The intent is that the Advocate works more from an educational point of view rather than an "energy cop" perspective. A recent study demonstrated how this process can be implemented successfully within organizations.[32]

Depending on the size of the tenant firm, the advocate may send out e-mails, contribute to a corporate newsletter, monitor the check metering, supply information needed for Energy Star benchmarking calculations, and be a source of peer information on energy efficiency options. They may have a LED desk lamp at their work station.

This advocate network could be supported by occasional training sponsored by utilities and/or articles on energy efficiency from an office perspective that could be placed in tenant newsletters or e-mails. If the sponsoring utility wanted to mobilize tenants for some reason, for example an efficiency contest or promotion, the Advocate would be the point of contact.

RECOMMENDATION

As the 25% Solution program comes to scale, consider the designation and support of a volunteer Energy Advocate within the tenant organization.

GREEN LEASES

Green leases are a relatively new concept, but several good examples are available from both government and private organizations. BOMA is currently working on a green lease for their member firms.

Green leases add specific elements to the basic lease agreement that may require use of certain types of cleaning products, carpeting, ongoing recycling options, or prohibit certain activities or devices, such as smoking or electric space heaters. The leases can come from either the tenant perspective, i.e. the tenant organization wants to assure that the spaces they are leasing support their environmental goals, or from the property owner perspective, for example the developer of a green building wants to assure that all building occupants support energy efficiency and other environmental goals.

Depending on the elements of the lease, energy efficiency savings can be strengthened or sustained over time. Offering of a green lease may be attractive to some tenants, even if it contains restrictions on some operational parameters of the buildings.

RECOMMENDATION

Review green lease options, and work with property owners and managers to offer a green lease to support energy efficiency goals.

PROGRAM RECOMMENDATIONS

The technical solutions for OTF are designed around the opportunities created in the leasing/releasing negotiations and tenant improvement process. During this process, there are several elements in play that create an opportunity to pursue deeper, more comprehensive energy solutions.

- Concerns regarding who pays and who benefits, the classic "split incentive barrier" in leased properties, can be resolved as part of the negotiated leasing arrangement. The tenant or the owner can bring additional financial resources to the table, monthly rent can be increased to cover owner energy efficiency investments over time, and/or the lease period can be extended.
- The space is typically vacant, and frequently needs some reconfiguration to meet tenant needs, allowing a more comprehensive space, lighting and HVAC design to be developed with less concern about work disruption.
- Comprehensive energy solutions can be developed for either new buildings or existing buildings with a change in tenancy.
- Efficiency options that provide benefits from both the owner and tenant perspectives can be pursued.

Focusing on the lease negotiation process also brings several complexities to the process that need to be considered in designing a program solution. First, buildings will be addressed on a piecemeal basis, as only a small percentage of office spaces will be in lease negotiations at any given time (except in new buildings), and some spaces may be relatively small in terms of the square footage involved. Second, there will be a well-defined timeline for tenant improvements that must be met. Third, transactions that introduce uncertainty and/or complexity into the lease/TI process will be unwelcome by one or more of the involved parties. And importantly, it may be difficult for a DSM program operator to identify when transactions are occurring on a timely basis.

These factors need to be considered in the program design, including marketing, technical approach, trade ally involvement, incentive design and other elements to ensure that the program is welcomed into the leasing/TI process as a business benefit. Depending on project scale and how vertically integrated the owner's business model is, there may be a variety of business parties included in the transaction. Minimally, both the tenant and owner should see benefits, but there may also be a separate realtor, an interior design firm, and various contractor/subcontractors to complete the work, and the tenant may have one party involved in financial elements of the transaction, and another individual or team involved in space planning and fit out. The recommendations below are initial thoughts about how to structure the program offering to support integration into the process.

1. **Design the program offering to offer business benefits to all key parties to the transaction.** While some of these benefits will be related to a reduction in energy bills, it is likely that other types of benefits will be available to all parties that exceed the direct energy savings benefits. These may include helping an owner improve the asset value or reposition a building in the real estate marketplace, improving the comfort, productivity and visual appeal of the tenant space, and increasing the value of the project to designers and contractors. A more detailed list of business benefits is included in the Market Strategy section of this report.

2. **Structure the program to reduce transaction costs.** The program needs to be simple to understand, easy to agree to, and straightforward to implement. Complexity will limit sales. Develop an incentive structure that is simple to understand and administer – perhaps based on the square footage involved rather than incremental costs, for example.

3. **Market the program though business allies, primarily property owners/managers and designers.** Property owners/managers need to be sold on the business benefits, and are in the best position to market the program to tenants and potential tenants as part of the leasing process. Interior designers may be an important secondary marketing agent for projects. Create a relationship with large owners/managers of commercial real estate and involve them in developing details of the program offering, collateral materials and creating the business case.

4. **Consider a broad marketing campaign in business related publications**. Creating market demand through tenants may be the best longer-term marketing strategy, but may be difficult to support in the short-term. Identification and timing of leasing is difficult to access from outside the market, but a strong marketing campaign has potential to move the tenant market over time to demand business benefits from their perspective.

5. **Train and support key trade allies, primarily interior design and lighting related firms, so that moving to the advanced lighting design platform has support within the industry.** Many property owner/managers execute tenant improvements in house, so reaching those staff with training is also important.

6. **Consider the relationship of the 25% Solution to other energy efficiency programs.** Internal to the utility, there may be program efforts focused on roof top units or retrocommissioning, or other efforts targeted to commercial real estate. External to the utility, the use of Energy Star or USGBC programs, described earlier in this report, may be particularly useful.

The 25% Solution scenarios would benefit from pilot efforts. While the modeled energy savings from the Tenant Electric Scenario appear to be robust, better savings estimates could be developed for the Whole Building Scenario, and elements of the behavior approaches would be very useful to test. An overall pilot data collection plan should be developed so that utilities implementing pilots can collect a data set that will allow for cross-fertilization of program learning. An essential element of any pilot program would be collection of useful energy data at the tenant space level.

CONSIDER HVAC, METERS, AND POLICY MEASURE INTEGRATION

On a stand-alone basis, proposed lighting and plug load measures offer a reduction in electrical energy usage of roughly 25%. However, interactive effect of these measures with HVAC systems, in all cases, reduces net savings. In extreme cases, such as older buildings with constant volume HVAC systems, these savings may be completely negated.

Although the initial Office of the Future concept assumed that it would not be necessary to address whole building systems, these interactive effects makes it clear that, at a minimum, HVAC systems must be evaluated to screen the best candidates for the 25% Solution. Beyond this screening, modest whole-building HVAC measures such as the Performance Review described in the *Technical Solution* section of this report can provide additional savings to offset interactive effects and maintain higher savings levels. If a decision is made to expand program boundaries beyond the tenant space, there are a variety of measures that should be considered for inclusion in Office of the Future solution sets.

These "best practice" HVAC measures (*Advanced Buildings: Core Performance Guide*, Section 3.7, NBI (2007)) were not modeled as part of the 25% Solution simulation modeling evaluation because of the great variety of potential systems and conditions and because their implementation implies crossing the tenant improvement boundary to address whole building systems.

