Updated Baseline

Compared to 1998 T-24 Code &

End Use Savings by Measure Category

A Follow-on to the
Nonresidential New Construction Baseline Study
Project 1

Final Report

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California State-Level Market Assessment and Evaluation Study

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1. Executive Summary

This study is a continuation of the California Nonresidential New Construction Baseline Study. The follow-on baseline study provides a deeper look at the energy efficiency of new commercial buildings built recently in California.

The study consists of three projects:

1. End Use Savings and Analysis of New LPD Baseline
    - Provide a better understanding of end use savings and the effect of the new lighting power density requirements in the 1998 version of Title 24.
2. Utility Program Paths
    - Compare the two major paths in utility energy efficiency programs: the whole-building (performance) approach and the systems (prescriptive) approach.
3. Lighting Assessment
    - Validate the accuracy of the lighting measurements and provide an in-depth look at lighting quality.

This report describes the results from Project 1. In this project we have prepared new DOE-2 engineering simulation runs for the existing baseline sample of buildings. One objective of this study has been to understand the effect of the changes in the 1998 version of Title 24. Therefore, two different baselines have been run reflecting the 1995 and 1998 Title 24 standards. The biggest change in the 1998 version was new lighting power density requirements and envelope specifications. These changes will tend to reduce the baseline lighting, cooling and ventilation energy consumption, while increasing heating energy consumption. There are other subtle differences in the directions for modeling and computer simulation given in the ACM manuals for each version of the code.

A second objective was to obtain a better understanding of energy savings at the end-use level. The original analysis used the end-use output of the as-built and baseline DOE-2 simulations to estimate savings by end use. But the prior analysis did not isolate direct effects from interactive effects. For example, the direct savings of HVAC measures were not separated from the interactive effect of lighting measures on HVAC savings. Using both the 1995 and 1998 baselines, a sequence of parametric runs have been prepared for the following measure categories: shell measures, lighting power densities, daylighting controls, other lighting controls, motors and HVAC. These runs have been designed to better understand the direct and interactive effects of these measures.

Key findings

The following are some of the key findings of this study:

- As expected, the 1998 Title 24 standards raised the bar for new-building energy efficiency. But buildings built between 1994 and 1998 generally met or exceeded the higher standards. More specifically, these buildings were on average almost 8% more efficient than the 1998 baseline. By contrast, these same buildings were about 14% more efficient than the 1995 baseline. So typical practice led the improvement in standards.

- Under both the new and prior standards, the majority of the savings were in the lighting end use. Relative to the 1998 baseline, the lighting end use had almost 5% of the 8% savings. By contrast, relative to the 1995 baseline, the lighting end use had over 11% of the 14% savings. The remaining savings were about equally split between the cooling and fan end uses.
- Under the new baseline, lighting power density measures account for 4% of the 8% savings, daylight controls account for 0.8% and other lighting controls another 0.7%, for a total of 5.5% of all savings. This includes the interactive effects of the lighting measures. The remaining savings come from motor measures (1.2%) HVAC measures (0.9%), and shell measures.
- About two-thirds of the savings in the cooling end-use are due to HVAC measures. Most of the remaining cooling savings are due to the indirect effect of lighting measures.
- Under the 1998 baseline, most of the savings in the fan end use are due to motor measures.

The report also provides a detailed analysis of lighting technologies by type of space. Some key findings are:

- Lighting controls are connected to less than 20% of the total connected lighting load.
- Fluorescent fixtures provide 67% of all lighting connected load. 70% of this load is served by T8 lamps and electronic ballasts. But almost 12% of this load is served by T12 lamps and Energy Server ballasts.
- Moreover, incandescent fixtures provide over 13% of all lighting connected load.

These results suggest there is substantial room for expanding the saturation of lighting controls and efficient lighting technologies.

2. Introduction

This is the final report for Project 1 of the follow-on baseline study of the Non-Residential New Construction (NRNC) market in California. The study was conducted by RLW Analytics and Architectural Energy Corporation on behalf of the California Public Utilities Commission (CPUC) under the management of Southern California Edison Company. This study was intended to give future program administrators and implementers some of the information needed to alter the long-term behavior of the actors in the NRNC market. Another intention of the study was to gain an understanding of how easy or difficult it will be for designers to meet the new Title 24 requirements.

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This report describes the results from Project 1. In this project we have prepared new DOE-2 engineering simulation runs for the existing baseline sample of buildings. One objective of this study has been to understand the effect of the changes in the 1998 version of Title 24. Therefore, two different baselines have been run reflecting the 1995 and 1998 Title 24 standards.

The 1995 and 1998 versions of Title 24 varied primarily in the areas of envelope specifications and lighting power density. These changes will tend to reduce the baseline lighting, cooling and ventilation energy consumption, while increasing heating energy consumption. There are other subtle differences in the directions for modeling and computer simulation given in the ACM manuals for each version of the code. A decision was made early in the project to update both the basic code provisions *and* the modeling approach, so the 1998 runs would more closely follow the code. The reader of this report should be aware that this approach confounds the comparison of 1995 and 1998 runs, since the differences in the results are caused by both the changes in envelope and LPD specifications and ACM-directed modeling assumptions.

A second objective was to obtain a better understanding of energy savings at the end-use level. The original analysis used the end-use output of the as-built and baseline DOE-2 simulations to estimate savings by end use. But the prior analysis did not isolate direct effects from interactive effects. For example, the direct savings of HVAC measures were not separated from the interactive effect of lighting measures on HVAC savings. Using both the 1995 and 1998 baselines, a sequence of parametric runs have been prepared for the following measure categories: shell measures, lighting power densities, daylighting controls, other lighting controls, motors and HVAC. These runs have been designed to better understand the direct and interactive effects of these measures.

On July 1, 1999 the new Title 24 lighting power density (LPD) requirements took effect. They represent a substantial increase in the stringency of required lighting system efficiency compared to the previous version of Title 24. Until now, there has been no clear assessment of how easy or difficult it is for designers to meet these new requirements.

Past NRNC efficiency programs have always encouraged lighting systems that were better than Title 24 (i.e., lower LPD). Likewise, the new statewide Savings By Design program provides incentives to those who design lighting systems that are 10% or better than the new requirements. The NRNC Baseline study shows that, for most occupancy categories, even the program non-participants in recent years routinely produced lighting systems with LPDs below the old Title 24. With the new, more stringent baseline, it will require further reductions in LPDs to design substantially below the new Title 24 requirements.

If the NRNC program is to encourage these improvements, we need to understand more about how that will be accomplished, compared to the way it has been done prior to now. Reduced LPDs are a function of two aspects of lighting design: equipment efficiency (lamps, ballasts, fixtures) and system design (number of fixtures, layout, controls). The NRNC Baseline study database has sufficient detail to document how it has been accomplished in the past and how much of an adjustment to current practice will be required to exceed the new Title 24 requirements. The goal of this project is to carry out this level of investigation of the survey data.

The final section of this report describes the distribution of lighting technologies and LPDs by space categories instead of building level. Existing LPDs were compared to new 1998 Title 24 baseline requirements. The lamp type, ballast type, fixture type, and lighting controls were also tabulated in order to better understand the technologies being installed, the lighting levels being achieved and how they vary among building and area types.

3. Methodology

In this section we will lay the foundation for the analysis used throughout this chapter. We will discuss:

- Our target population and the sample data, and
- The use of energy simulation to control for differences between buildings.

Follow-On Baseline Report Sample Sizes

The population characteristics and sample sizes were described in full detail in the original Baseline study. The same methodology was used for this follow-on study, thus the same sites were selected for each of the analyses by building type, ownership type, or program year.

In the original Baseline study, we sought to carefully choose the part of our sample used in each type of analysis. The following table summarizes the approach that was ultimately selected. For the analysis of energy efficiency by building type, all 667 sample points were included. In the comparison between ownership sectors – public, private owner occupied, and speculative –the sample sites from the 1995 SDG&E impact evaluation were dropped because the ownership status of these sites was unknown.

In comparing participants to non-participants, the 1998 sample was dropped since it was originally intended to capture non-participants only. In looking at time trends, the program participants were excluded in order to compare the 1994, 1996 and 1998 data. The 1995 SDG&E sites were dropped from the time comparisons because that part of the sample was small and was out of phase with the rest of the sample. In the original Baseline study, when we analyzed cooling results by building type and ownership, we restricted the analysis to the 1998 sample because of the trend in cooling efficiency. However, to maintain consistency in the body of the report, we analyzed the cooling end use using all of the 667 sites with cooling. The last section in this report contains an additional section on cooling using only the 148 sites from 1998.

	1994		1995		1996		1998		
Type of Analysis	**Participant**	**Non-Participant**	**Participant**	**Non-Participant**	**Participant**	**Non-Participant**	**Participant**	**Non-Participant**	**Total Number in Sample**
Building Type	130	124	17	10	112	126	4	144	667
Ownership Type	130	124	0	0	112	126	4	144	640
Participant vs. Non-Participant	130	124	17	10	112	126	0	0	519
Time Trends	0	124	0	0	0	126	4	144	398

Table 1: Sample Sizes

Follow-On Baseline Population Characteristics

The target population of this study is new construction in California for the office, retail, schools and public assembly sectors during the period 1994 through 1998. We defined the population using a listing of new construction projects obtained from F. W. Dodge. The database seeks to list all new construction projects that are valued over $200,000 and are expected to start within 60 days. The data include renovations and expansions as well as entirely new buildings.[1]

Table 2 shows that the population contains a large percentage of offices relative to the other building types. As shown in Table 2, our sample consists of 667 new construction projects. 148 of these sites were 1998 projects audited specifically for the present study. To expand the database, we borrowed 519 audits from the following four prior studies:

- 1994 SCE and PGE joint NRNC program evaluation
- 1995 SDGE NRNC program evaluation
- 1996 SCE NRNC program evaluation
- 1996 PGE NRNC program evaluation

All of the samples were stratified by building type. The program evaluation samples were stratified to provide a representative sample of program participants and a sample of non-participants matching the participants in terms of square footage and building type. In preparing the data for our follow-up analysis, we have created new case weights to properly project the sample sites up to our target population[2]. These case weights adjust for differences between our sample and the population in terms of program participation, building type and square footage. For example, the case weights adjust for the fact that schools represent 25% of the sample projects but only 17% of the projects in the population.

	Office	Public Assembly	Retail	School	Total
Percentage of Total Population	38%	23%	22%	17%	0%
Percentage of Total Floor Area	43%	14%	27%	16%	0%
Percentage of Total Energy	38%	16%	36%	11%	0%
Sample Size	231	105	162	169	667
Percentage of Sample	35%	16%	24%	25%	0%

Table 2: Population Characteristics by Building Type

[1] The data is thought to cover over 95% of all projects that are competitively bid.

[2] Our target population was modified from the original target population due to a project that was completed subsequent to the Baseline study in which all of the dodge data were cleaned for duplicates. The case weights were modified as a result of the cleaned and reduced Dodge data.

DOE-2 Models

An automated process was used to develop basic DOE-2 models from data contained in the on-site surveys, Title 24 compliance forms, program information and other engineering data. The modeling software took information from these data sources and created a DOE-2 model. The data elements used, default assumptions, and engineering calculations are described for the Loads, Systems, and Plant portions of the DOE-2 input file in the appendix to this report, in addition to the model calibration process, model review and quality control.

Baseline

Once the models were calibrated and quality checked, a batch process was used to create a series of parametric simulation runs. These runs were used to simulate energy use on a whole-building and measure-class basis. Each DOE run yields an estimate of energy consumption for the whole building, lighting, cooling, and fan end uses. The parametric runs were first completed using the 1995 Title 24 as the reference, then the 1998 Title 24 was used as the reference. Thus, there were a total of 14 runs that were used in the analysis for this report. The parametric runs performed for this study are listed below.

As-Built Parametric Run

Once the models were completed, checked for reasonableness, and/or calibrated, the as-built parametric run was done. Monthly schedule variations resulting from partial occupancy and building startup were eliminated, and the models were run using long-term average weather data from the CEC CTZ long term average weather data files.

Baseline Parametric Run

Key building performance parameters were reset to a baseline condition to calculate gross energy savings for participants on an end-use basis. The California Building Energy Efficiency Standard (Title 24) was the primary reference for establishing baseline performance parameters. The Title 24 specifies minimum specifications for building attributes such as:

- Opaque shell conductance
- Window conductance
- Window shading coefficient
- HVAC equipment efficiency
- Lighting power density

Title 24 applied to most of the building types covered in the programs covered under this evaluation, with the exception of:

- Hospitals
- Unconditioned space (including warehouses)

Incentives were also offered by the programs for building attributes not addressed by Title 24. In situations where Title 24 does not address building types or equipment covered under the program, baseline parameters equivalent to those used for the program baseline efficiencies were used.

Envelope

Opaque shell U-values were assigned based on Title 24 requirements as a function of climate zone and heat capacity of the observed construction. For windows, Title 24 specifications for maximum relative solar heat gain were used to establish baseline glazing shading coefficients. Fixed overhangs were removed from the baseline building. Glass conductance values as a function of climate zone were applied. For skylights, shading coefficients and overall conductance were also assigned according to climate zone.

Mechanical

Baseline specifications for HVAC equipment efficiency were derived from the Title 24 requirements as a function of equipment type and capacity. Maximum power specifications for fans were established based on Title 24 requirements, which address fan systems larger than 25 hp. Specific fan power was held energy neutral (as built W/CFM = baseline W/CFM) for fan systems under 25 hp. Additionally, all systems larger than 2500 CFM (except for hospitals) were simulated with economizers in the baseline run. All VAV fan systems larger than 50 hp were simulated with inlet vane control. All variable-volume pumps were simulated with throttling valve control.

HVAC system sizing

HVAC system sizing for the as-built case was determined by direct observation of the nameplate capacities of the HVAC equipment. The installed HVAC system capacity was compared to the design loads imposed on the system to determine a sizing ratio for the as-built building. Once established, the sizing ratio was held constant for each subsequent DOE-2 run. A separate sizing run was done prior to the baseline and parametric runs. The peak cooling system size was calculated using the equipment sizing algorithms in DOE-2. The system capacity was reset using the calculated peak cooling capacity, and the as-built sizing ratio. A new system size was calculated for the baseline run and each parametric run.

Lighting

The Title 24 area category method was used to set the baseline lighting power for each zone as a function of the observed occupancy. Task lighting and exit signs were not included in the baseline lighting calculation. A lighting power density appropriate for corridor/restroom/support areas was assigned according to the portion of each space allocated to these areas. All lighting controls were turned off for the baseline simulation.

Parametric Runs

Once the as-built and baseline building models were defined, an additional set of parametric runs were done to estimate the program impact on the lighting, HVAC, and shell / daylighting end-uses. The baseline model was returned to the as-built design in a series of steps outlined as follows:

1. **All Shell.** Baseline Run, plus all baseline envelope properties (glazing U-value and shading coefficient; and opaque surface insulation) were returned to their as-built condition.
2. **All LPD.** Run 1 above, plus all baseline lighting power densities returned to their as-built condition.
3. **All Daylighting Controls.** Run 2 above, plus all baseline daylighting controls returned to their as-built condition.
4. **All Other Lighting Controls.** Run 3 above, plus all baseline lighting controls (other than daylighting) returned to their as-built condition.
5. **All Motors.** Run 4 above, plus all baseline motor efficiency and fan power indices (W/CFM) returned to their as-built condition.
6. **All HVAC.** Run 5 above, plus all HVAC parameters returned to their as-built condition. This run is equivalent to the full as-built run.