RESEARCH PLAN

The calculation of the interactive effects from energy savings measures of the 25% Solution, as applied to the two office prototypes, demonstrates that the diversity of HVAC system types and other characteristics in existing office buildings can result in significantly different energy savings, building-by-building. Phase III Office of the Future development efforts will further investigate the impact of this diversity upon utility program design and the opportunities that might be available to expand targeted measures beyond the tenant space to strategies and measures targeted upon specific system types.

ASSESS SAVINGS SIGNIFICANCE OF BUILDING CHARACTERISTICS

The two DEER prototypes selected for this analysis offered vetted characteristics representing various office sizes and vintages. Yet, as carefully as these California prototypes were designed and maintained (they are currently under revision by the CEC/CPUC), they may not be comprehensive enough to represent building characteristics commonly found in other parts of the country. Additional work needs to be done in this area, to determine the optimum representation of offices for program development purposes.

There have been a modest number of large-scale studies which attempt to link differing building characteristics with energy performance. The best known and most widely accessed data set is the Commercial Buildings Energy Consumption Survey (CBECS)[33], first conducted in 1979 and most recently updated by the USDOE Energy Information Administration. This data is often maligned, because of its lack of rigor, but there are no other comparable sets.

The Commercial Building Stock Assessment (CBSA)[34] was performed in the Pacific Northwest and published in 2004. (An updated assessment of new [2001-2005] commercial buildings, under contract to the Northwest Energy Efficiency Alliance is currently under final review.) Great effort was made to link energy performance with building characteristics; the resulting information is very useful, but is regional, rather than national and does not have as large a population of older, larger office buildings as can be found in parts of the country with larger, older urban centers. The CBSA data is also deficient in climate zones with latent cooling loads.

California's CEUS[35] database is an excellent resource of EUI data, but a planned follow up study linking building characteristics to EUI has not yet begun.

ADDITIONAL MODELING

Additional modeling, to more fully assess HVAC interactions and to consider the impact of various HVAC measures across the diversity of system types will provide necessary data to more broadly support estimates of energy savings from the 25% Solution. These same prototypes and the modeling that is being done to support the 25% Solution will provide the basis for the additional analysis needed for 50% and 75% solution sets.

PILOT PROJECT(S)

The **OTF Consortium** recommends that at least one demonstration pilot be conducted with an industry partner to assess the technical and non-technical aspects of the program before roll-out. Metering should be installed before the measures are implemented to provide M&V.

APPENDIX A – DETAILED LIGHTING DESIGN OPTIONS AND SAVINGS PROJECTIONS REFERENCES

OPEN PLAN OFFICES

The lighting design options listed below have been prepared for the purposes of the analysis described in this report. In most cases they have been drawn from pre-existing designs36 that are similar to the designs being developed for delivery via the Commercial Lighting Solutions (CLS) web tool. The CLS design development process includes stakeholder review and input, which will take place in spring and summer of 2009. The revised designs will then be incorporated into the web tool allowing for easy online access by utility programs.

The list below serves to provide transparency for the modeling assumptions underlying the conclusions in this report, but would not suffice as the only final product for program application of prescriptive lighting solutions. More design options will be prepared, with detailed specification guidance to support practical application by users.

Baseline

- 1.1 W/SF (Std. 90.1-2004/2007)
- Controls: Some type of automatic shut-off (e.g., occupancy sensor, timeswitches)
    - Selected: Time-switches with 2-hour override

Option 1 – Recessed curved lensed 2'x4' troffer

- Total LPD for all lighting systems (*LS*): 1.05 W/SF
    - *LS1 - 0.85 W/SF* for recessed high performance luminaires. These luminaires use a high-performance lens to provide high-angle brightness, while limiting the glare. These luminaires can be either 2-lamp T5 or T8, T8 lamps selected.
    - *LS2 - 0.13 W/SF* for linear fluorescent wallwashers. Vertical brightness is as important in an office as the illumination on the workplane. These luminaires supplement the lighting on the walls where the recessed lensed luminaires cannot reach. These luminaires use linear 4' lamps, best to use the same lamp as installed in the recessed 2'x'4 luminaires.
    - *LS3 - 0.05 W/SF* for decorative surface-mounted CFL sconces to provide for ambiance.
    - *LS4 - 0.02 W/SF* for recessed round aperture adjustable CMH accent luminaires. These luminaires highlight items mounted on walls or columns. CMH selected because of the beam distribution options and lamp efficacy is better than standard incandescent/halogen
- Controls: Daylight Harvesting (e.g., continuous linear dimming)
    - Only applied to LS1 (recessed 2'x4' luminaires)
    - 38% of the luminaires that comprise the 0.85 W/SF are located in the daylighting zone
        - Daylighting zone – closet rows of luminaires mounted parallel to the window within 15 horizontal feet from the window
    - 20% energy savings (averaged across the day) per industry literature

Option 2 – Suspended linear fluorescent (direct/indirect) pendants

- Total LPD for all lighting systems (*LS*): 0.84 W/SF
  - *LS1 - 0.43 W/SF* for suspended 2-lamp (in profile) T8 lamps with normal ballast factor (0.87/0.88). These luminaires are suspended 18" below the ceiling. Light is directed towards the ceiling making the space feel brighter and redirecting light to the workplane.
  - *LS2 - 0.14 W/SF* for recessed round aperture CFL wallwashers. Vertical brightness is as important in an office as the illumination on the workplane. These luminaires supplement the lighting on the walls.
  - *LS3 - 0.04 W/SF* for decorative surface-mounted CFL sconces to provide for ambiance.
  - *LS4 - 0.03 W/SF* for surface-mounted track with current limiting device (CLD) providing the entire track to be counted at 120W rather than at 30 W/ LF as per most energy codes
  - *LS5 – 0.2 W/SF* for surface-mounted linear fluorescent task lighting mounted to the underside of the bins in the cubicles
- Controls: Occupancy Sensors & Time-based switching
  - Occupancy sensors only applied to LS5 (fluorescent under cabinets)
    - 20% energy savings (average across the day) per literature
    - Energy savings driven by office use and how the control system is designed
  - Time-based Switching
    - LS5 controlled via occupancy sensors, so this lighting system is not factored into every hour in the load profile
    - Only applied to LS1 in after-hours (override) switching

Option 3 – Suspended linear fluorescent workstation-specific 1

- Total LPD for all lighting systems (*LS*): 0.84 W/SF
  - *LS1 - 0.225 W/SF* for the downlight component of a 2-lamp in profile (stacked over/under) direct/indirect luminaire mounted in the center of each workstation
  - *LS2 - 0.225 W/SF* for the uplight component of a 2-lamp in profile (stacked over/under) direct/indirect luminaire mounted in the center of each workstation
  - *LS3 - 0.14 W/SF* for recessed round aperture CFL wallwashers. Vertical brightness is as important in an office as the illumination on the workplane. These luminaires supplement the lighting on the walls.
  - *LS4 - 0.08 W/SF* for recessed round aperture CFL downlights. These luminaires provide fill light where the light from the workstation-specific luminaires cannot reach
  - *LS5 - 0.02 W/SF* for decorative surface-mounted CFL sconces to provide for ambiance.
  - *LS6 – 0.15 W/SF* for LED-dedicated task and under-cabinet luminaires
- Controls: Daylight Harvesting, Occupancy Sensors, Personal Controls, Time-based switching
  - Time-based switching only applies to LS2. The uplight provides ample illumination for the cleaning crew and general

- Local switches with time clock sweeps at the end of the day turn off LS3, LS4, and LS5
- Daylight harvesting only applied to LS2
- 44% of the luminaires that comprise the 0.225 W/SF are located in the daylighting zone
  - Daylighting zone – closet rows of luminaires mounted parallel to the window within 15 horizontal feet from the window
- 20% energy savings (averaged across the day) per industry literature
- Both occupancy sensors and personal controls are applied to LS1. The personal control allows the user to set the desired illuminance level.
- 20% energy savings per industry literature when using personal controls
- 20% energy savings per occupancy sensors which turn out the already dimmed load (from the personal controls) when the cubicle is not occupied
- Occupancy sensors turn off the task (articulated and under cabinet) lighting in LS6 when the cubicle is not occupied
- 20% energy savings from occupancy sensors per industry literature

Option 4 – Suspended linear fluorescent workstation-specific 2

- Total LPD for all lighting systems (*LS*): 0.84 W/SF
  - *LS1 - 0.46 W/SF* for the downlight component (2-lamps) of a 3-lamp in profile (outside lamps) direct/indirect luminaire mounted in the center of each workstation
  - *LS2 - 0.23 W/SF* for the uplight component (1-lamp) of a 3-lamp in profile (inside lamp) direct/indirect luminaire mounted in the center of each workstation
  - *LS3 - 0.14 W/SF* for recessed round aperture CFL wallwashers. Vertical brightness is as important in an office as the illumination on the workplane. These luminaires supplement the lighting on the walls
  - *LS4 - 0.08 W/SF* for recessed round aperture CFL downlights. These luminaires provide fill light where the light from the workstation-specific luminaires cannot reach
  - *LS5 - 0.02 W/SF* for decorative surface-mounted CFL sconces to provide for ambiance
- Controls: Daylight Harvesting, Occupancy Sensors, Personal Controls, Time-based switching
  - Time-based switching only applies to LS2. The uplight provides ample illumination for the cleaning crew and general
  - Local switches with time clock sweeps at the end of the day turn off LS3, LS4, and LS5
  - Daylight harvesting only applied to LS2
  - 44% of the luminaires that comprise the 0.23 W/SF are located in the daylighting zone
    - Daylighting zone – closet rows of luminaires mounted parallel to the window within 15 horizontal feet from the window
  - 20% energy savings (averaged across the day) per industry literature
  - Both occupancy sensors and personal controls are applied to LS1. The personal control allows the user to set the desired illuminance level.

- 20% energy savings per industry literature when using personal controls
- 20% energy savings per occupancy sensors which turn out the already dimmed load (from the personal controls) when the cubicle is not occupied

PRIVATE OFFICES

Baseline

- 1.1 W/SF (Std. 90.1-2004/2007)
- Controls: Some type of automatic shut-off (e.g., occupancy sensor, timeswitches)
  - Selected: Manual-Off option with time sweep

Option 1 – Recessed curved lensed 2'x4' troffer

- Total LPD for all lighting systems (*LS*): 0.98 W/SF
  - *LS1 - 0.78 W/SF* for recessed high performance luminaires. These luminaires use a high-performance lens to provide high-angle brightness, while limiting the glare. These luminaires can be either 2-lamp T5 or T8, T8 lamps selected.
  - *LS2 – 0.2 W/SF* for surface-mounted linear fluorescent task lighting mounted to the underside of the bins in the cubicles
- Controls: Vacancy sensor
  - Applied to only LS1 (overhead lighting)
    - Vacancy sensor is similar to occupancy sensor, except the lighting is manually turned on by the occupant
    - 30% energy savings per industry literature for this strategy
    - Savings come from the "manual-on" option (if daylight provides ample light, the electric lighting may not be turned on), as well as, the "automatic-off" from the vacancy sensor when the occupant leaves the office
  - Time-based switch applied to LS2 (under cabinet lighting)

Option 2 – Suspended linear fluorescent lighting

- Total LPD for all lighting systems (*LS*): 1.00 W/SF
  - *LS1 - 0.85 W/SF* for suspended linear fluorescent pendant
  - *LS2 – 0.15 W/SF* for LED surface-mounted and articulated task lighting
- Controls: Vacancy sensor
  - Applied to only LS1 (overhead lighting)
    - Vacancy sensor is similar to occupancy sensor, except the lighting is manually turned on by the occupant
    - 30% energy savings per industry literature for this strategy
    - Savings come from the "manual-on" option (if daylight provides ample light, the electric lighting may not be turned on), as well as, the "automatic-off" from the vacancy sensor when the occupant leaves the office
  - Time-based switch applied to LS2 (under cabinet lighting)

Option 3 – Intelligent Lighting

- Total LPD for all lighting systems (*LS*): 0.88 W/SF
  - *LS1 - 0.44 W/SF* for the downlight component of a 2-lamp in profile (stacked over/under) direct/indirect luminaire mounted in the center of each workstation
  - *LS2 – 0.44 W/SF* for the uplight component of a 2-lamp in profile (stacked over/under) direct/indirect luminaire mounted in the center of each workstation
- Controls: Vacancy sensor, personal control, and daylight harvesting
  - Vacancy sensor and personal control applied to LS1 (downlight)
    - Vacancy sensor is similar to occupancy sensor, except the lighting is manually turned on by the occupant
    - 30% energy savings per industry literature for this strategy
    - Savings come from the "manual-on" option (if daylight provides ample light, the electric lighting may not be turned on), as well as, the "automatic-off" from the vacancy sensor when the occupant leaves the office
    - Personal control allows for the office inhabitant to dim the downlight to the desired illuminance
    - 20% energy savings per industry literature for this strategy
  - Daylight harvesting only applied to LS2 (uplight)
    - 20% energy savings per industry literature for this strategy

CONFERENCE ROOMS

Baseline

- 1.3 W/SF (Std. 90.1-2004/2007)
- Controls: Some type of automatic shut-off (e.g., occupancy sensor, timeswitches)
  - Selected: Occupancy sensor with time sweep

Option 1 – Recessed curved lensed 2'x4' troffer

- Total LPD for all lighting systems (*LS*): 1.09 W/SF
  - LS1 - 0.86 W/SF for recessed high performance luminaires. These luminaires use a high-performance lens to provide high-angle brightness, while limiting the glare. These luminaires can be either 2-lamp T5 or T8, T8 lamps selected.
  - LS2 – 0.23 W/SF for linear fluorescent wallwashers. Vertical brightness is as important in an office as the illumination on the workplane. These luminaires supplement the lighting on the walls where the recessed lensed luminaires cannot reach. These luminaires use linear 4' lamps, best to use the same lamp as installed in the recessed 2'x'4 luminaires.
- Controls: Occupancy sensor
  - Applied to both LS1 and LS2
  - No savings attributed to controls. See Lighting References.

Option 2 – Suspended linear fluorescent pendant

- Total LPD for all lighting systems (*LS*): 1.10 W/SF
  - *LS1 - 0.28 W/SF* for suspended linear fluorescent pendant. This layer of light enhances the appearance of the room. Subconsciously, occupants will feel this luminaire is lighting the entire space, but the recessed luminaires (other layers of light) are providing the real illumination
  - *LS2 – 0.47 W/SF* for recessed round aperture CFL downlights for an additional layer of light
  - *LS3 – 0.35 W/SF* for recessed round aperture CFL wall washers. This layer of light provides vertical brightness on walls for display or pin-up
- Controls: Occupancy sensor
  - Applied to LS1 – LS3
  - No savings attributed to controls. See Lighting References.