Several model variables were held “energy neutral” during the parametric run process. Energy neutral is defined as keeping specific model variables equal to baseline model runs so as not to effect energy consumption. For example, operating schedules for a rebated lighting system remain unchanged in the as-built and baseline runs so that only the delta in connected lighting load between the two models is used to estimate energy and demand impacts.

Changes to Data since Original Baseline Evaluation

Model-IT

The Model-IT software that was used to construct the DOE-2 models for this study was modified during the process of conducting two evaluation studies that were completed subsequent to the original Baseline study. An example of one of the changes that was made was the flagging of buildings where auditors had specified more exhaust flow than ventilation air. This situation is not allowed by DOE-2 (nor by physics) so it causes problems in the subsequent parametric runs. Previously exhaust fans had been turned off in the DOE-2 simulations because of the problems, but with the most recent evaluations, the exhaust fans were turned on and the data were fixed when the flag appeared. The data were cleaned for every study site that had this problem.

Another example of a change that was made is related to the fact that the 1995 version of Title 24 requires that supply air temperature be controlled, specifically:

“Mechanical space conditioning systems supplying heated or cooled air to multiple zones must include controls that automatically reset the supply air

temperature in response to representative building loads, or to outdoor air temperature."

When Model-IT was initially created, the default/baseline assumption was the former option; resetting temperature based on loads. While investigating negative savings for some participant sites during the 1998 evaluation studies, it was found that this selection for the baseline caused the problem. The sites in question employed supply air temperature reset based on outdoor air temperature, and that was being compared to a baseline model employing supply air temperature reset based on load. A decision was made to change the baseline to outdoor temperature reset, impacting the calculated savings for some sites. The difference is most pronounced in buildings with VSD controlled fans.

ACM Changes

The 1995 and 1998 versions of Title 24 varied primarily in the areas of envelope specifications and lighting power density. These changes will tend to reduce the baseline lighting, cooling and ventilation energy consumption, while increasing heating energy consumption. Other subtle changes relate to computer simulation modeling directions given in the ACM manuals for each version of the code. A decision was made early on in the project to update both the basic code provisions ***and*** the modeling approach, so the 1998 runs would more closely follow the code. This approach confounds the comparison of 1995 and 1998 runs, since the differences in the results are caused by both the changes in envelope and LPD specifications and ACM directed modeling assumptions. The ACM changes adopted for this study are:

Default occupant densities. Default occupancy densities for specific space types were increased dramatically. This change will have a small impact on the space heating and cooling loads resulting from occupant heat gains.

Default ventilation rates. The default outdoor air ventilation rates (in CFM/SF) were increased for some space types. The heating and cooling loads associated with conditioning the outdoor air in these spaces increased as a result.

Baseline motor efficiency. The values used to establish default motor efficiency were increased on the order of 3-5%. This change will tend to reduce motor energy consumption overall, and decrease the savings calculated for energy-efficient motors.

Supply air temperature control. The 1995 ACM requires supply air temperature control reset based on outside air temperature in the baseline runs. The 1998 ACM requires reset based on outdoor air or zone temperature, depending of the as-built design. The magnitude of the cooling load impact can be substantial, and the direction can be positive or negative. The baseline cooling end-use increases if the as-built control has no reset (e.g. fixed setpoint temperature), decreases if the as-built system controls supply air temperature based on zone temperature, and remain the same if the as-built system controls on outdoor temperature.

Chiller performance curves. A full set of chiller performance curves was added, replacing the default curves used in DOE-2. The impact of this change is not known, as some of the chillers were simulated with custom curves supplied by the manufacturer.

Cooling tower simulation assumptions. The 1995 ACM specified a single tower with a single-speed fan and fixed condenser water setpoint temperature control for the baseline simulation. The 1998 ACM specified one tower per chiller, with a two-speed fan, reduced fan power, and the same setpoint temperature control as the design. These changes will reduce baseline energy consumption in all buildings with cooling towers.

The LPD and envelope changes will tend to reduce the loading on fans, pumps, packaged AC equipment, chillers, and towers; and thereby reduce the savings from HVAC plant efficiency improvements. The other changes may increase or decrease the motor and HVAC savings, depending on the mix of space types, control strategies and cooling equipment used in the building.

Energy Efficiency from Simulations

In order to examine the overall energy efficiency of an individual building or a set of buildings, we first compared (a) the as-built energy consumption of the building or buildings and (b) the baseline energy consumption of the same building or buildings. The baseline energy consumption for each building is defined to be the energy consumption of the building as if all of the equipment was specified to be minimally compliant with Title 24 and the building was operated on the schedule found during the on-site survey.[3]

Consider a modern office building. To understand its energy efficiency, we need to consider the level of lighting, how the waste heat from the lighting fixtures is removed, how the windows are orientated, the reflection and convection of the glazing, the type, size and efficiency of the air conditioning, etc. Moreover we have to think of the building as a system of zones - each with their own characteristics and subsystems, each interacting with one another.

With energy simulation we can represent all of these systems and subsystems and combine their individual efficiencies and interactions to determine the efficiency of the building as a whole. The overall energy efficiency is measured by comparing the simulated annual energy of the office as we have found it to what the annual energy would have been if it had been built according to the Title 24 specifications. In effect, we have reduced the complex building down to two numbers – the as-built energy and the baseline energy.

Now suppose we want to describe the energy efficiency in the office market segment. The office segment contains a wide variety of buildings ranging from

[3] This comparison is not an appropriate way to determine the degree of compliance of specific buildings with Title 24. Our analysis uses actual schedules rather than the default Title 24 operating schedules. And our simulations use the area category method for each building regardless of the Title 24 compliance path actually elected. Nevertheless, the baseline does provide a general indication of the relative efficiency of buildings in specific NRNC market segments. Since our comparisons are all based on ratios, we feel it is appropriate to draw general conclusions about the energy efficiency of groups of buildings.

glass and steel skyscrapers to one-story wood frame buildings. It is not very meaningful to discuss the average roof U-value or the average EER of the air conditioning across the office market segment. In fact it is virtually impossible to summarize the relevant characteristics of these diverse buildings in a meaningful way.

Fortunately, through simulation, we can define the collective efficiency of the buildings in the office market very simply – by comparing the following two quantities:[4]

- The total simulated annual energy of the buildings in the office market segment as they have been built, and
- The total simulated annual energy of the buildings in the office market segment if they had been built to the baseline conditions.

Suppose, for example, that the as-built electricity use is found to be 90 million kWh per year and the baseline use is found to be 100 million kWh per year. Then we say that the energy ratio is 0.90 in this market segment, or equivalently, that this collection of buildings is 10% more efficient than the baseline.

With this approach, we can compare the energy efficiency of one market segment to another, even though it contains vastly different buildings.

This approach offers several key advantages. It helps us:

- Systematically record the relevant physical characteristics of a specific building
- Look at the physical characteristics of the building as a system
- Consider the often complex interactions between the many elements of the building
- Reduce the diverse physical characteristics down to a few meaningful numbers, e.g., the simulated annual energy consumption of the building
- Combine information across different buildings by comparing each individual building to a fixed, common baseline
- Make meaningfully comparisons between various market segments despite the differences in the types of buildings in the segments.

Organization of Results

With the proceeding foundation, we can begin to analyze the sample data. This section describes all of the following sections of results.

- **Overall (As-Built v. Baseline) Savings and Energy Ratio**: The overall savings are calculated as the difference between the as-built and the baseline parametric run. The energy ratio is calculated as the ratio between the as-built energy consumption and the baseline energy consumption.

[4] Of course we can't simulate the total energy for all buildings in the market, but we can estimate the total from a statistical sample of buildings.

- **Whole Building Savings by Measure Category**: This section summarizes the results of the whole building analyses by each parametric run.
- **End Use Savings by Measure Category:** This section summarizes the lighting, cooling, and fan end uses individually, summarizing the effect of each parametric run on each end use. Each parametric run is summarized in separate sections in this chapter, summarizing the percentage of savings attributed to each end use for each parametric run, and the energy factor for each parametric run.

4. Overall (As-Built v. Baseline) Savings and Energy Ratio

To simplify this analysis, we will consider all four building types taken together. We will show that the buildings on average were almost 8% more efficient than the 1998 baseline and about 14% more efficient than the 1995 baseline. We will show that about three-fourths of the savings relative to 1995 T-24 are due to the lighting end use, and the remaining savings are about equally divided between the cooling and fan end uses. Based upon this initial inspection of the savings, most of the cooling and fan savings appear to be due to the interactive effects of the lower lighting loads. Based on this background, subsequent sections will focus on these three end uses: lighting, cooling and fans.

The data shown are the results of "whole-building" simulations, which account for the interactive effects of changes in building characteristics across all affected end-uses. For example, buildings with lighting energy ratios less than one will also show cooling energy ratios less than one, even if the cooling system efficiency characteristics remain unchanged. Reductions in lighting energy results in reduced lighting heat gain to the building, thus reducing the cooling energy required to remove this heat. Similarly, the heating energy will increase in response to decreased lighting loads.

Between the as-built and baseline simulation runs, the cooling system capacity is adjusted in response to changes in all building characteristics that affect cooling system size, such as lighting loads and glazing characteristics. Similarly, the fan system size is adjusted in response to the change in the cooling system size, since smaller cooling systems require smaller fans. Reductions in cooling and fan system size result in reduced cooling and fan energy, even if the efficiency characteristics of these systems are unchanged. The simulation models suggest that much of the cooling and fan savings are, in fact, due to the interactive effects of reduced lighting loads.[5]

We will focus the remainder of the analysis on the whole-building energy and these three end uses. The results will be presented at the whole building level, and then broken down into the three end uses. The heating end use, however, is included in Figure 1 in order to show the minimal amount of savings in that end use. Since the Energy Ratios for Refrigeration and the residual energy are very minimal, they will be excluded from all following graphs.

One way to look at this information is to consider the energy savings in each of the end uses as a percentage of the whole-building baseline electricity use. The energy savings have been calculated as (a) / (b) where:

> (a) is the baseline end-use energy use minus the as built end-use energy use, and
>
> (b) is the baseline whole-building energy use.

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[5] Parametric runs were needed to isolate interactive effects. This type of simulation had been done for the 1994 and 1996 impact evaluation studies but was not done for the new 1998 sample sites. New parametric runs were conducted for all 990 sites in the database in order to separate out the interactive effects.

Figure 1 shows the overall energy savings as a percentage of the whole building baseline energy use. The whole building energy savings relative to 1995 T-24 baseline are 14.0% and the savings relative to the 1998 T-24 baseline are 7.7%. The direct lighting end use savings account for 10.1% of the savings relative to 1995 baseline and 4.9% of savings relative to 1998 baseline. The cooling and fan savings are a combination of both direct savings due to shell, HVAC, and motor savings, and the interactive savings due to the effects of the lighting measures. The heating savings are due to high efficiency heat pumps and shell measures, which offset the higher heating energy resulting from the lowered lighting heat loss.

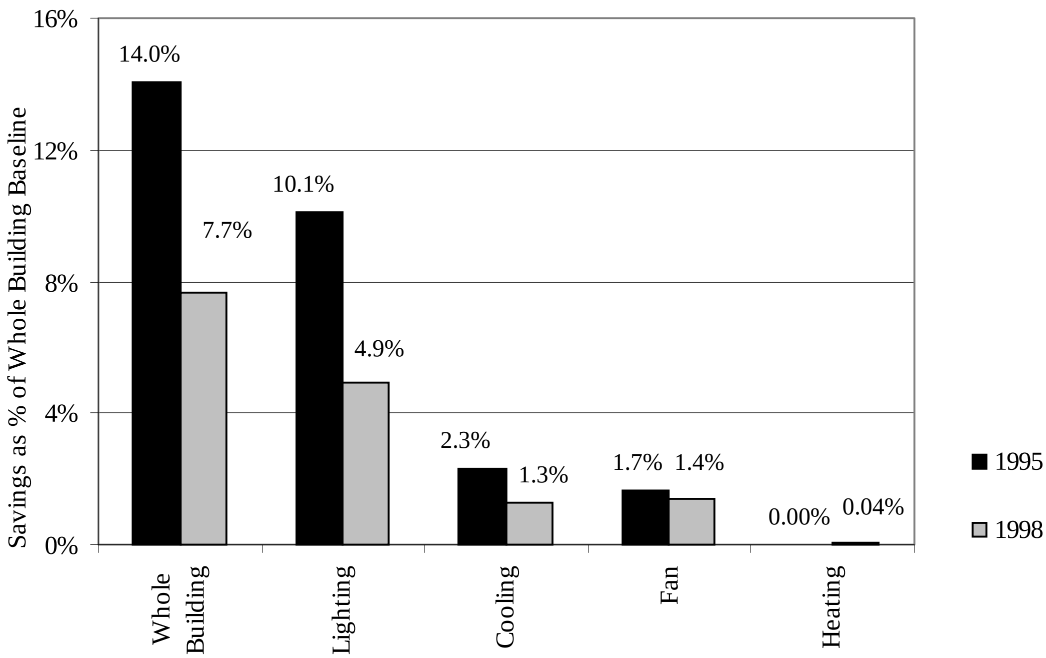

Figure 1: Overall Energy Savings as % of Whole Building Baseline Energy Use

Figure 2 shows the overall energy savings relative to whole building 1995 T-24 energy use for the lighting, cooling, and fan end uses. Figure 3 shows the overall energy savings relative to whole building 1998 T-24 energy use. The lighting savings relative to the 1995 T-24 constitute a much larger percentage of the total savings than lighting savings relative to 1998 T-24.

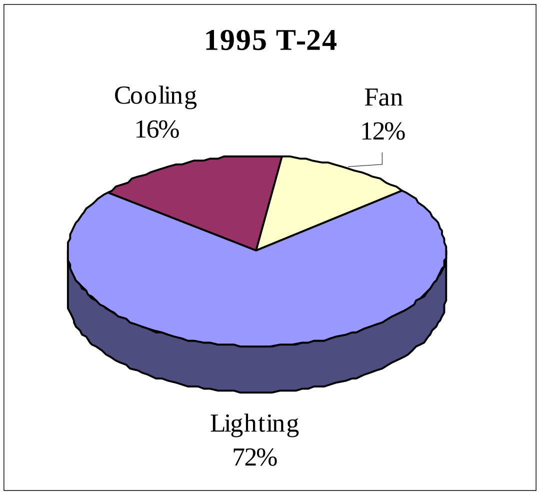

Figure 2: Overall Energy Savings Relative to Whole Building 1995 T-24 Baseline

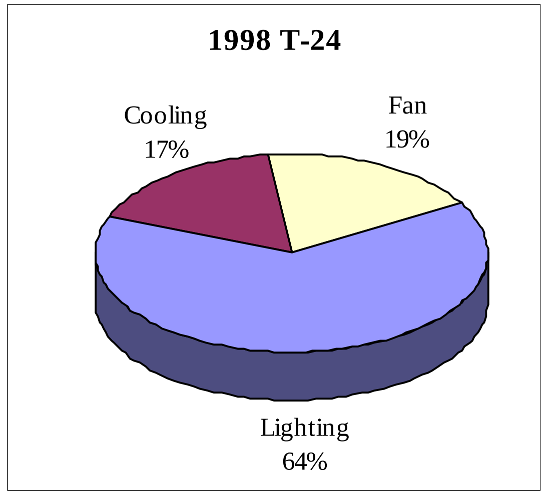

Figure 3: Overall Energy Savings Relative to Whole Building 1998 T-24 Baseline

In this follow-on report, we not only report on the overall energy ratio, but on end-use energy ratios as well. Since parametric runs were created with the intention of isolating the interactive effects of the measures on each end use, we also needed a way to quantify the influence of each parametric run on the energy ratio for each end use. Thus, an 'energy factor' was calculated as the following for each parametric run:

$$Energy\ Factor = \frac{End\ Use\ kWh_{\ Parametric\ Run\ X}}{End\ Use\ kWh_{\ Parametric\ Run(X\ -\ 1)}}$$

Where X is the parametric for which the energy factor is being calculated, and (X-1) is the previous parametric in the series of runs.