CORRIDOR

Baseline

- 0.5 W/SF (Std. 90.1-2004/2007)
- Controls: Some type of automatic shut-off (e.g., occupancy sensor, timeswitches)
  - Selected: Time switches tied to building security (door locks)

Option 1 – Recessed 2'x2' basket troffer

- Total LPD for all lighting systems (*LS*): .40 W/SF
  - *LS1 - 0.40 W/SF* for recessed 2'x2' basket luminaires. 2'x2' luminaires are often selected because the square shape allows for various orientations, however, these luminaires can use extremely inefficient lamps (e.g., bent U-shaped T8 lamps). Sufficient lighting in the corridor can be accomplished via the 2-lamp 2' T8s housed in the 2'x2' fixture. Recommend using short linear fluorescent lamps, then biaxial CFL lamps.
- Controls: Occupancy sensor
  - Applied to LS1
  - 25% energy savings (averaged across the day) per industry literature
    - Energy savings affected by length of corridor, offices adjacent to the corridor, and the usage pattern of the corridor
    - Reduced LPDs will affect the number of luminaires installed; spacing directly affects the possible energy savings
    - Luminaires for emergency egress lighting will also affect the spacing and controls schemes for this type of space, which directly affects the energy savings in this space

RESTROOM

Baseline

- 0.8 W/SF (Std. 90.1-2004/2007)

- Controls: Some type of automatic shut-off (e.g., occupancy sensor, timeswitches)
  - Selected: Time switches tied to building security (door locks)

Option 1 – Recessed linear fluorescent wall slot & CFLs

- Total LPD for all lighting systems (*LS*): 0.66 W/SF
  - *LS1 - 0.39 W/SF* for recessed linear fluorescent wall slots. These luminaires wash light down the wall providing vertical brightness and enhancing the space
  - *LS2 – 0.27 W/SF* for recessed round aperture CFL downlights for an additional layer of light
- Controls: Occupancy sensor
  - Applied only to LS1
    - Linear fluorescent lamps can be easily connected to program rapid-start ballasts for quick restrike
  - Time switch applied to LS2
    - Belief that people do not want to enter dark bathroom, even though lighting is on occupancy sensor
    - The CFLs provide some illumination in the space when not occupied

OTHER LIGHTING-RELATED RECOMMENDATIONS

Controls

- Significantly affected by usage of the space, pick the correct control strategy with how the occupants will use/occupy the space
- Rule of thumb - Two control strategies should be applied to a lighting system
  - Every layer of control makes the system more complicated and can actually fail to save energy if the systems are not all properly commissioned
  - Savings are not additive, for instance if three controls that save 10%, 20%, and 30% respectively are used, the resultant energy savings is not 60% (sum of 10%+20%+30%). The actual savings are probably in the range of 49.6% (90%*80%*70% - this is the actual energy consumption)
  - Diminishing returns – after about two control strategies, the additional incremental savings becomes less cost effective

Architecture

- High reflectance finishes should be used
  - Ceilings should be 75%+ reflective
    - Limit the perforation in diffusers
    - Specify high reflectance ACT
    - Ceiling reflectance is aggregate, sprinklers, diffusers, ceiling-support structure all affect the overall reflectance of the ceiling
  - Walls should be 50%+ reflective
    - Avoid dark, saturated colors
    - Paint manufacturers provide reflectance values

    - Floors should be 20% reflective
        - Avoid specular, shiny floor finishes
    - Partition reflectances
        - Avoid dark partition finishes (i.e., think grey, tan)
- Strive for high ceilings
    - Ideally ceiling heights should be 9'-0"+
    - Ceiling heights lower than 9'-0" can be problematic, force spacing of the luminaires, and can limit specific options
    - Allows for the interaction of light
- Incorporate daylighting into architecture
    - Site the building properly if possible
    - Provide sufficient glazing **AND** sun control devices
- Mixture of office types and location directly affects energy use in lighting
    - Private offices harder to light
        - Use more power/equipment per sq ft due to the walls
        - Reduced contribution from adjacent luminaires
        - Limit the number of private offices if possible
        - Consider the location of private offices, perimeter may not be the best place for these offices
        - Interior private offices with borrowed light may be a good strategy
    - Open plan offices allow for most energy savings
        - Can effectively use daylight
        - Larger space allows light to bounce around rather than being absorbed by the walls in a private office
        - Limit partition height to 56" AFF if possible

LIGHTING DESIGN SAVINGS REFERENCES FOR MODELING

Open Office – Daylight Harvesting

- 20% energy savings (averaged across the day) per industry literature
    - Daylighting Initiative - Lighting the Way. PG&E; http://www.pgee.com/003_save_energy/003c_edu_train/pec/daylight/di_pubs/1487gate_repaginated.pdf stated a range of savings between 16% - 41%
    - Dimming Controls for Lighting. PG&E. May 1997 stated a range of savings between 30% - 40%
    - The potential simplified Concepts for Daylight Harvesting – Lighting Research Center, did not provide a range, but a single value of savings from their study of 24%.
    - Energy Saving Lighting Control Systems for Open-Plan Offices: A Field Study. Leuokos Vol 4. No. 1 July 2007 Pages 7-29, did not provide a range, but a single value of savings from the study of 20%.

- The values range because there are numerous environmental and core/shell issues that affect the actual values. To be conservative because of all of the unknowns, a value of 20% has been selected.

Open Office – Occupancy Sensors

- 20% energy savings (averaged across the day) per industry literature
  - Advanced Sensors and Controls for Building Applications: Market Assessment and Potential R&D Pathways. April 2005. PNNL stated a range of savings between 20% - 28%
  - Reducing Barriers to Use of High Efficiency Lighting Systems, Final Report Year 2. Lighting Research Center, RPI Jan 2003., pg 92-99 stated a range of savings between 25% - 40%
  - Energy Saving Lighting Control Systems for Open-Plan Offices: A Field Study. Leuokos Vol 4. No. 1 July 2007 Pages 7-29 did not provide a range, but a single value of savings from the study of 35%
  - A number of variables will affect the actual savings. A conservative value of 20% was chosen. The 35% range listed from Leukos report is from a work-station specific design at BC Hydro. There is some fuzziness to the data; it appears that weekend savings are being used to derive the 35% value. However, the data shows inconsitent usage between the baseline and the measured floor during the weekends. The first study projected savings apply to the entire commercial building.

Open Office – Personal Controls

- 20% energy savings (averaged across the day) per industry literature
  - Individual Lighting Control: Task Performance Mood & Illuminance: Lighting Research Center. www.lrc.rpi.edu/resources/pdf/67-1999.pdf stated a range of savings between 35% - 42%
  - Occupant Use of Manual Lighting Controls in Private Offices. IESNA Paper #34. Lighting Research Center, RPI did not provide a range, but a single value of savings from the study of 6%
  - LightRight Consortium Lab Field Study did not provide a range, but a single value of savings from the study of 30%
  - Energy Saving Lighting Control Systems for Open-Plan Offices: A Field Study. Leuokos Vol 4. No. 1 July 2007 Pages 7-29 did not provide a range, but a single value of savings from the study of 11%
  - The data is all over the place here. The mood study at the top was not for open-plan work station specific, so the values are cannot directly be applied to this installation. Also, the second study was in a private office, so the values cannot be applied directly here as well. Finally, the Light Right study and the recent BC Hydro studies can be applied here. Although averages can be messy, an average of the two values was chosen for modeling the energy savings.

Private Office – Vacancy Sensors

- 30% energy savings (averaged across the day) per industry literature

- A 2008 Lightfair presentation by CLTC & Wattstopper compared energy savings between a vacancy sensor (manual-on/manual off or Automatic-off) to an occupancy sensor (automatic-on/automatic-off) for a series of offices with bi-level switching. Below are the components of the energy savings. The value of the data is the comparison between the vacancy and occupancy sensors, not the bi-level portion. Data from study:

Manual-On Bi-Level	**Portion of Load**	**Portion of time**
Off (2-lamps off)	0%	30%
Bi-Level Setting (1-lamp on)	50%	32%
All on (2-lamps on)	100%	38%
Automatic-On Bi-Level		
Off (2-lamps off)	0%	17%
Bi-Level Setting (1-lamp on)	50%	70%
All on (2-lamps on)	100%	13%

- Although bi-level switching is a good strategy, it was not used in the Office of the Future designs, therefore, only the Off (2-lamps) values could be used.
- The 30% for the vacancy value should be used. The 70% of bi-level operation in the with the occupancy sensor set-up is fuzzy. It is understandable that 13 percentiles of that 70% stems from the lack of automatic-on (Automatic is at 0% for 17% and 30% for vacancy). This 13% then would shift into the 50% Load of the occupancy sensor, what does not make sense is why the Full-on values are not similar between the two control strategies. This study only lasted for 3-weeks in 8 offices. Seasonal effects have not been accounted for, so the 30% savings from the vacancy sensor is a conservative value to use.

Conference Rooms – Occupancy Sensors

- 100% automatic off, no savings were considered for this space type
  - It is assumed that the baseline is meeting code and turning off the lighting when the space is not occupied. Using data from PNNL about the usage patterns of conference rooms of different sizes in differently-sized buildings, conference rooms are assumed to be occupied 50% of the given working period of the day.
    - Baseline-Automatic-off 100%
    - Control Strategy-Automatic-off 100%
  - Most lighting in conference rooms are multi-zoned (if multiple lighting systems are installed). However, it would be hard to account for the differences in loading of the different systems installed in the space because each space and loading will be very different. A vacancy sensor bi-level or multi-level strategy could be applied to this space type. However, the data could not be directly applied. Conference rooms are not typical working environments therefore most people turn on many (if not all) the lights when they enter because they are unfamiliar with the space. Therefore, no control savings are projected for this space type.

Corridors – Occupancy Sensors

- 25% energy savings (averaged across the day) per industry literature
  - Advanced Sensors and Controls for Building Applications: Market Assessment and Potential R&D Pathways. April 2005. PNNL stated a range of savings between 20% - 28%

- http://www.p2pays.org/ref/32/31316.pdf which references: Energy Advisor: Lighting: Occupancy Sensors, Florida Power and Light, 2003 at http://www.fpl.com/savings/energy_advisor/PA_10.html stated a range of savings between 30% - 80%
- PNNL's study that references between 20%-28% savings applies to the entire commercial building. The 30%-80% savings seems to only apply to corridors, yet, the FL&P report is unavailable. A conservative value of 25% was chosen. This is near the high-end of the DOE report and on the low end of the FL&P report. The actual savings will vastly depend on the type of building and usage patterns.

APPENDIX B – PERFORMANCE REVIEW

CONTROLS TUNE-UP

- Calibrate the indoor and outdoor building sensors
- Calibrate room thermostats, duct thermostats, humidistats, and pressure and temperature sensors to the original design specifications
- Review static pressure specifications and consider pressure reduction
- Inspect damper and valve controls for proper function
- Check for leaks in compressed air lines
- Inspect and calibrate optimum start/stop, night flush or pre-cooling/preheating control
- Inspect and calibrate all water and air resets ("Reset" is the practice of modifying the air or water temperature, flow or pressure in order to reduce energy consumption without impacting comfort.)
- Inspect and calibrate mechanical cooling and boiler modulation
- Inspect and calibrate air or water side economizer sequence and operation
- Inspect and calibrate heat recovery and humidification/dehumidification equipment sequence and operation
- Review building operating schedules, seasonal time changes and set-backs
- Review the utility load profiles from metering and review utility rate schedule

Typical savings can range up to 30% of annual heating and cooling costs.

HEAT EXCHANGE EQUIPMENT TUNE-UP

The controls and flow issues for heat exchange equipment were addressed in the previous controls section. The remaining action is to ensure that all surfaces and filters are clean to improve heat transfer, decrease pressure loss, and decrease energy use.

- Clean the air side heating and cooling coils, filters, and/or baseboard heating systems
- Check ongoing water treatment and filtering of the HVAC water side
- Check for covered or blocked terminal units and/or baseboards

Typical heating and cooling system cost savings can range up to 10%

CORE HEATING AND COOLING EQUIPMENT TUNE-UP

- Tune the boiler burner (nozzle size and combustion air)
- Clean boiler heat exchanger tubes
- Clean the chiller heat exchanger tubes
- Repair steam traps
- Proper water treatment for both heating and cooling systems
- Consider replacing mechanically controlled, or over-sized variable speed fans and pumps with electronic Variable Speed Drives

- Consider replacing inefficient motors with high efficiency motors
- Install flow restrictors in DHW fixtures and lower water temperature to 105 deg F where possible

Typical heating and cooling system cost savings can range up to 30%

STAFF TUNE-UP

Make certain that facility staff receive training so that they are familiar with tuning and maintaining building systems.

SINGLE-ZONE PACKAGED EQUIPMENT MEASURES

In light of past research, The **OTF Consortium** is recommending a specific Performance Review Procedure akin to a Retro-commissioning program for buildings with a packaged single zone (PSZ) or unitary system. These configurations are typically one or more rooftop mounted units that provide forced air heating and cooling for a tenant space.

Research shows the best opportunities for savings in these systems exists within five general areas:

REFRIGERANT CHARGE

In The **OTF Consortium** research refrigerant charge was found to be out of range in 46% of Roof-top Packaged HVAC units (RTUs). The refrigerant charge can be easily checked and recharged by a qualified HVAC technician as part of the Performance Review.

ECONOMIZERS

The same research shows that the economizer was in need of adjustment on 64% of RTUs surveyed throughout California, the Pacific Northwest, and other western states. The economizer may fail in a number of modes from simple mechanical failure to a lack of proper set-up on installation. The lowest estimate of savings from economizer repair is 15% annual energy consumption.

Some facilities may be without an economizer or energy recovery unit and could be a good candidate for a retrofit item. These facilities need to seek out a qualified engineering firm to perform the rigorous cost/benefit analysis required if not provided by the utility.

AIRFLOW

The **OTF Consortium** research concluded that airflow rates of the main supply air were out of range in 42% of units of the units studied. Airflow rate is more difficult for a technician to verify due to geometrical constraints. The airflow calibration would produce an estimated savings of 10%.