For example, suppose the LPD parametric cooling end use electricity use is found to be 95 million kWh per year and the shell parametric cooling end use energy is found to be 100 million kWh per year. The LPD parametric cooling end use energy factor would then be 0.95.

Suppose again that for each parametric, the cooling energy factor was found to be 0.95. The overall cooling energy ratio would then be calculated as the result of the multiplication of all of the factors:

$$(0.95*0.95*0.95*0.95*0.95*0.95) = 0.74$$

In order to calculate what the energy ratio would be if the energy factor for one parametric run was equal to 1 (no change from previous parametrics' measures), the energy ratio can be divided by the energy factor. The resulting ratio would be the energy ratio if the parametric run had no influence on the reduction in energy use.

Using the previous example, if you wanted to see what the energy ratio would be if the shell measures were not changed (shell measures energy factor=1), then the new ratio would be calculated as:

$$0.74 / 0.95 = 0.77$$

Or, the shell measures lower the overall cooling energy ratio by 0.03, which means that they contribute 3% to the cooling energy savings.

Figure 4 shows the average overall energy ratio by end use relative to each T-24 baseline. The energy ratio is defined to be the consumption of a building or set of buildings relative to what their consumption would have been under Title 24. An energy ratio of one indicates that the buildings are performing just at the Title 24 baseline. An energy ratio below one indicates that the buildings are using less energy than code. Notice that for all the end uses, on average the buildings are using less energy than both 1995 and 1998 code, indicating that there may be room for making the codes more stringent.

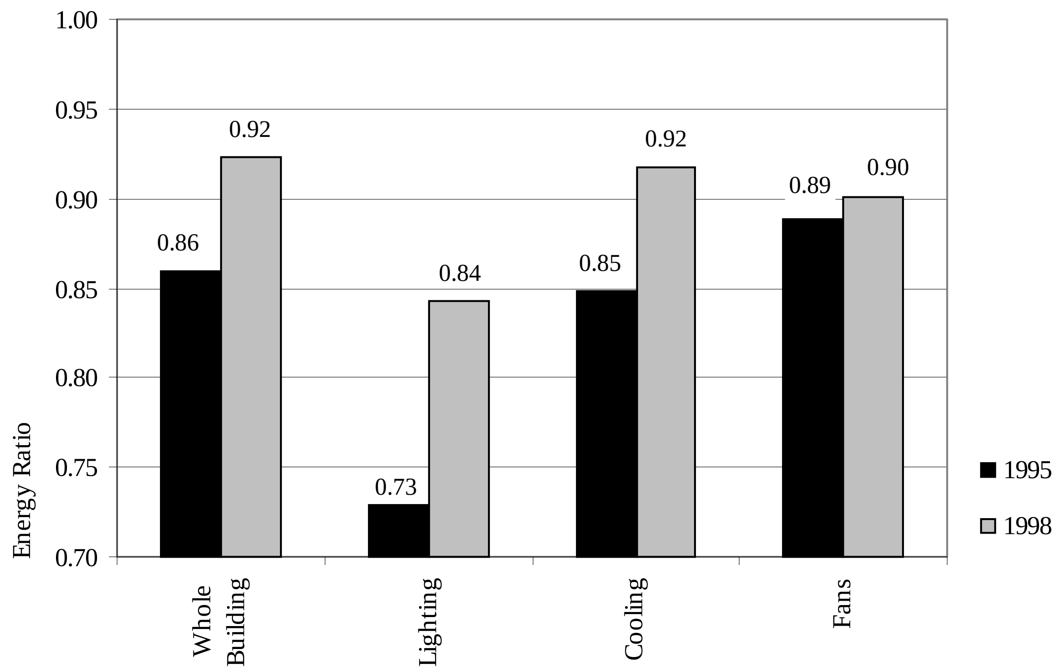

Figure 4: Average Overall Energy Ratio by End Use and T-24 Baseline

Table 3 shows that among the three end uses, the largest percentage of buildings that are using less energy than code occurs in the lighting end use, where the average lighting energy ratio is 0.84 relative to 1998 T-24. A 90% confidence interval can be calculated by adding and subtracting the error bound from the average value. In the case of the lighting energy ratio for the 1998 T-24, we can say with 90% certainty that on average, the installed lighting relative to 1998 T-24 is between 0.81 and 0.87.

	End Use	Sites Better Than Baseline	Average Value	Error Bound	Sample Size
1995 T-24	Whole Building	82.2%	0.86	0.01	667
	Lighting	82.3%	0.73	0.03	667
	Cooling	73.0%	0.85	0.03	637
	Fans	65.8%	0.89	0.03	656
1998 T-24	Whole Building	69.6%	0.92	0.01	667
	Lighting	65.9%	0.84	0.03	667
	Cooling	58.7%	0.92	0.02	638
	Fans	51.2%	0.90	0.03	656

Table 3: Overall Energy Ratio by End Use and T-24 Baseline [6]

Figure 5 shows the percentage of buildings by whole building energy ratio for both the 1995 and 1998 baselines. The dashed vertical line indicates an energy ratio of one. The most apparent difference between the two energy ratios is between the range of 0.5 and 0.7, where a much larger percentage of buildings have a 1995 T-24 than a 1998 T-24 energy ratio. This indicates that the 1998 T-24 code is resulting in a smaller percentage of buildings having low energy ratios.

[6] The sample size for the cooling relative to 1995 T-24 is 1 site fewer than the 1998 T-24 due to the fact that at one site a thermostat schedule was not input making the heating setpoint 45°F and the cooling setpoint 99°F 24/7. The default occupancy density increased dramatically for this type of space in the 1998 run, and this pushed the temperature in the space above 99°F, activating the cooling system for a few hours.

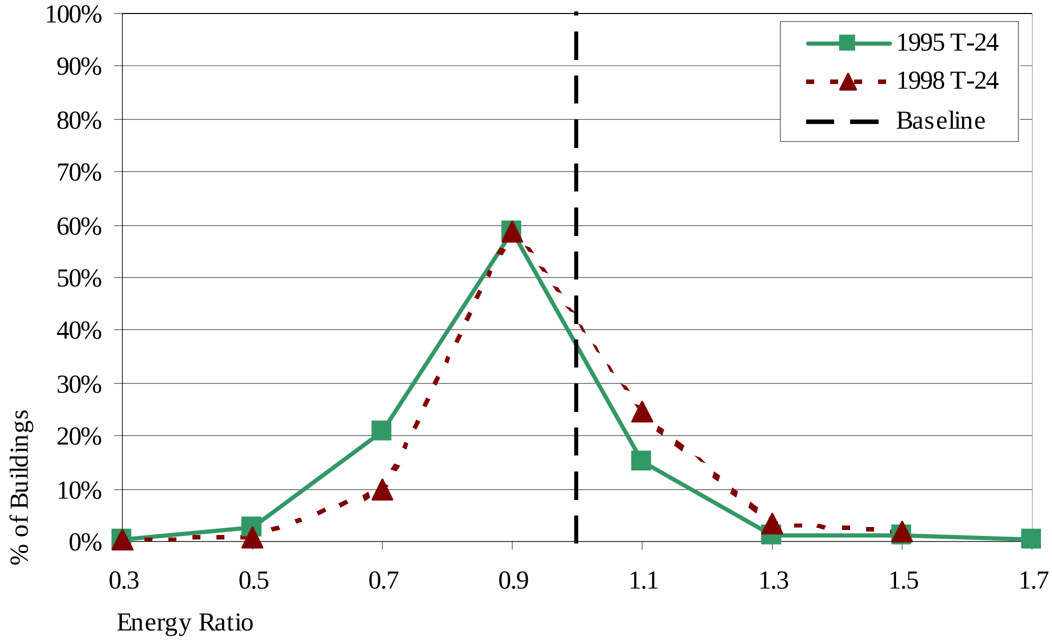

Figure 5: Percentage of Buildings by Whole Building Overall Energy Ratio for 1995 and 1998 Baselines

Figure 6 shows the distribution of buildings by energy ratio using the 1995 T-24 baseline by end use. Among the three end uses, lighting has the largest percentage of sites with low energy ratios, followed by cooling and then fans.

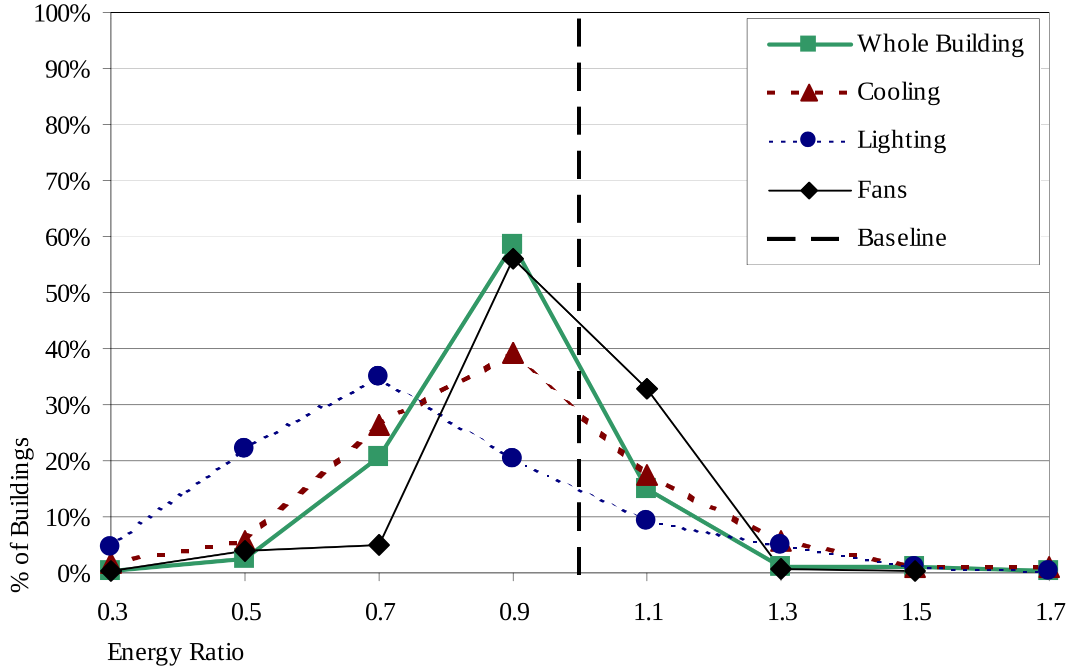

Figure 6: Percentage of Buildings by End Use and 1995 T-24 Overall Energy Ratio

Figure 7 shows the distribution of buildings by energy ratio using the 1998 T-24 baseline by end use. Not surprisingly, a rightward shift in the peak of the lines is seen below. In comparing Figure 7 to Figure 6, the most apparent difference is that for the all the energy ratios, there is a much lower percentage of buildings with energy ratios in the range between 0.3 to 0.7.

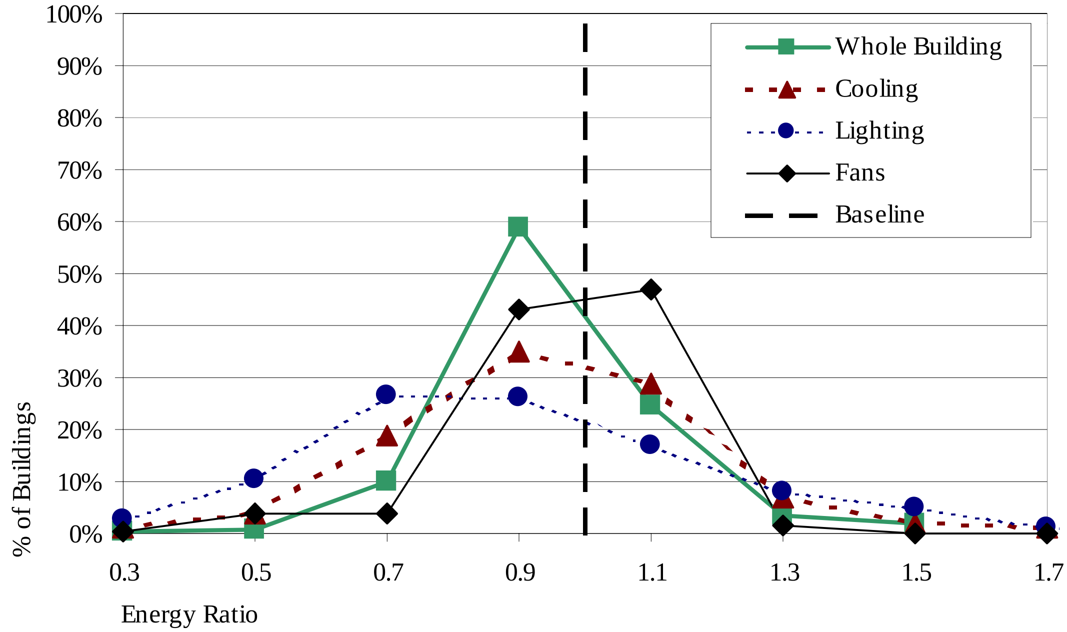

Figure 7: Percentage of Buildings by End Use and 1998 T-24 Overall Energy Ratio

Table 4 shows the ranges of values that are represented by the midpoints on the x-axes of the line graphs in this report.

Midpoint	Range of Values
0.3	0.20-0.39
0.5	0.40-0.59
0.7	0.60-0.79
0.9	0.80-0.99
1.1	1.00-1.99
1.3	1.20-1.39
1.5	1.40-1.59
1.7	1.60-1.79
1.9	1.80-1.99
2.1	2.00-2.19

Table 4: Intervals for the X-axis Values

5. Whole Building Savings by Measure Category

This section of the report shows the whole building savings summary for each parametric run.

Figure 8 shows the percentage of whole building savings relative to baseline for each parametric run. The chart shows that of the 14% savings relative to 1995 T-24 baseline, 11.3% is due to lighting measures, and the remainder is due to the shell, motors, and HVAC measures. A total of 5.5% of the 7.7% total savings relative to 1998 T-24 baseline is due to lighting measures, and the remainder is due to the shell, motors, and HVAC measures.

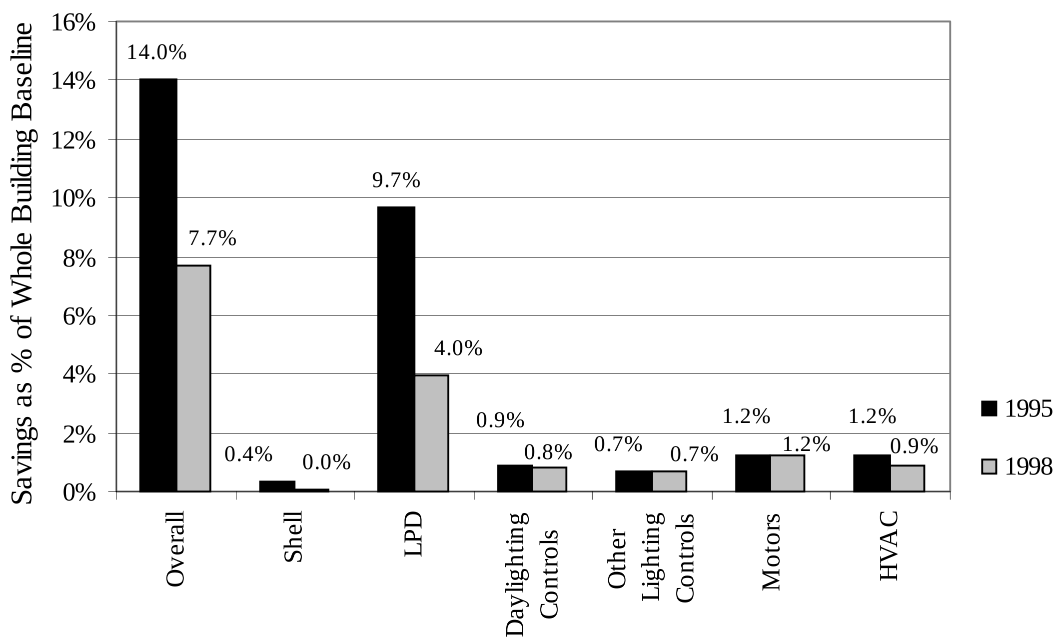

Figure 8: Whole Building Parametric Energy Savings as % of Whole Building Baseline Energy Use

Figure 9 shows the whole building energy savings for each parametric run as a percentage of the whole building 1995 T-24 baseline energy use. Figure 10 shows the whole building energy savings for each parametric run as a percentage of the overall whole building 1998 T-24 baseline energy use. Relative to both 1995 and 1998 T-24 baselines, the LPD parametric measures account for the majority of the savings. However, the amount of savings due to the LPD measures decreases from 68% relative to 1995 T-24 to 52% relative to 1998 T-24. Interestingly, all savings relative to baseline for measures other than Shell increase from the 1995 to 1998 T-24 baseline. This is most likely caused by the standards for windows being changed significantly, which affects the majority of buildings since most have windows. Keep in mind, however, that the actual savings due to shell measures are minimal.

Again, it can be seen that motors have the largest absolute increase in savings, but the largest percentage change occurs in the daylighting controls measure, with an increase of over 80% relative to 1995 and 1998 code.

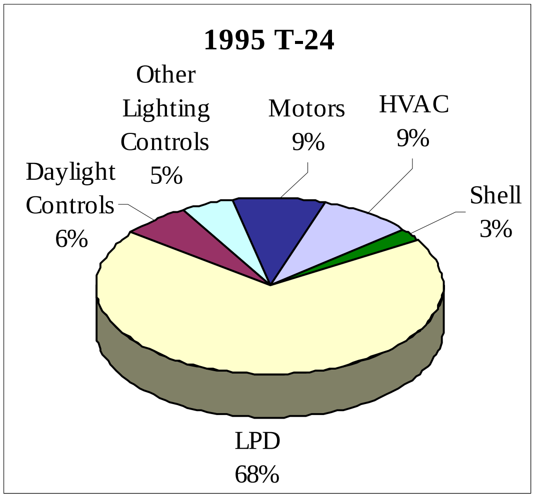

Figure 9: Whole Building Energy Savings by Parametric Relative to Whole Building 1995 T-24 Baseline

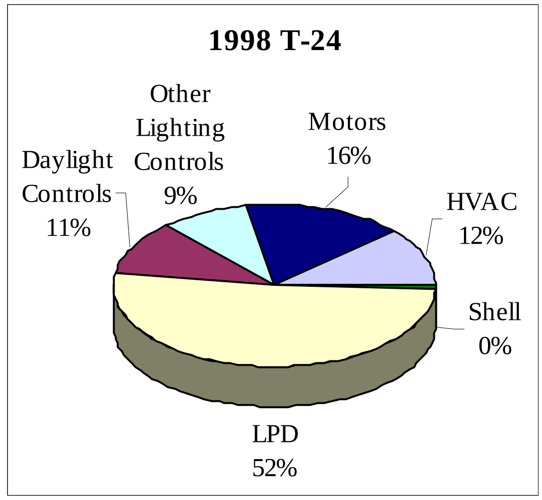

Figure 10: Whole Building Energy Savings by Parametric Relative to Whole Building 1998 T-24 Baseline

Figure 11 shows the average whole building energy factor for each parametric for the 1995 and 1998 T-24 baselines. The ‘overall’ bar is actually the overall energy ratio, which is a result of the multiplication of each of the energy factors from each parametric run. In this graph, the actual savings for all four building types over 1998 code for the LPD parametric at the whole building level are 4%, while the overall savings are 8%.

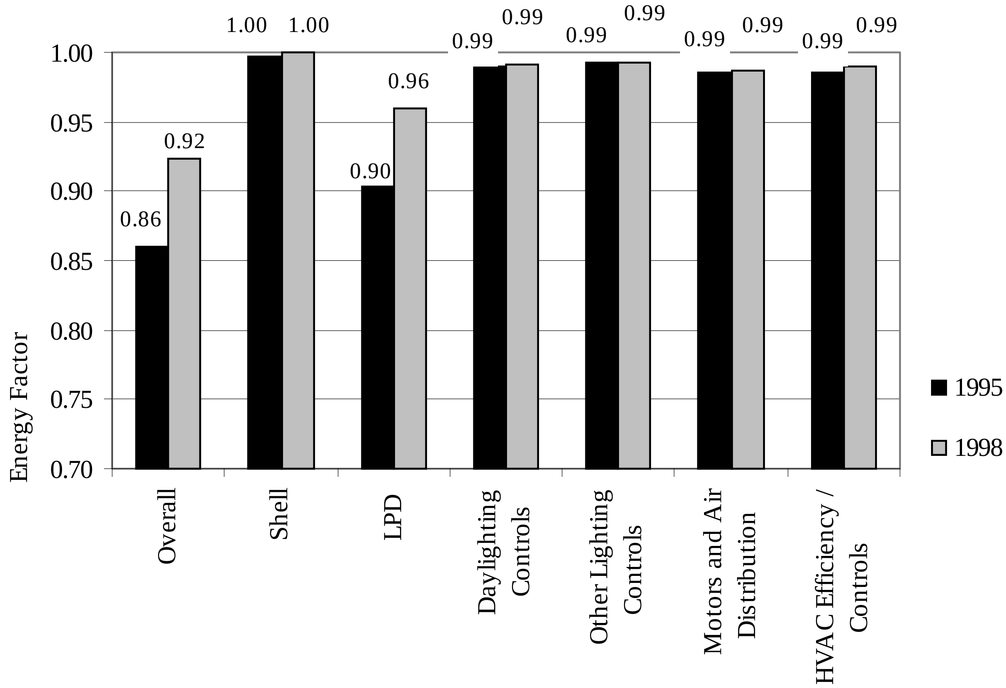

Figure 11: Average Whole Building Energy Factor by Parametric

Table 5 shows the energy factor by end use, the percentage of sites better than baseline, the average value of the energy factor, and the error bounds. Very few of the sites resulted in a lower energy use when the daylighting controls were returned to as-built, because few sites had daylighting controls. The shell parametric has a large percentage of sites that were better than baseline but a high average energy factor. This indicates that the building shell of many of the sites is slightly better than code.

	End Use (n=667)	Sites Better Than Baseline	Average Value	Error Bound	Sample Size
1995 T-24	Overall	82.2%	0.86	0.01	667
	Shell	50.0%	1.00	0.00	667
	LPD	80.6%	0.90	0.01	667
	Daylighting Controls	5.3%	0.99	0.00	667
	Other Lighting Controls	26.8%	0.99	0.00	667
	Motors	15.8%	0.99	0.01	667
	HVAC	56.5%	0.99	0.01	667
1998 T-24	Overall	69.6%	0.92	0.01	667
	Shell	34.4%	1.00	0.00	667
	LPD	63.2%	0.96	0.01	667
	Daylighting Controls	5.3%	0.99	0.00	667
	Other Lighting Controls	26.8%	0.99	0.00	667
	Motors	12.9%	0.99	0.01	667
	HVAC	56.1%	0.99	0.00	667

Table 5: Overall Energy Factor by End Use and T-24 Baseline

6. End Use Savings by Measure Category

Lighting End Use

We have seen that lighting directly accounts for about three-quarters of the overall energy savings relative to 1995 T-24, and two-thirds of the overall energy savings relative to 1998 T-24, in the NRNC market. This section provides more information about lighting efficiency. An energy-efficient lighting system consists of technologies aimed at reducing peak demand and electrical energy consumption, including lighting controls.

Figure 12 shows the percentage of overall lighting savings due to each measure type relative to the 1995 T-24 lighting baseline use. Figure 13 shows the percentage of overall lighting savings due to each measure type relative to the 1998 T-24 lighting baseline use. Not surprisingly, the LPD parametric measures contributed the largest percentage of the lighting end use savings, while the daylighting and other lighting control parametric measures contributed about 14% and 27% of the savings relative to the 1995 and 1998 baselines respectively. These results show that the reduction in lighting energy is not a result of interactive effects of other measures, but simply a result of more efficient lighting-related technologies.

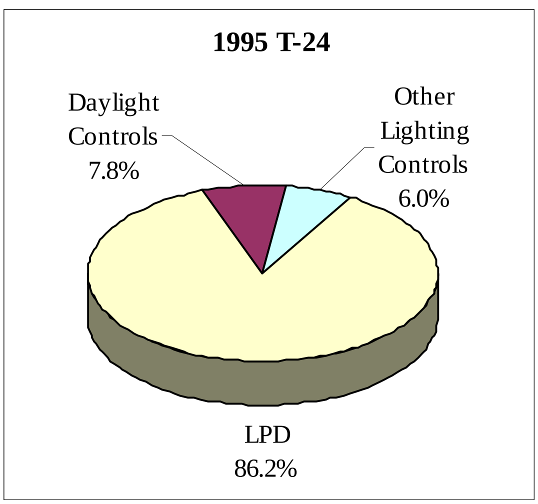

Figure 12: Savings Relative to 1995 T-24 Lighting End Use Baseline by Parametric Run for Lighting End Use

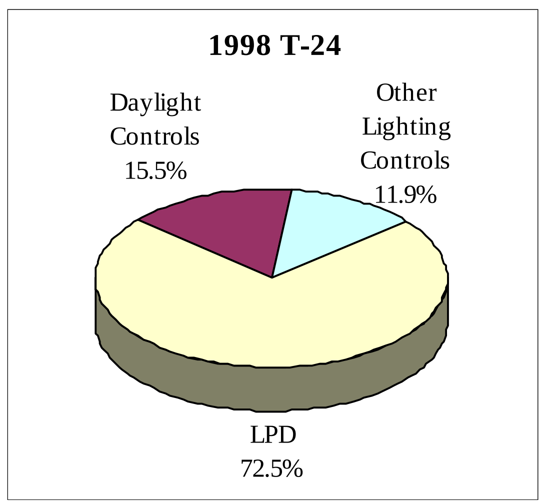

Figure 13: Savings Relative to 1998 T-24 Lighting End Use Baseline by Parametric Run for Lighting End Use

Cooling End Use

This section provides information on cooling energy efficiency. As discussed in the original Baseline study, it was hypothesized that much of the cooling savings were due to the adjustment in cooling loads and capacity in response to lower lighting loads and more efficient envelope measures. Another possible reason for the cooling savings was the installation of higher efficiency units, although this appeared to have had a much smaller impact on cooling savings than the interactive effects with lighting. Recall from Figure 2 and Figure 3 that the cooling savings contributed 16% of the overall whole building savings relative to 1995 T-24 baseline, and 17% relative to 1998 T-24.

Figure 14 shows the percentage of cooling savings due to each measure type relative to the 1995 T-24 cooling baseline use. Figure 15 shows the percentage of cooling savings due to each measure type relative to the 1998 T-24 cooling baseline use. As hypothesized in the original study, lighting measures constitute 41% of cooling savings relative to 1995 T-24 and 37% relative to 1998 T-24.

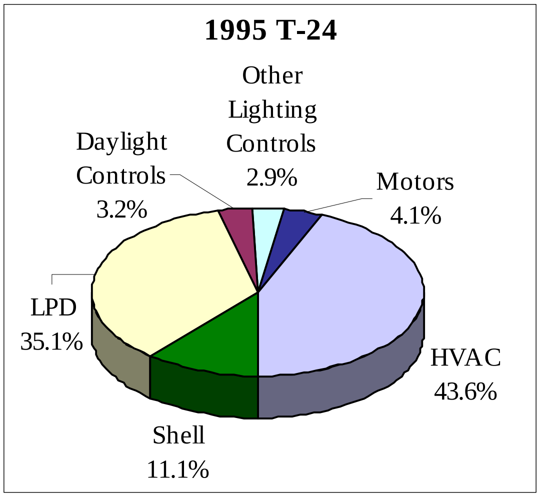

Figure 14: Savings Relative to 1995 T-24 Cooling End Use Baseline by Parametric Run for Cooling End Use

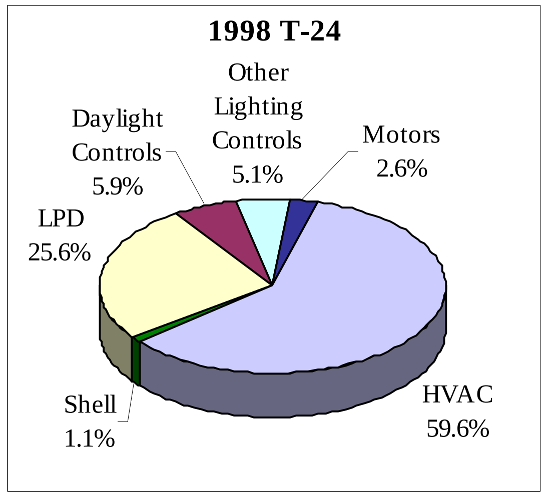

Figure 15: Savings Relative to 1998 T-24 Cooling End Use Baseline by Parametric Run for Cooling End Use

Fan End Use

This section provides information on ventilation system fans. Ventilation systems are the fans that supply and return conditioned and outside air to building spaces. Cooling, heating, and ventilation systems require a supply fan, and in some cases, a return fan to move conditioned and fresh air. High efficiency and premium efficiency motors can be installed on these fans to increase efficiency. Adjustable frequency drives (AFD) also called variable frequency drive (VFD), are also used to increase fan energy savings. These drives control motor speed to correspond to varying load requirements resulting in optimized loading of the fan motor. Installing lower pressure ductwork can also lower the fan energy.

Just as with HVAC, the lower fan energy can be a secondary effect of lowered lighting energy and cooling energy. Any influence on the lighting and cooling loads will also have an impact on the fan load.

Fans are an integral part of the HVAC system, but the fan energy has consistently been separated out from cooling and heating energy in the simulations. In order to provide more detailed information on the energy savings of HVAC, the fans are analyzed separately from the cooling efficiencies, primarily for the following reasons:

- Fan energy is consumed in heating mode. However, heating systems are not being analyzed in this report since their impact on energy consumption in California is small.
- Fan systems operate at times when mechanical heating and cooling is not occurring (economizer mode, morning flush cycle).

Fan savings constituted about 12% of the overall whole building savings relative to 1995 T-24 and 19% relative to 1998 T-24.

Figure 16 shows the percentage of fan savings due to each measure type relative to the 1995 T-24 fan baseline use. Figure 17 shows the percentage of fan savings due to each measure type relative to the 1998 T-24 fan baseline use. The motors parametric measures constitute the overwhelming majority of the overall fan savings. However, it is apparent that about one-quarter of the savings relative to 1995 T-24 are due to interactive effects, and about 15% relative to 1998 T-24.