THERMOSTATS

Problems were found with the thermostats on an average of 58% of the units. Thermostat problems include:

- Improper thermostat (single-stage cooling only)
- Cycling fans during occupied periods
- Continuous fans during unoccupied periods
- Improperly installed resistors
- No nighttime setup or setback

Savings estimates vary greatly depending upon the failure mode. In the case of cycling fans during occupied periods, correcting this so fans run continuously during occupied periods (as required by code) will cause the fan energy use to go up but will improve the ventilation and indoor air quality. Savings from thermostat corrections range up to 40%. The highest savings occur when the thermostat is preventing the economizer from operating.

SENSORS

Sensors were problematic in approximately 20% of the units. Problems included:

- Failed sensors
- Snap discs that cannot be calibrated or adjusted.
- Broken wires

As with thermostats, the energy savings for repairing failed sensors varies greatly. Savings may be modest by replacing a snap disk to one that raises the economizer changeover set point or may be on the order of 40% if it enables a nonfunctioning economizer.

The Performance Review measures of the 25% Solution are oriented towards addressing these typical problem areas while allowing for detailed analysis regarding upgrades to be conducted at the discretion of the owner. Significant upgrades may save more energy than a tune-up of an existing system but these situations are far more difficult to predict and provide incentives. There is also an increased opportunity for unnecessary upgrades to access program funds.

If the utility has an existing successful retro-commissioning program that is oriented towards the small office segment then the 25% Solution program will incorporate the requirements of this program, which shall facilitate adoption.

ADDITIONAL HVAC OPPORTUNITIES

A Performance Review, with metering, ensures that the HVAC system is freshly tuned and operating properly and does not undermine savings from other systems. For Tenant Improvements that share an HVAC system with other tenants, i.e., a multi-tenant building with a central HVAC system, Performance Review must extend to the whole HVAC system, not just the portion within the TI, unless the building has had a Performance Review completed within the previous two years. The **OTF Consortium** is also recommending seven additional measures.

ZONING AND CONTROL

To minimize energy use (avoid simultaneous heating and cooling) and ensure occupant comfort, the TI space HVAC zoning and control must meet the following criteria:

- Every solar exposure must have a separate control zone
- Interior spaces must be separately zoned
- Private offices and special use spaces (e.g., conference rooms) must have occupancy or CO2 control of the HVAC system supplying the space.

HVAC Equipment Efficiency

HVAC equipment that is being replaced must comply with the efficiency requirements outlined in the New Buildings Institute, Inc.'s publication *Advanced Buildings: Core Performance Guide*, Section 2.9, Mechanical Equipment Efficiency Requirements. Tables are provided for all standard HVAC components.

Dedicated Mechanical Systems

The intent of this measure is to isolate process loads from comfort conditioning. Zone cooling systems are often driven by such 24/7 cooling loads. Installing dedicated high-efficiency mechanical systems usually services the load more efficiently and avoids the operation of space conditioning systems at low part-loads. If high energy density continuous loads, such as server rooms, are included in the TI space, a separate, dedicated HVAC unit must be employed such that meeting these loads shall not require operation of the main space conditioning system. Zones under 1,000 ft^2 requiring only comfort conditioning can be served by a process load system if they require less than 25% of the system supply air.

Server Room Treatment

The server room in a small to medium office is not considered a serious load to be addressed through direct measures. The load is constantly powered up and supports fundamental corporate activity resisting attempts to improve efficiency, which in itself is not typically a large opportunity for savings. Small offices that have dedicated servers have small models that are nearer to desktop computers than mainframes. If office size increases and loads increase or the office serves as a computing center support for other offices then actions around the server room may present savings opportunities.

Most, if not all, research is oriented around analyzing data centers that have many hundreds of servers and significant heating, cooling, and power consumption issues. Small office server rooms have some of these issues but the list of countermeasures can be reduced significantly to arrive at a small list of design considerations and purchasing policy recommendations to implement in the server room.

- Size the UPS accurately for the power requirements of the server system.
- Install a dedicated HVAC system to service the heating load if large enough. Consider modular in-line cooling strategies.
- Install an occupancy sensor on the server room light

Purchase Energy Star (90 Plus) compliant server and switching equipment

Coordinated Control of Multiple Systems

If multiple HVAC units are used to condition the TI space and they are not operated by a single control system, install new or expand existing controls to coordinate their operation to eliminate simultaneous heating and cooling and, where feasible, provide demand response capability.

Economizer / Heat Recovery Retrofit

If no airside economizer, water-side economizer, or exhaust air energy recovery exists, retrofit to reduce the need for mechanical cooling. Energy savings are on the order of 20% to 60% savings on mechanical cooling. There are additional savings on heating for the energy recovery

system. The installation of energy recovery ventilation systems should be considered whenever any of the following obtain:

- The building will be operated for extended hours, increasing the number of hours with a higher temperature differential between interior and exterior conditions.
- Buildings in cold or moist climates
- Buildings or systems with high outside air ventilation rates as percentage of total air flow
- Buildings with high occupant densities or critical functions which drive increased ventilation rates

APPENDIX C – SAMPLE DESCRIPTION OF PERFORMANCE PACKAGES (TO BE REVISED IN PILOT)

SAVINGS OPPORTUNITY	OPTION 1	OPTION 2	OPTION 3
Lighting	Recessed Curved-Lens Troffers	Direct/Indirect	Workstation Specific - Intelligent Lighting
Plug Load - Office Equipment	Networked Computer and Office Equipment Management	Networked Computer Management and Office Equipment Night Timer Control	Thin Client Architecture or All Laptop/Docking Station Design*
Education and Procurement (All Apply)	General Equipment Procurement Policy	Energy Advocate/ Efficiency Education Program	Participation in Green Building Program such as LEED CI

SAVINGS OPPORTUNITY	OPTION A	OPTION B
Tenant Feedback / Metering	Basic Office Space Electric Meter (wiring permitting)	Revenue-Grade Office Space Sub-meter with Reporting (wiring/code permitting)
Whole Building Feedback / Metering	Advanced Electric Meter with Remote Data Access	Utility AMI Meter or Pulse Output Meter
Tenant Space Serving HVAC	Low Cost/No Cost Performance Review	Formal Utility Retro-Commissioning Program Participation
Plug Load - Workstation Miscellaneous Equipment	Occupancy Sensing Power Strips	Night Timer Controls

SAVINGS OPPORTUNITY	REQUIRED
Plug Load - Kitchen Miscellaneous Equipment	Night Timer Controls Vending Miser Refrigerator Minimum Performance Requirement
Demand Response	Demand Response Capable Thermostats (Where applicable and supported by utility)

*These are not program measures, but companies which utilize these strategies for other reasons would meet this requirement.

APPENDIX D – DEVELOPMENT OF PLUG LOAD SCHEDULES

Office and miscellaneous equipment measures were modeled as an electric power density (EPD) and schedule change to better comply with the DOE 2.2-45m energy simulation programs used to predict the net energy benefits of the OTF measures in representative climate zones with characteristic HVAC system types. This allowed the simulation software to multiply the nominal amount by the fraction to calculate the power density contribution due to plug loads at any given hour during the simulation. Refer to Table 14 in the section Energy Modeling for a summary of initial and final conditions for equipment annual energy and power density.