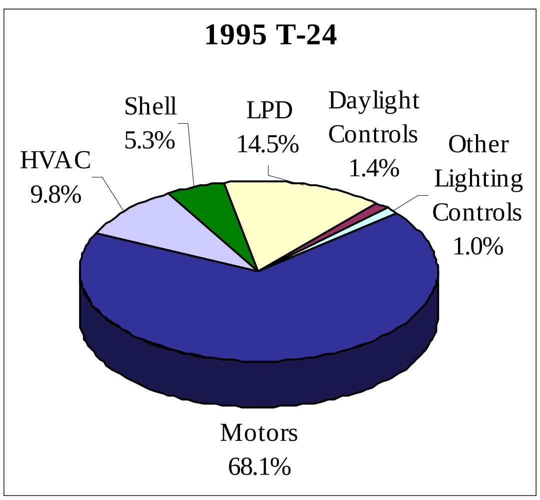

Figure 16: Savings Relative to 1995 T-24 Fan End Use Baseline by Parametric Run for Fan End Use

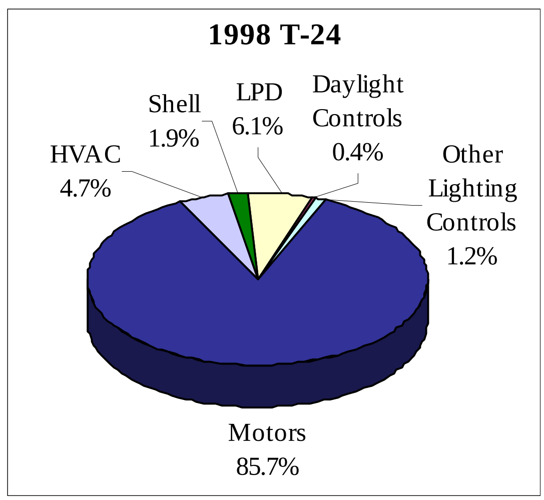

Figure 17: Savings Relative to 1998 T-24 Fan End Use Baseline by Parametric Run for Fan End Use

Parametric Run Results

Shell Parametric

The shell parametric measures contributed the smallest amount of energy savings to the overall whole building savings relative to both baselines among all the parametric run measure groups. The cooling end use is directly affected by the more efficient shell measures, while the fan end use is indirectly affected by the reduction in cooling energy.

Figure 18 shows the shell parametric savings by end use as a percentage of the whole building baseline energy use. It is apparent that the whole building savings due to the shell parametric measures are a very small portion of the overall savings. Cooling accounts for the majority of the savings from this parametric, while the fan end use also sees a reduction in the energy use.

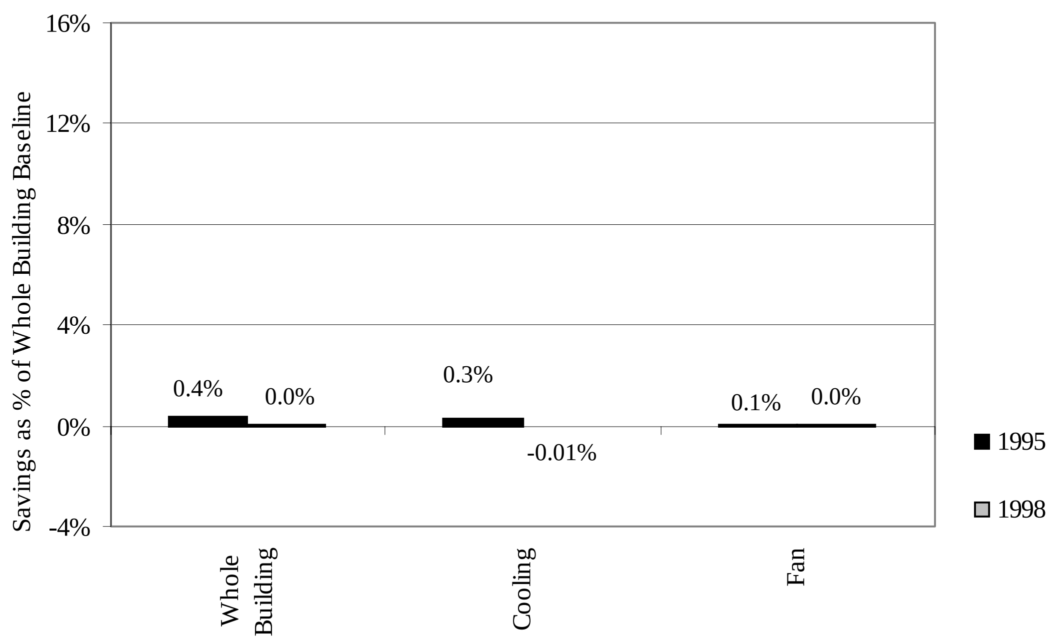

Figure 18: Shell Parametric Energy Savings as % of Whole Building Baseline Energy Use

Figure 19 and Figure 20 show the shell parametric end use energy savings as a percentage of the whole building savings relative to each T-24 baseline. There is a significant change in the percentage of savings due to cooling and fans relative to 1995 T-24 and 1998 T-24 baselines. Keep in mind that the actual percentage of whole building savings that these numbers are referring to is minimal, thus the percentages can vary a lot with only a slight change in the amount of savings. Relative to the 1995 T-24 baseline, cooling constitutes a large majority of the whole building savings, at 75%, with fans contributing the remaining 25%. However, relative to the 1998 T-24, fans constitute the large majority of the whole building savings at 65%, with cooling contributing the remaining 35%.

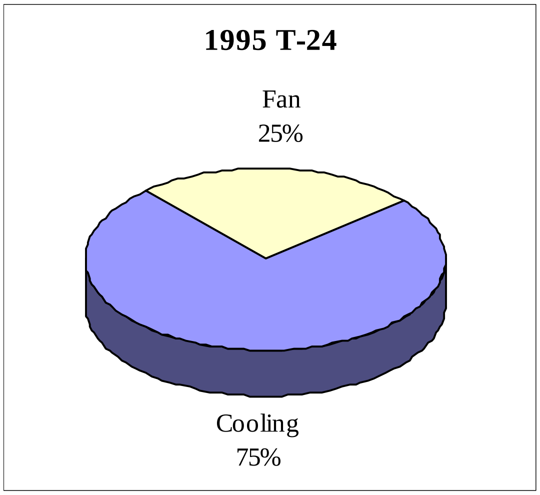

Figure 19: End Use Energy Savings Relative to Whole Building 1995 T-24 Baseline

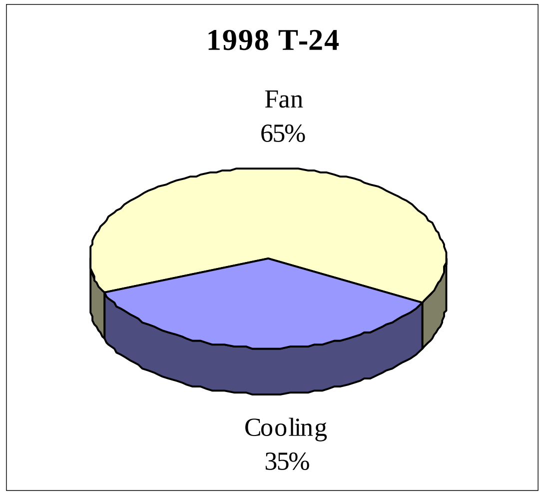

Figure 20: End Use Energy Savings Relative to Whole Building 1998 T-24 Baseline

Figure 21 shows the average shell parametric energy factor for each affected end use and each T-24 baseline. The energy factors are very near 1; thus they do not have much influence on the energy ratio.

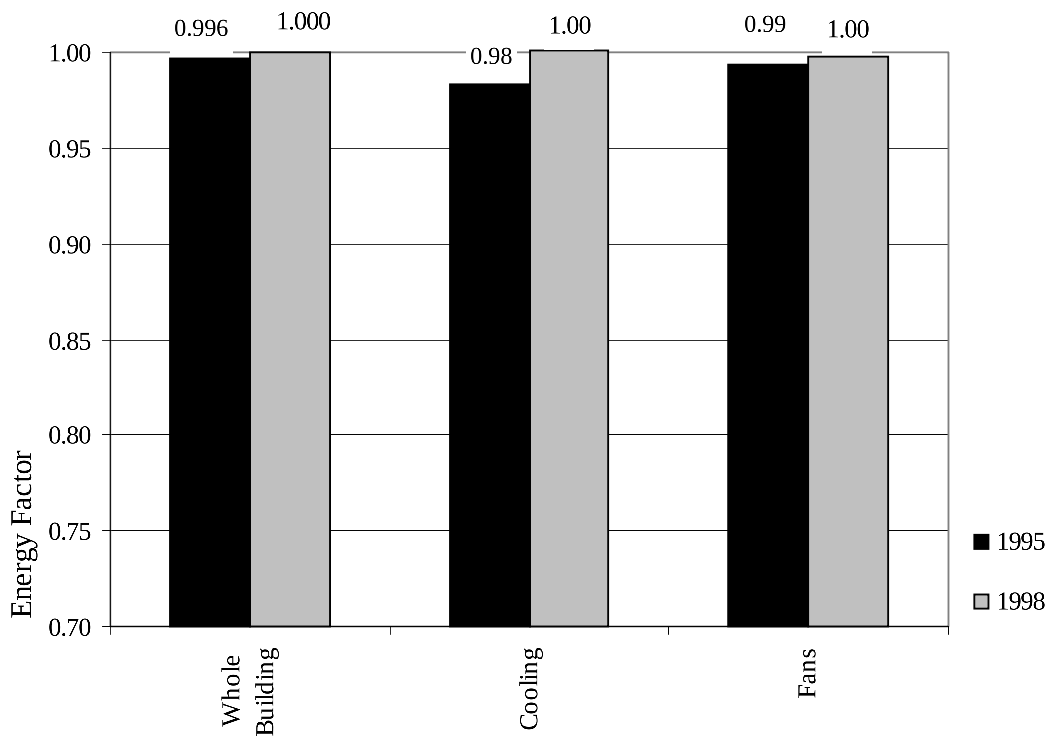

Figure 21: Average Shell Parametric Energy Factor by End Use and T-24 Baseline

Table 6 shows the percentage of sites better than the baseline, the average value of the energy factor, the error bound, and the sample size. In the case of the cooling end use, we can state with 90% certainty that on average, installed cooling energy relative to 1998 T-24 is between 0.994 and 1.008 as much as baseline. The table also indicates that 31% of buildings with cooling have an energy ratio lower than baseline.

	End Use	Sites Better Than Baseline	Average Value	Error Bound	Sample Size
1995 T-24	Whole Building	50.0%	0.996	0.001	667
	Cooling	48.6%	0.983	0.007	637
	Fans	25.5%	0.994	0.003	656
1998 T-24	Whole Building	34.4%	1.000	0.001	667
	Cooling	31.0%	1.001	0.007	638
	Fans	21.5%	0.998	0.003	656

Table 6: Shell Parametric Energy Factor by End Use and T-24 Baseline

LPD Parametric

The LPD measures contribute the largest amount of savings to the overall whole building energy savings. The lighting end use is directly affected by the more efficient LPD measures. The cooling and fan end uses are indirectly affected by the reduction in lighting energy by a reduction in the capacity of the cooling and fan units in response to the lowered temperature due to the reduction in heat from the lighting reduction.

Figure 22 shows the LPD parametric energy savings for the whole building and the affected end uses as a percentage of the whole building baseline energy use. The graph shows that the LPD measures constitute a large portion of the overall whole building savings, totaling 4.0% of the whole building savings relative to T-24 baseline. The overall whole building savings are 7.7% relative to 1998 T-24 baseline, thus the lighting parametric whole building savings constitute over 50% of the overall whole building savings[7]. The lighting end use contributes the largest amount of savings to the whole building savings for this parametric run, followed by the cooling and then the fan end uses. Approximately 3.6% of the 4.0% total savings relative to baseline are due to direct lighting effects. 0.4% is due to the interactive effects of cooling and fans with the lighting.

[7] The overall whole building savings of 7.7% relative to 1998 T-24 baseline can be seen in Figure 8. The lighting parametric whole building savings constitute 4.0% (see Figure 22) of the overall whole building savings of 7.7%, which equals over 50% of the overall whole building savings.

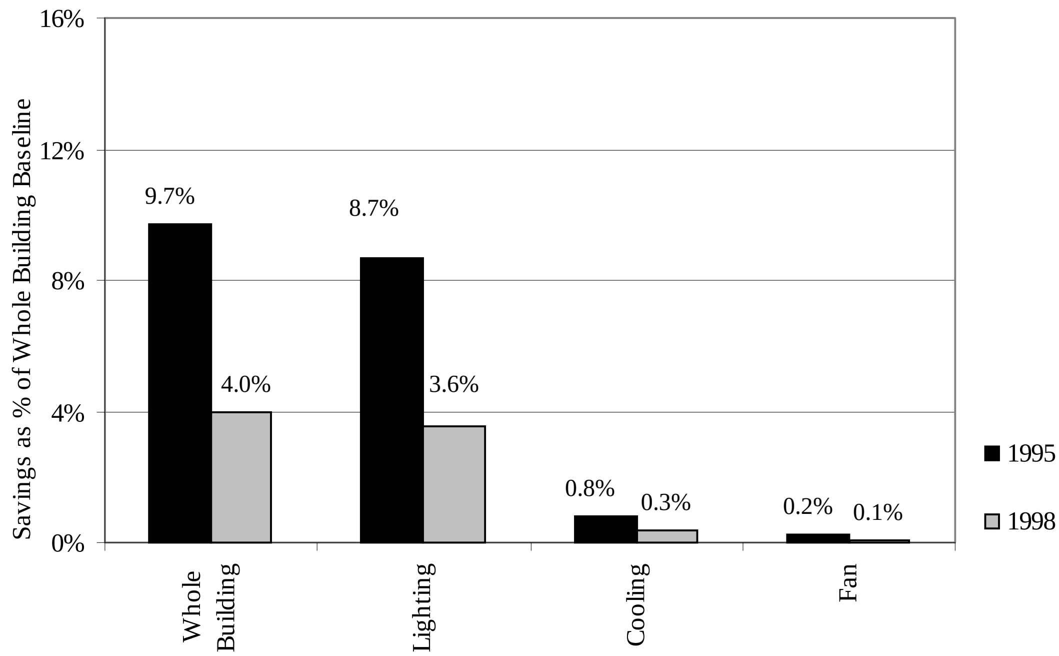

Figure 22: LPD Parametric Energy Savings as % of Whole Building Baseline Energy Use

Figure 23 and Figure 24 show the LPD parametric end use energy savings as a percentage of the whole building savings relative to each T-24 baseline. As discussed previously, it can be seen that the lighting end use constitutes a large majority of the whole building LPD parametric savings relative to both baselines. Also notice that cooling makes up almost 10% of the whole building savings which, in the case of this LPD parametric, makes up 35% of overall cooling savings relative to 1995 T-24 and 26% of overall cooling savings relative to 1998 T-24.