In modeling the effect of the plug load measures The OTF Consortium needed to model an office building with an initial set of conditions and compare the modeled energy performance with a building using a final set of conditions. Despite the high frequency of implementation by utilities for some of the plug load measures, like Vending Misers or network power management, there are very few published studies[37] of the effect of these measures where the results are calculated as an EPD and schedule change. The overwhelming calculation of evaluators is to present results as an ex-ante annual energy savings in kWh and sometimes a peak demand reduction in kW. The difficulty with modeling these results is that the annual energy savings does not inform the EPD and schedule change necessary to precisely reflect the affect of the measure on the building so that interactive effects can be determined. It was important to include the plug load reductions in the computer model to capture the net energy savings due to sensible heat load reduction over the course of a year. The **OTF Consortium** undertook a process to derive an EPD and schedule change for each sub-category of plug load equipment that compares annual data with data calculated using a proposed EPD and schedule.

Two commercial office configurations of 4,900 ft^2 and 20,000 ft^2 published by PNNL adapted from the NC^3 database combined with survey data were used, listing typical numbers and types of office equipment found within the space. The annual energy consumption for plug loads was then calculated, based on published data for each piece of office equipment and an estimate of miscellaneous workstation and office equipment loads. The result for each prototype was compared with the annual energy consumption for plug loads calculated with an EPD and schedule using the number of weekdays and weekends for a typical calendar year. The schedule was taken from the DEER prototype and the EPD was derived to calibrate with the annual energy savings. The calibrated EPD and resulting annual equipment energy density were compared to published literature including CEUS and CBECS 2003[38] to ensure the EPD and schedule were providing results in line with major studies of office plug loads. The initial EPD and schedule were divided into five sub-categories defined by the OE or ME type in order to apply measures accordingly.

The annual energy savings for each plug load was estimated using the prototypes and published studies[39,40] for typical annual energy consumption. Then the initial EPD and schedule for each equipment category were modified using quantitative analysis based on program evaluation results[41] and vendor supplied information[42] to arrive at a final EPD and schedule.

The total annual energy savings expected was compared with results in published studies of the implementation of similar measures.

This process resulted in an initial and final EPD and schedule used as inputs to the model.

APPENDIX E - ALIGNMENT OF THE 25% SOLUTION WITH LEED

Building owners seeking LEED EB (Existing Buildings) certification, or tenants seeking LEED CI (Commercial Interiors) certification, will benefit from aspects of the 25% Solution that can contribute to meeting a number of LEED requirements.

LEED EB

25% Solution Domestic Hot Water measures apply towards meeting the following requirements:

- Water Efficiency (WE) Prerequisite 1: Minimum Indoor Plumbing Fixture and Fitting Efficiency
- WE Credit 2: Additional Indoor Plumbing Fixture and Fitting Efficiency

25% Solution Performance Review activities apply towards meeting the following requirements:

- Energy and Atmosphere (EA) Prerequisite 1: Energy Efficiency Best Management Practices – Planning, Documentation and Opportunity Assessment
- EA Prerequisite 2: Minimum Energy Efficiency Performance
- EA Credit 2.1: Existing Building Commissioning: Investigation and Analysis
- EA Credit 2.2: Existing Building Commissioning: Implementation
- EA Credit 2.1: Existing Building Commissioning: Ongoing Commissioning

25% Solution Metering protocol applies towards meeting the following requirements:

- EA Credits 3.2 & 3.3: Performance Measurement: System-Level Metering

LEED CI

25% Solution Performance Review activities apply towards meeting the following requirements:

- EA Prerequisite 1: Fundamental Commissioning
- EA Prerequisite 2: Minimum Energy Performance

25% Solution Additional Measures activities apply towards meeting the following requirements:

- EA Prerequisite 3: CFC Reduction in HVAC&R Equipment
- EA Credit 1.3: Optimize Energy Performance, HVAC

25% Solution Equipment/Miscellaneous Uses activities apply towards meeting the following requirement:

- EA Credit 1.4: Optimize Energy Performance, Equipment & Appliances

25% Solution Metering protocol applies towards meeting the following requirement:

- EA Credit 3: Energy Use, Measurement and Payment Accountability

APPENDIX F - DETAILED ENERGY MODEL DESCRIPTION AND RESULTS

The DEER models provide a large office and a small office. The characteristics of the offices construction and details of the HVAC model are below.

The large office prototype is a 10-story, 175,000 ft^2 , building served by 3 VAV air systems serving multiple zones with fan-less VAV boxes and hot water reheat (gas fired). The primary differences by vintage are the VAV supply air temperature control, envelop insulation levels, windows, duct insulation/leakage, and dry bulb economizer controls. The pre-78 building is actually a constant volume reheat system (CVRH) with no economizer.

The small office prototype is a 2-story 10,000 ft^2, building served by package single zone gas furnace/DX cooling units. The primary differences by vintage are overall insulation level, duct insulation/leakage, and economizer controls. In the original DEER runs lighting and equipment levels varied with vintage as well. In this work lighting and equipment densities and energy use are adjusted to the OTF baseline levels.

Building Type	Total Area	Vintage (years)	Data Source*	Area Served (sqft)	Area Served (descrip)	System Type (type)	Alternative System Type (type)
14 Office - Large	175,000	< 1978	DEER	175,000	all	Blt-Up CV-reheat	n/a
		78-92	DEER	175,000	all	Blt-Up VAV-reheat	n/a
		93-01	DEER	175,000	all	Blt-Up VAV-reheat	n/a
		> 2001	NCC	175,000	all	Blt-Up VAV-reheat	n/a
15 Office - Small	10,000	< 1978	DEER	10,000	all	Rooftop Gas Pack	Rooftop HP
		78-92	DEER	10,000	all	Rooftop Gas Pack	Rooftop HP
		93-01	DEER	10,000	all	Rooftop Gas Pack	Rooftop HP
		> 2001	NCC	10,000	all	Rooftop Gas Pack	Rooftop HP

Building Type	Vintage (years)	Data Source*	Cooling Type (type)	# Chlrs	Heating Type (type)	Alternative Heating Type (type)	Cooling Efficiency (kW/ton)	Cooling Efficiency (COP)	Cooling Efficiency (EER)
Office - Large	< 1978	DEER	C Cent Ch	2	Boiler	n/a	0.75	n/a	n/a
	78-92	DEER	C Cent Ch	2	Boiler	n/a	0.75	n/a	n/a
	93-01	DEER	C Cent Ch	2	Boiler	n/a	0.75	n/a	n/a
	> 2001	NCC	C Cent Ch	2	Boiler	n/a	0.63	n/a	n/a
Office - Small	< 1978	DEER	DX	n/a	Gas Furnace	Heat Pump	n/a	2.25	7.7
	78-92	DEER	DX	n/a	Gas Furnace	Heat Pump	n/a	2.6	8.9
	93-01	DEER	DX	n/a	Gas Furnace	Heat Pump	n/a	2.9	9.9
	> 2001	NCC	DX	n/a	Gas Furnace	Heat Pump	n/a	3.0	10.1