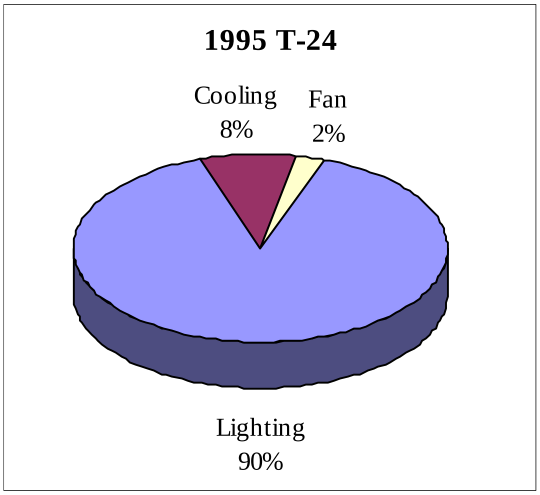

Figure 23: LPD Parametric Energy Savings Relative to Whole Building 1995 T-24 Baseline

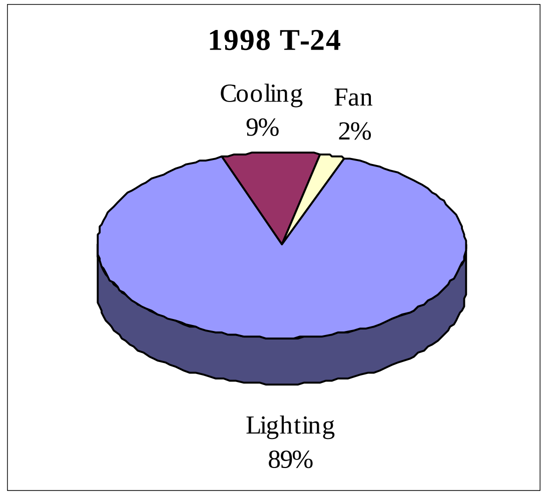

Figure 24: LPD Parametric Energy Savings Relative to Whole Building 1998 T-24 Baseline

Figure 25 shows the average overall energy factor by whole building and each affected end use relative to each T-24 baseline. The lighting end use energy factor has a large impact on the energy ratio since it is much lower than 1.

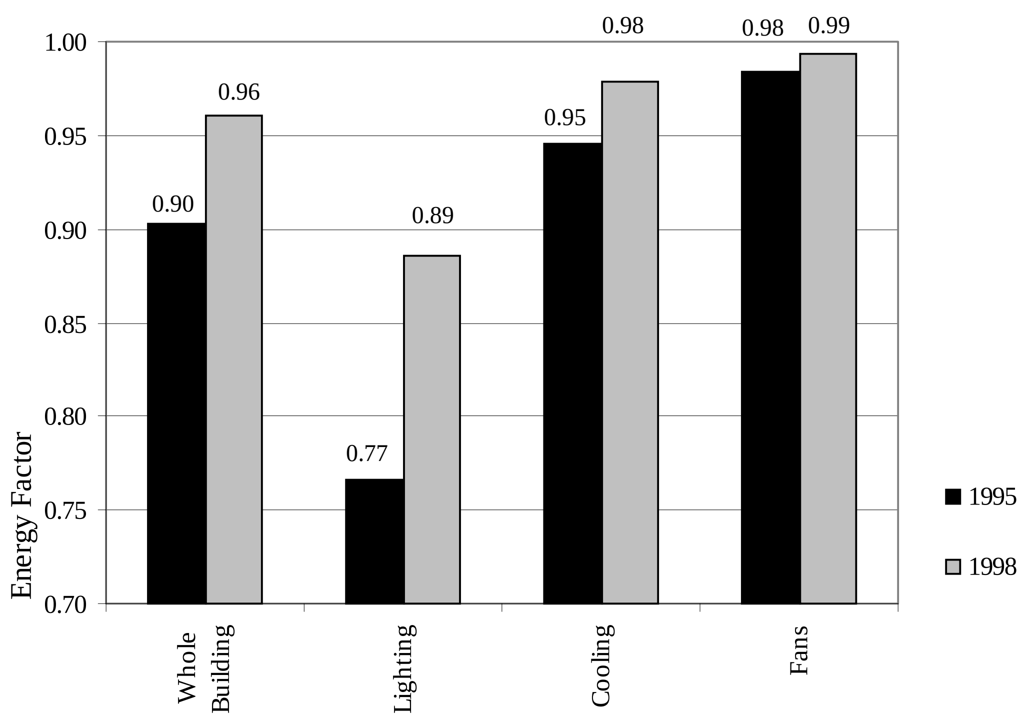

Figure 25: Average LPD Parametric Energy Factor by End Use and T-24 Baseline

Table 7 shows the percentage of sites with an LPD parametric energy factor less than 1, the average energy factor, the error bound, and the sample size. The average whole building energy factor for the 1998 T-24 baseline is between 0.95 and 0.97, while over 60% of the sites have an LPD parametric energy factor less than 1.

	End Use	Sites Better Than Shell Parametric	Average Value	Error Bound	Sample Size
1995 T-24	Whole Building	80.6%	0.90	0.01	667
	Lighting	80.9%	0.77	0.02	667
	Cooling	78.4%	0.95	0.01	637
	Fans	66.6%	0.98	0.00	656
1998 T-24	Whole Building	63.2%	0.96	0.01	667
	Lighting	64.2%	0.89	0.02	667
	Cooling	63.0%	0.98	0.01	638
	Fans	53.5%	0.99	0.00	656

Table 7: LPD Parametric Energy Factor by End Use and T-24 Baseline

Figure 26 shows the distribution of buildings by the LPD parametric whole building and lighting energy factor using the 1995 T-24 baseline. It is apparent from the graph that the majority of the buildings have an LPD parametric lighting energy factor that is below 1.

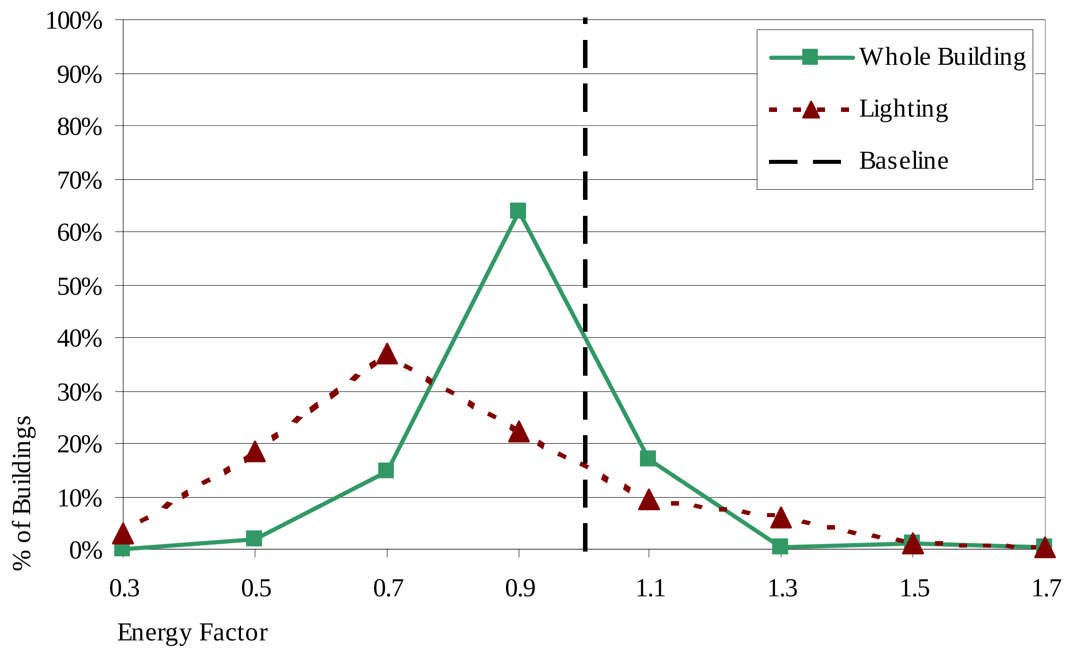

Figure 26: Percentage of Buildings by End Use and 1995 T-24 Energy Factor[8]

[8] The 'Baseline' line in the following line graphs indicates where the energy factor is equal to 1. The term 'Baseline' was used for ease of presentation, however the line does not actually indicate the code baseline. The line instead accentuates the separation between the buildings that are

Figure 27 shows the distribution of buildings by the LPD parametric whole building and lighting energy factor using the 1998 T-24 baseline. A large percentage of the buildings still have a lighting energy factor less than 1 even with the more stringent T-24 code.

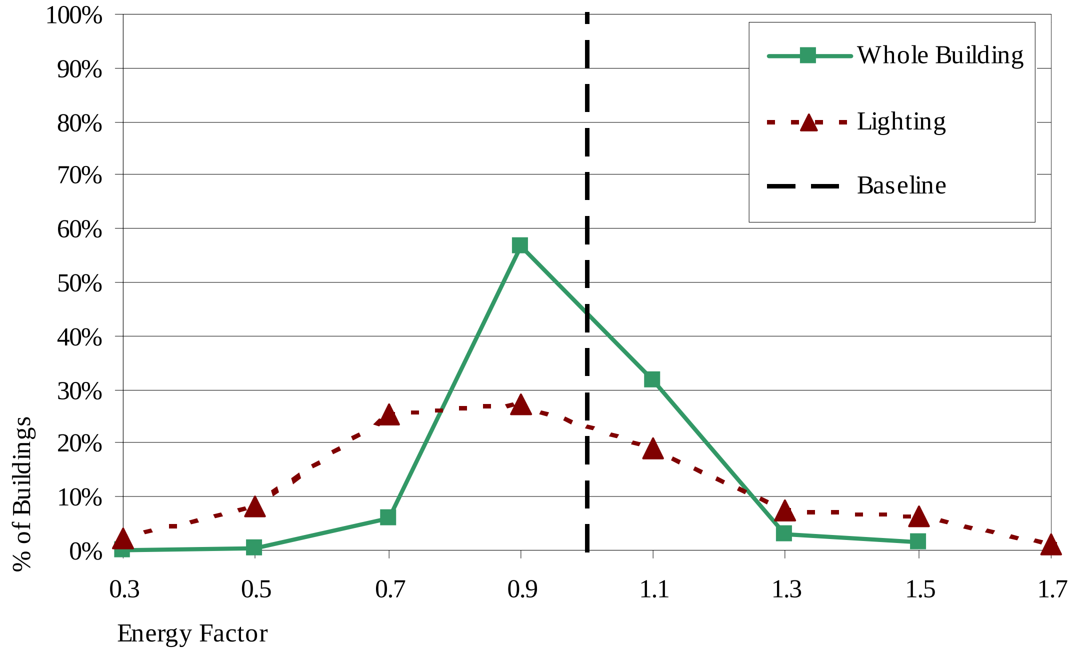

Figure 27: Percentage of Buildings by End Use and 1998 T-24 Energy Factor

Daylighting Controls Parametric

The daylighting controls parametric only constituted 6% of the whole building overall savings relative to the 1995 T-24 and 11% relative to the 1998 T-24 baseline. The lighting end use was primarily affected by the daylighting control measures being returned to as-built, with the cooling and fan end uses experiencing a reduction due to interactive effects with the reduced lighting.

Figure 28 shows the overall energy savings as a percentage of the whole building baseline energy use.

performing *better* than the previous parametric run due to the current run's measures (sites to the left of the line), and the sites that are consuming *more* energy in the current parametric than in the previous parametric run.

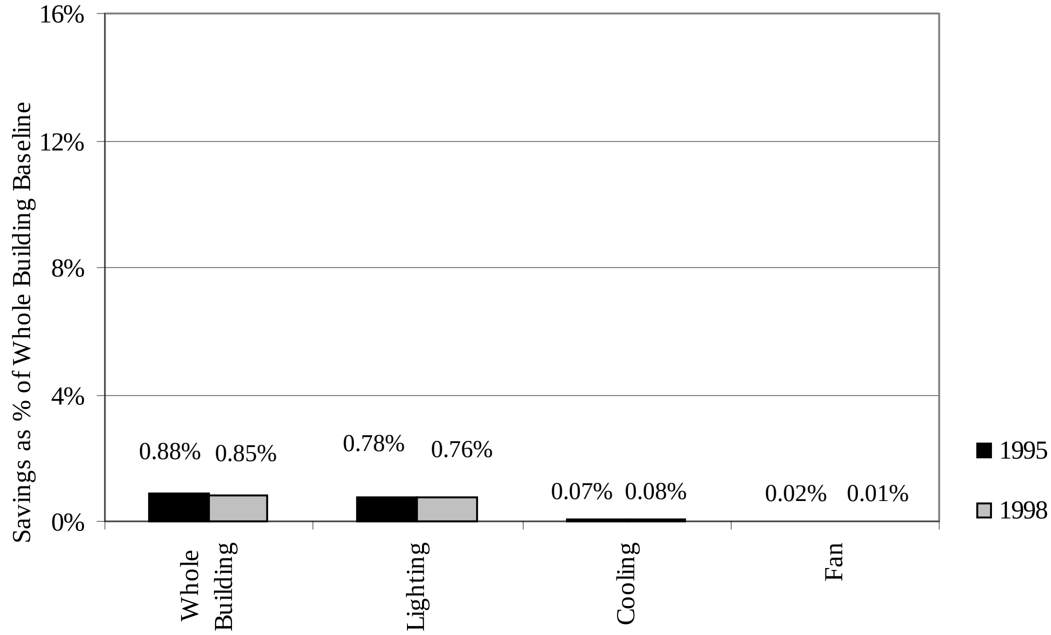

Figure 28: Daylighting Controls Parametric Energy Savings as % of Whole Building Baseline Energy Use

Figure 29 and Figure 30 show the percentage of whole building daylighting control parametric savings by end use. As one would expect, the lighting end use is the most affected by the daylighting measures.

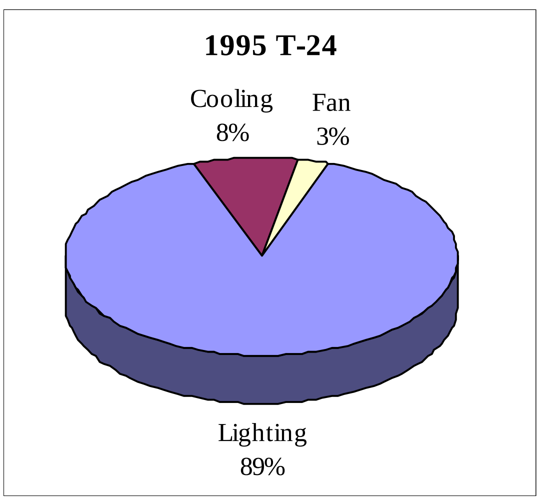

Figure 29: Daylighting Controls Parametric Energy Savings Relative to Whole Building 1995 T-24 Baseline

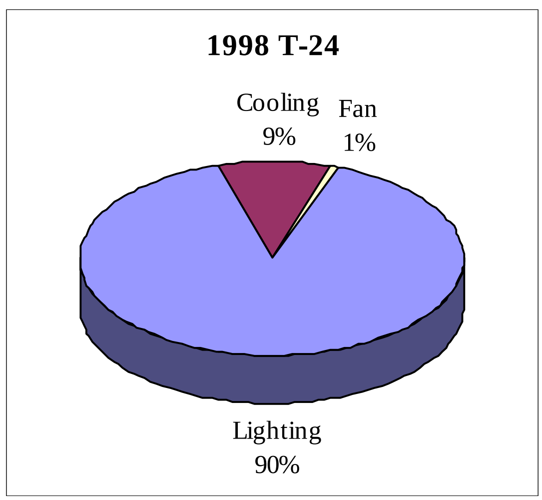

Figure 30: Daylighting Controls Parametric Energy Savings Relative to Whole Building 1998 T-24 Baseline

Figure 31 shows the average overall energy factor by end use and each T-24 baseline. The energy factors for all of the end uses and the whole building are relatively close to 1, indicating that the daylighting controls parametric has little influence on lowering the overall energy factor.