Building Type	Vintage (years)	Heating Efficiency (Eff)	(COP)	(AFUE)	Economizer (type)	Cool Reset (y/n)
Office - Large	< 1978	80%	n/a	n/a	none	no
	78-92	80%	n/a	n/a	DB	no
	93-01	80%	n/a	n/a	DB	yes
	> 2001	80%	n/a	n/a	DB	yes
Office - Small	< 1978	80%	2.4	n/a	none	n/a
	78-92	80%	2.4	n/a	DB	n/a
	93-01	80%	2.7	n/a	DB	n/a
	> 2001	80%	3.2	n/a	DB	n/a

Building Type	Vintage (years)	Heat Reset (y/n)	Pipe Gain (deltaT, F°)	HW Pipe Loss (deltaT, F°)	CHW Valve (type)	HW Valve (type)	Fan Control (type)	Design Duct DT (deltaT, F°)
Office - Large	< 1978	no	2.0	2.0	3-way	3-way	CV	6
	78-92	no	2.0	2.0	3-way	3-way	Inlet	4
	93-01	yes	2.0	2.0	3-way	3-way	Inlet	2
	> 2001	no	0.75	1.7	2-way	3-way	VSD	1
Office - Small	< 1978	n/a	n/a	n/a	n/a	n/a	CV	3
	78-92	n/a	n/a	n/a	n/a	n/a	CV	2
	93-01	n/a	n/a	n/a	n/a	n/a	CV	1
	> 2001	n/a	n/a	n/a	n/a	n/a	CV	1

Savings reports from the modeling process are below.

SMALL OFFICE

		Energy Savings					Interaction Ratios			Peak Savings	
		Electric		Gas	Net		Electric	Gas			
climate	vintage	KWh/sf	% of Elec	kBtu/sf	% of Site	% of Source	kWh/kWh	KBtu/kWh	KBtu/kBtu	W/sf	Btu/hr.sf
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Boston (bostonma.bin)	Pre 78	2.91	22.6	-5.77	4.6	13.4	1.13	-2.24	-0.66	0.94	-3.00
	78-91	2.75	24.0	-5.45	5.5	15.1	1.07	-2.11	-0.62	0.90	-2.00
	91-01	2.73	26.5	-5.95	4.7	15.5	1.06	-2.31	-0.68	0.90	-2.00
	01-05	2.73	27.3	-5.76	5.8	17.1	1.06	-2.23	-0.65	0.87	-2.00
	Post 05	2.77	27.9	-5.86	5.8	17.4	1.07	-2.27	-0.67	0.90	-2.00
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San Francisco (Bay Area CZ3)	Pre 78	3.12	25.2	-2.98	15.2	21.5	1.21	-1.16	-0.34	0.95	-1.00
	78-91	2.76	25.9	-2.81	15.1	21.8	1.07	-1.09	-0.32	0.90	-1.00
	91-01	2.74	28.0	-3.35	14.3	22.7	1.06	-1.30	-0.38	0.88	0.00
	01-05	2.74	28.1	-2.58	17.3	24.1	1.07	-1.00	-0.29	0.88	-3.00
	Post 05	2.77	28.7	-2.63	17.6	24.6	1.08	-1.02	-0.30	0.89	-3.00
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Los Angeles (CZ6)	Pre 78	3.26	23.6	-1.07	19.9	22.3	1.27	-0.42	-0.12	1.05	-3.00
	78-91	2.89	24.3	-0.95	20.4	23.0	1.12	-0.37	-0.11	0.99	-3.00
	91-01	2.85	26.7	-1.46	20.6	24.6	1.11	-0.57	-0.17	0.96	-3.00
	01-05	2.86	26.8	-0.86	22.7	25.4	1.11	-0.33	-0.10	0.96	-5.00
	Post 05	2.89	27.4	-0.89	23.1	25.9	1.12	-0.35	-0.10	0.97	-5.00
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Lake Tahoe (Mountains CZ16)	Pre 78	2.90	21.7	-5.39	5.7	14.3	1.13	-2.09	-0.61	0.91	-2.00
	78-91	2.72	23.4	-4.83	7.1	16.2	1.06	-1.87	-0.55	0.86	-1.00
	91-01	2.70	26.2	-5.48	6.1	16.9	1.05	-2.13	-0.62	0.85	-2.00
	01-05	2.72	25.1	-4.34	9.4	18.5	1.06	-1.68	-0.49	0.84	-2.00
	Post 05	2.75	25.8	-4.43	9.5	19.0	1.07	-1.72	-0.50	0.84	-2.00

LARGE OFFICE

		Energy Savings					Interaction Ratios			Peak Savings	
		Electric		Gas	Net		Electric	Gas			
climate	vintage	KWh/sf	% of Elec	kBtu/sf	% of Site	% of Source	kWh/kWh	KBtu/kWh	KBtu/kBtu	W/sf	Btu/hr.sf
Boston (bostonma.bin)	---	---	---	---	---	---	---	---	---	---	---
	Pre 78	2.64	13.3	-8.58	0.2	5.9	1.01	-3.28	-0.96	0.69	-1.89
	78-91	2.80	21.9	-4.51	7.1	15.2	1.07	-1.73	-0.51	0.80	-3.54
	91-01	2.78	24.6	-4.92	7.2	16.8	1.06	-1.88	-0.55	0.81	-2.91
	01-05	2.85	27.3	-4.50	9.6	19.6	1.09	-1.72	-0.50	0.83	-3.60
	Post 05	2.85	27.8	-4.50	9.7	19.9	1.09	-1.72	-0.50	1.19	-3.60
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San Francisco (Bay Area CZ3)	Pre 78	2.63	12.4	-9.18	-0.1	5.7	1.00	-3.51	-1.03	0.64	-2.23
	78-91	2.79	20.1	-3.52	8.4	15.1	1.07	-1.35	-0.39	0.82	-4.29
	91-01	2.79	22.7	-3.39	9.8	17.2	1.07	-1.30	-0.38	0.81	-4.46
	01-05	2.97	26.4	-2.30	14.6	21.5	1.13	-0.88	-0.26	0.78	-4.23
	Post 05	2.96	27.1	-2.28	14.9	22.0	1.13	-0.87	-0.26	0.78	-4.23
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Los Angeles (CZ6)	Pre 78	2.64	11.1	-9.72	-0.4	5.2	1.01	-3.72	-1.09	1.40	-1.20
	78-91	2.84	18.2	-3.87	7.9	13.9	1.09	-1.48	-0.43	0.87	-2.11
	91-01	2.83	20.8	-3.34	9.8	16.3	1.08	-1.28	-0.37	0.83	-4.52
	01-05	2.99	24.3	-1.95	14.9	20.6	1.15	-0.75	-0.22	0.82	-2.86
	Post 05	3.00	25.2	-1.94	15.3	21.3	1.15	-0.74	-0.22	0.83	-2.86
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Lake Tahoe (Mountains CZ16)	Pre 78	2.63	12.5	-8.67	0.2	5.4	1.01	-3.32	-0.97	0.62	6.40
	78-91	2.79	21.5	-4.27	7.1	14.9	1.07	-1.63	-0.48	0.83	-4.17
	91-01	2.76	24.4	-4.42	7.9	17.0	1.06	-1.69	-0.50	1.26	-2.06
	01-05	2.81	25.6	-3.42	10.5	18.9	1.08	-1.31	-0.38	0.80	-4.00
	Post 05	2.82	26.1	-3.40	10.7	19.3	1.08	-1.30	-0.38	0.81	-4.00

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