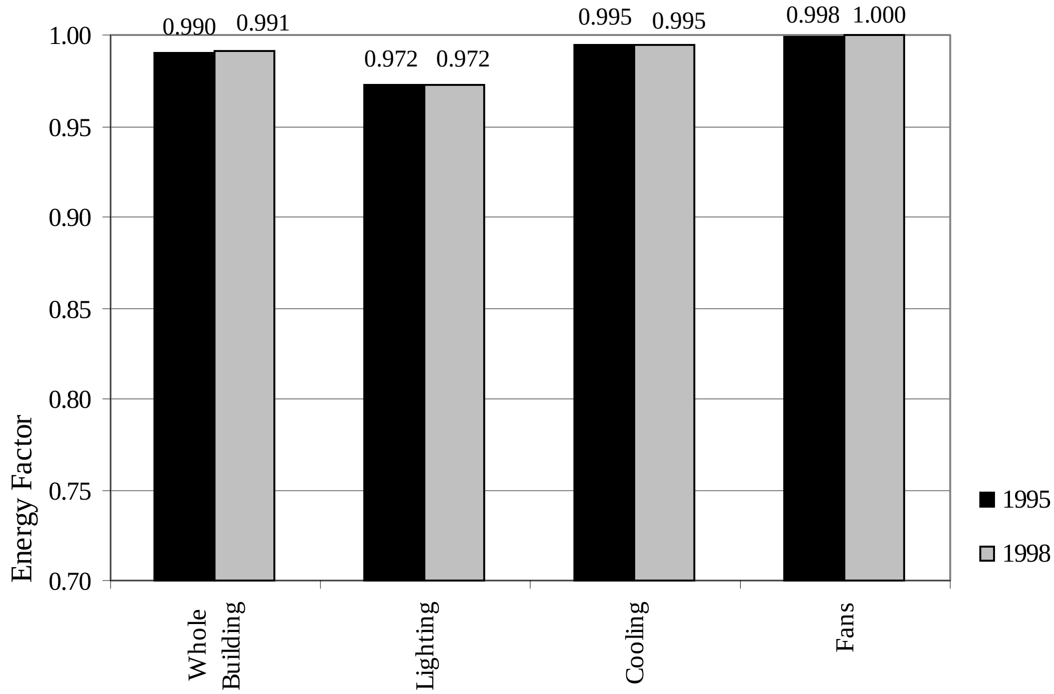

Figure 31: Average Daylighting Controls Parametric Energy Factor by End Use and T-24 Baseline

Table 8 shows the percentage of sites with lower energy consumption due to daylighting control measures, the average energy factor, the error bound, and the sample size. A very small percentage of the sites, 5.3%, had a lower energy consumption when the daylighting control measures were returned to as-built from both baselines. Also notice that the average value of the energy factors for each end use and the whole building differ only slightly between both codes, indicating that the actual code requirements have not impacted the design of daylighting controls. Since such a small percentage of the sites were actually impacted by the daylighting measures, it seems appropriate that the codes only slightly changed regarding the installation of additional or more efficient daylighting control measures.

	End Use	Sites Better Than LPD Parametric	Average Value	Error Bound	Sample Size
1995 T-24	Whole Building	5.3%	0.990	0.005	667
	Lighting	4.8%	0.972	0.014	667
	Cooling	5.4%	0.995	0.003	637
	Fans	4.4%	0.998	0.001	656
1998 T-24	Whole Building	5.3%	0.991	0.004	667
	Lighting	4.8%	0.972	0.014	667
	Cooling	5.4%	0.995	0.003	638
	Fans	4.1%	1.000	0.000	656

Table 8: Daylighting Controls Parametric Energy Factor by End Use and T-24 Baseline

Other Lighting Controls Parametric

This parametric run contributed only 5% of the savings to the overall whole building energy savings relative to 1995 T-24, and 9% relative to 1998 T-24. Some of the lighting controls changed to as-built for this parametric run include occupancy sensors and lumen maintenance controls. As seen with the daylighting control measures, the lighting end use is the primarily affected end use, while cooling and fans experience a reduction in energy presumably in response to the reduction in lighting.

Figure 32 shows the other lighting controls parametric energy savings as a percentage of the whole building baseline energy use.

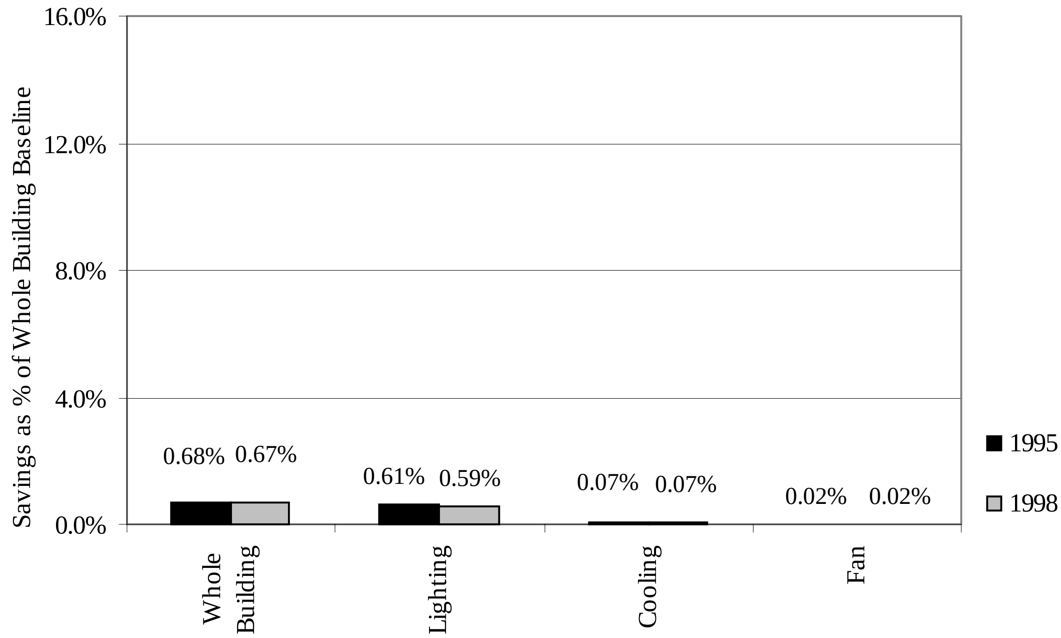

Figure 32: Other Lighting Controls Parametric Energy Savings as % of Whole Building Baseline Energy Use

Figure 33 and Figure 34 show the other lighting controls parametric end use energy savings as a percentage of the whole building energy savings. Recall again that the whole building savings for this parametric are a very small portion of the overall savings. Not surprisingly, the lighting end use constitutes the large majority of the whole building savings, with the cooling and fan end uses contributing fewer than 15% between the two.

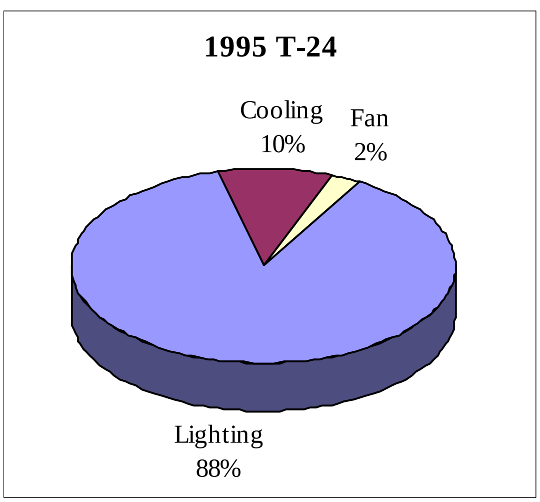

Figure 33: Other Lighting Controls Parametric Energy Savings Relative to Whole Building 1995 T-24 Baselines

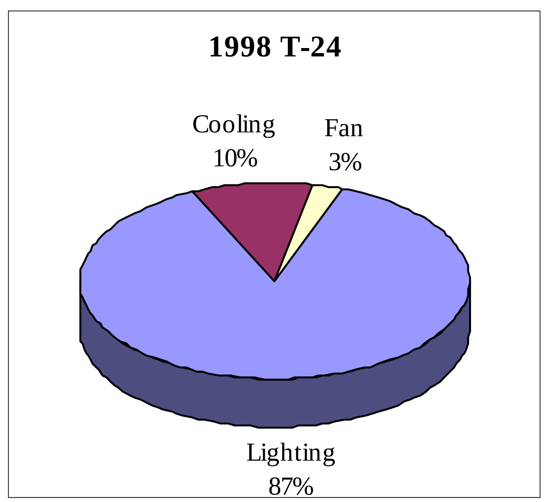

Figure 34: Other Lighting Controls Parametric Energy Savings Relative to Whole Building 1998 T-24 Baseline

Figure 35 shows the average overall energy factor by end use and each T-24 baseline. All of the energy factors for this parametric run are near 1, which indicates that they do not have a lot of influence on lowering the overall energy ratio. The code is only slightly changed from the previous code since the energy factors for each T-24 year are so similar.

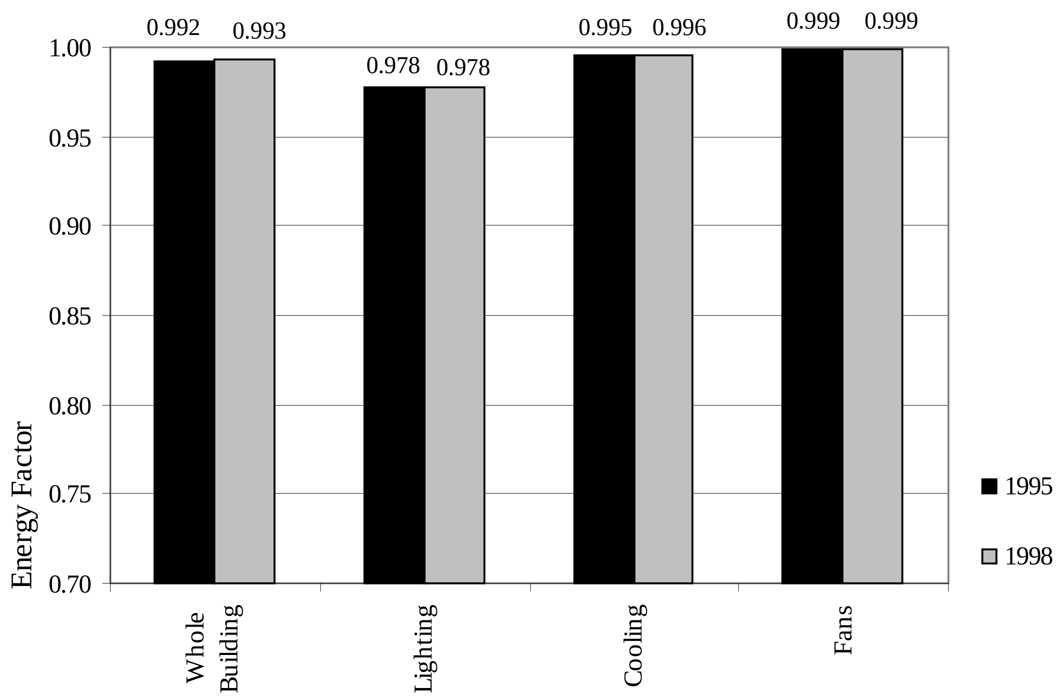

Figure 35: Average Other Lighting Controls Parametric Energy Factor by End Use and T-24 Baseline

Table 9 shows the percentage of sites with lower energy use due to the 'Other Lighting Controls' measures, the average energy factor, the error bound, and the sample size. Approximately one-quarter of the sites had a whole building energy factor under 1.

	End Use	Sites Better Than Daylighting Controls Parametric	Average Value	Error Bound	Sample Size
1995 T-24	Whole Building	26.8%	0.992	0.002	667
	Lighting	26.8%	0.978	0.005	667
	Cooling	26.6%	0.995	0.001	637
	Fans	18.5%	0.999	0.000	656
1998 T-24	Whole Building	26.8%	0.993	0.002	667
	Lighting	26.8%	0.978	0.005	667
	Cooling	26.5%	0.996	0.001	638
	Fans	19.0%	0.999	0.000	656

Table 9: Other Lighting Controls Parametric Energy Factor by End Use and T-24 Baseline

Motors and Air Distribution Parametric

The motors parametric measures constitute the second highest percentage of overall savings, second only to the LPD parametric measures. The motors and air distribution measures primarily affect the energy consumption of the fan end use, contributing the majority of the overall fan savings. The cooling end use is also slightly affected by the reduction in fan energy.

Figure 36 shows the overall energy savings as a percentage of the whole building baseline energy use. This graph shows that the motors parametric whole building savings are made up of primarily fan and some cooling savings.

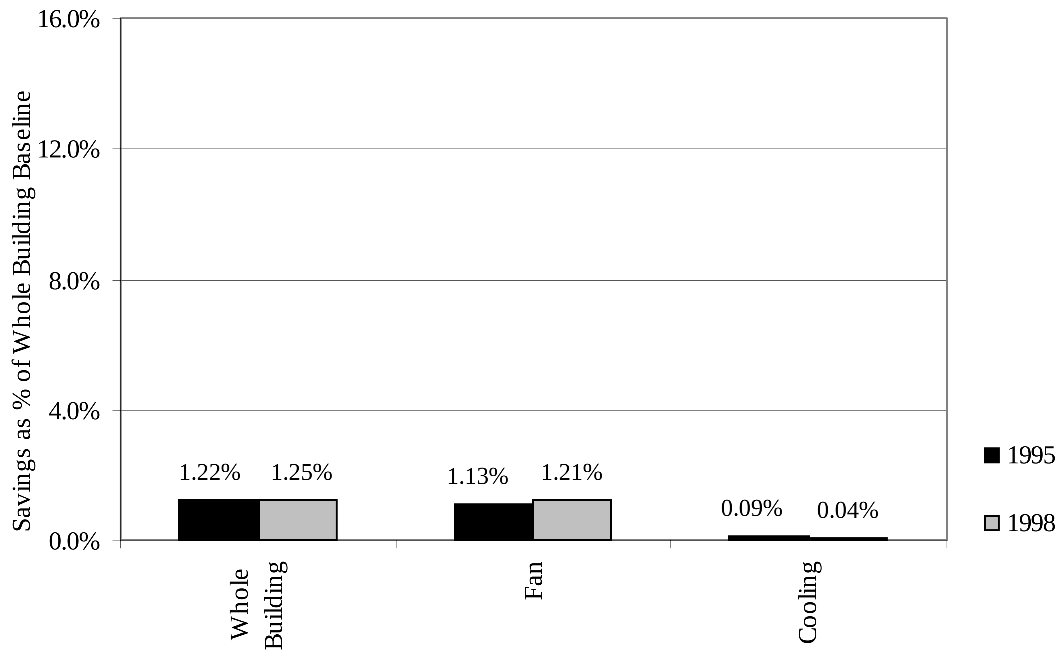

Figure 36: Motors Parametric Energy Savings as % of Whole Building Baseline Energy Use

Figure 37 and Figure 38 show the end use motor parametric energy savings as a percentage of the whole building savings for this parametric run. It can be seen that fan savings constitute over 90% of the savings relative to both baselines.

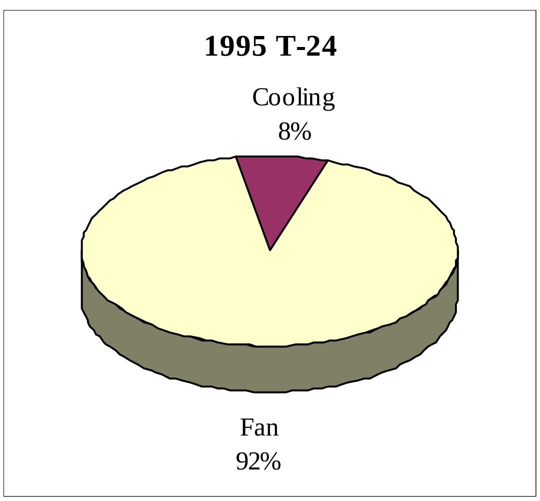

Figure 37: Motors Parametric Energy Savings Relative to Whole Building 1995 T-24 Baseline

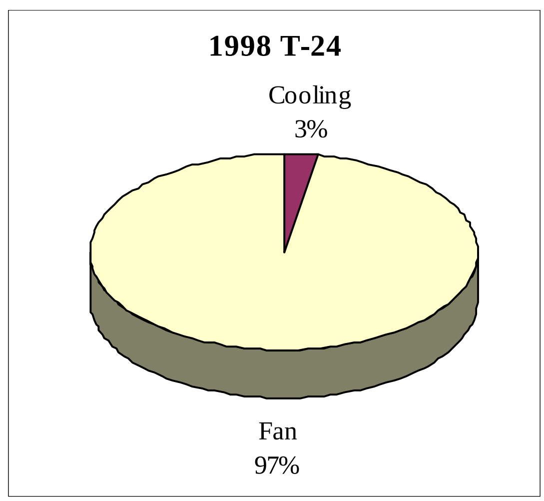

Figure 38: Motors Parametric Energy Savings Relative to Whole Building 1998 T-24 Baseline

Figure 39 shows the average motors parametric energy factor by end use and each T-24 baseline. The fan end use has a low energy ratio for both T-24 years, which indicates that it has a relatively large impact on the lowering of the overall fan energy ratio.

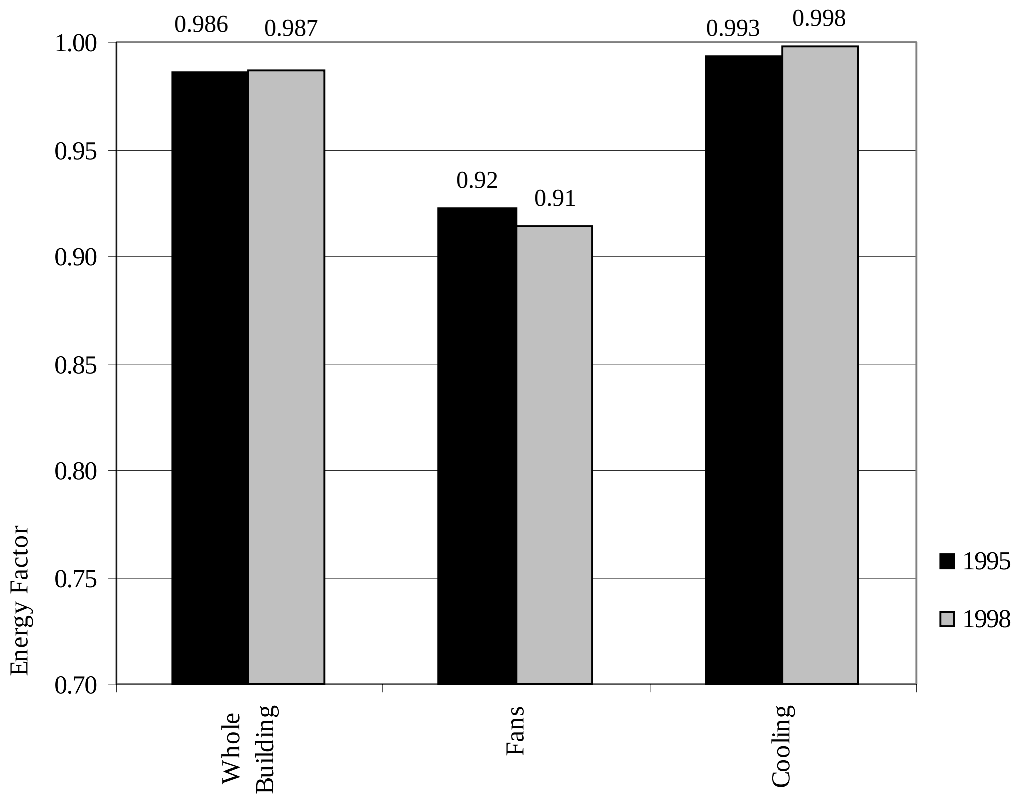

Figure 39: Average Motors Parametric Energy Factor by End Use and T-24 Baseline

Table 10 shows the percentage of sites with a reduced energy usage due to motor measures, the average energy factor, the error bounds, and the sample sizes. Almost 13% of the sites had an 1998 T-24 energy factor less than 1.

	End Use	Sites Better Than Other Lighting Controls Parametric	Average Value	Error Bound	Sample Size
1995 T-24	Whole Building	15.8%	0.986	0.006	667
	Fans	14.5%	0.922	0.033	656
	Cooling	10.3%	0.993	0.002	637
1998 T-24	Whole Building	12.9%	0.987	0.005	667
	Fans	13.1%	0.914	0.034	656
	Cooling	5.9%	0.998	0.001	638

Table 10: Motors Parametric Energy Factor by End Use and T-24 Baseline

Figure 40 shows the distribution of buildings by energy factor using the 1995 T-24 baseline by the whole building and fan end use. It can be seen that the majority of the sites had an energy factor of 1, indicating that a large number of the sites did not differ from baseline for this measure.

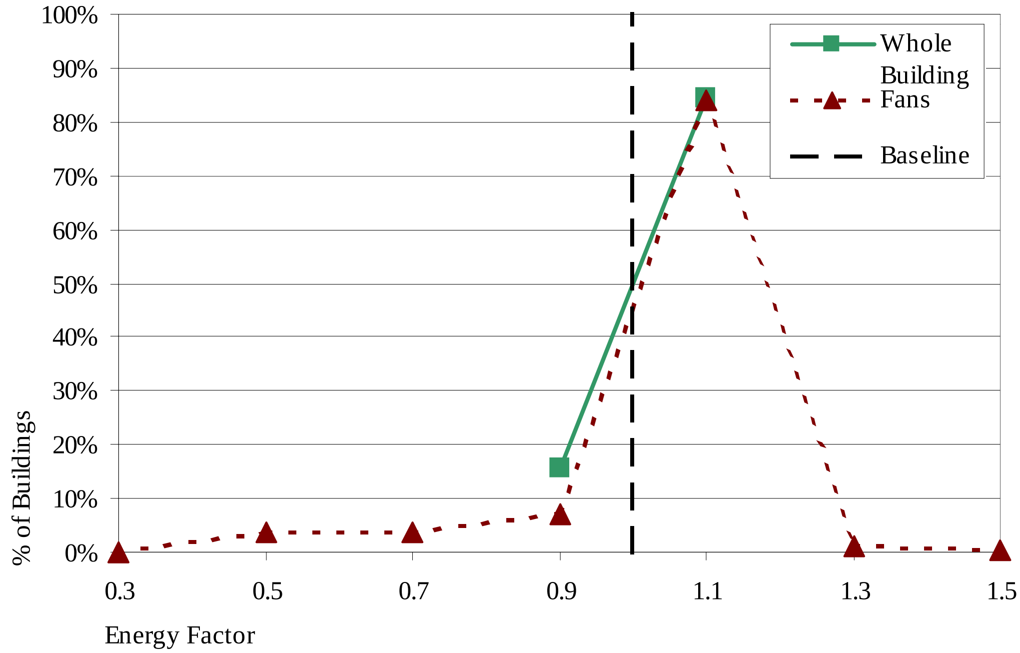

Figure 40: Motors Parametric Energy Factor by End Use - 1995 T-24 Baseline

Figure 41 shows the distribution of buildings by energy factor using the 1998 T-24 baseline by end use. Again, it can be seen that the majority of the sites had an energy factor of 1, indicating that the motor measures had little affect on the savings.

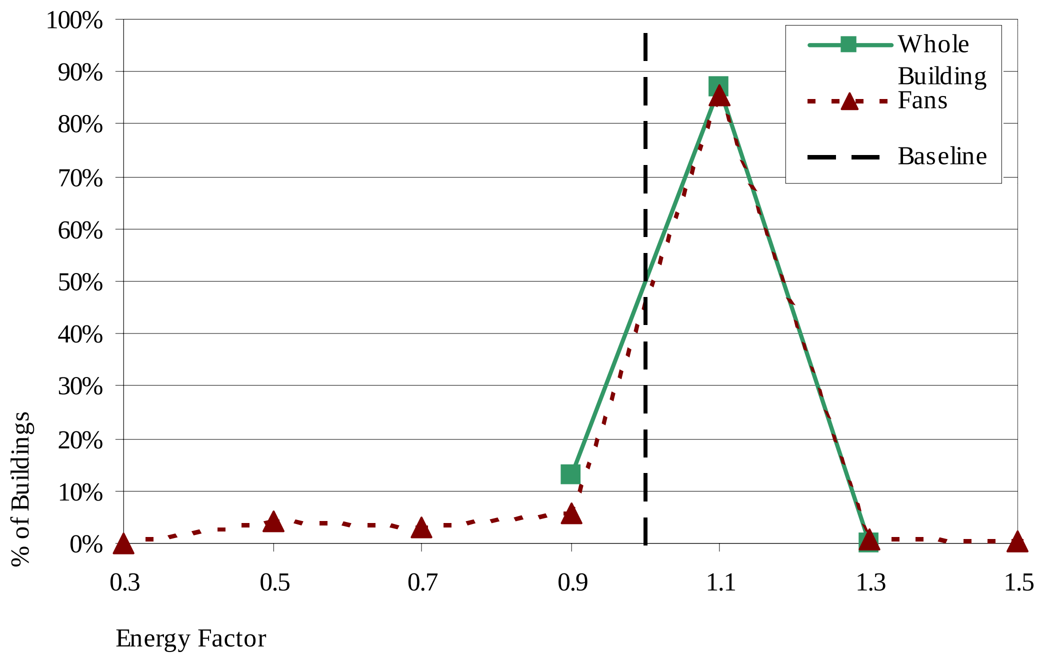

Figure 41: Motors Parametric Energy Factor by End Use - 1998 T-24 Baseline

HVAC Parametric

The HVAC parametric measure savings constituted only 9% of the overall savings relative to the 1995 T-24, and 12% of the overall savings relative to the 1998 T-24. The cooling end use was primarily affected by the HVAC measures, which constituted 44% of the overall savings relative to 1995 T-24 and 59% of the savings relative to the 1998 T-24.

Figure 42 shows the HVAC parametric energy savings by end use as a percentage of the whole building baseline energy use. It is clear from the graph that the savings due to this measure type are relatively small, and that the cooling end use constitutes the majority of the savings.

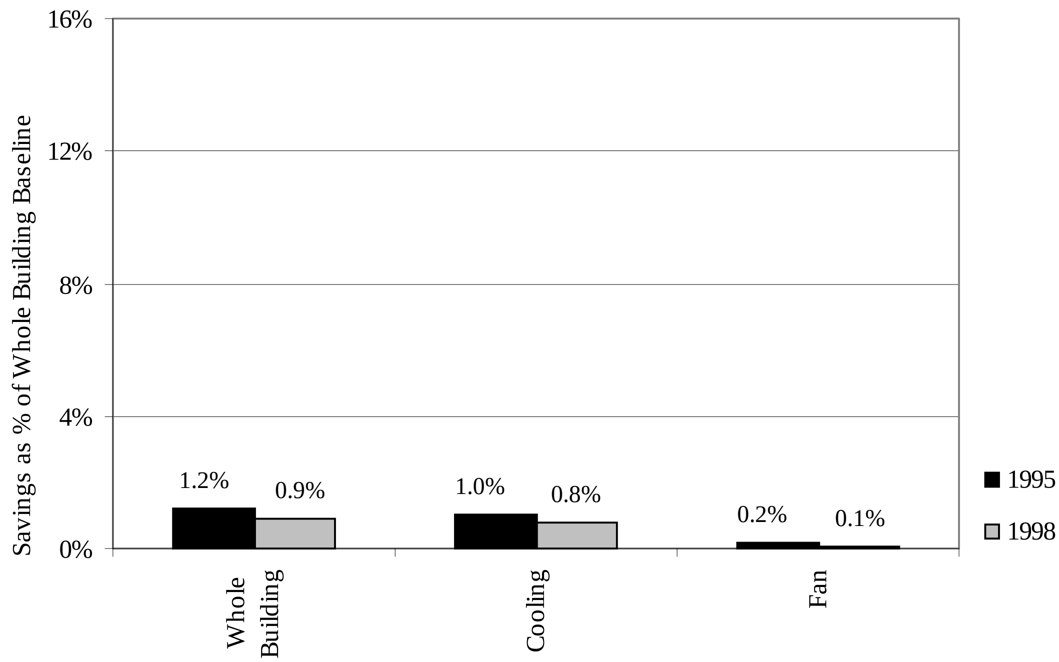

Figure 42: HVAC Parametric Energy Savings as % of Whole Building Baseline Energy Use

Figure 43 shows the HVAC parametric energy savings by end use as a percentage of the whole building HVAC parametric savings relative to 1995 T-24 baseline energy use. Figure 44 shows the HVAC parametric energy savings by end use as a percentage of the whole building HVAC parametric savings relative to the 1998 T-24 baseline energy use. The graph shows that relative to both the 1995 and 1998 T-24 codes, cooling makes up the large majority of the savings for the HVAC measures.

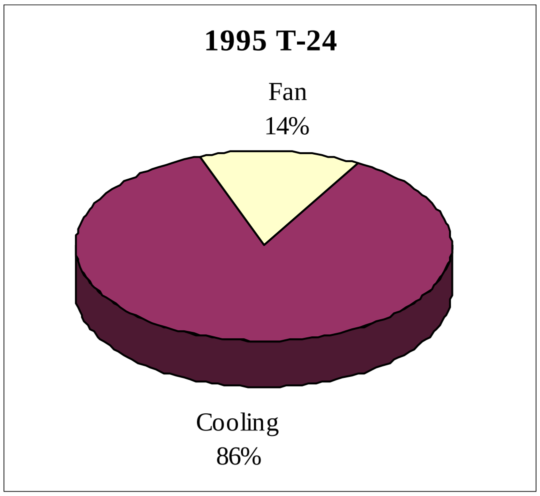

Figure 43: HVAC Parametric End Use Energy Savings Relative to Whole Building 1995 T-24 Baseline

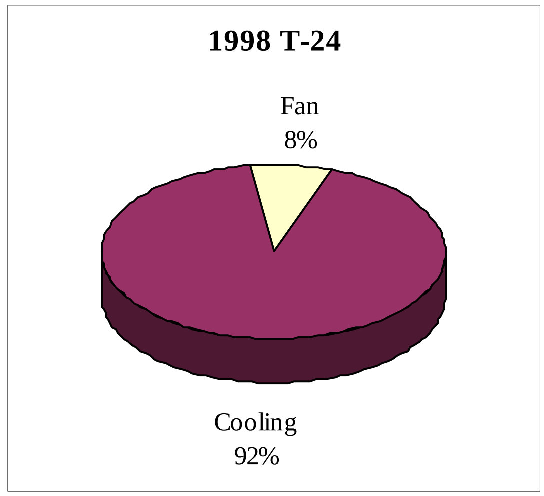

Figure 44: HVAC Parametric End Use Energy Savings Relative to Whole Building 1998 T-24 Baseline

Figure 45 shows the average HVAC energy factor for the whole building and each affected end use relative to each T-24 baseline. The cooling energy factors are relatively low, resulting in a lower energy ratio.

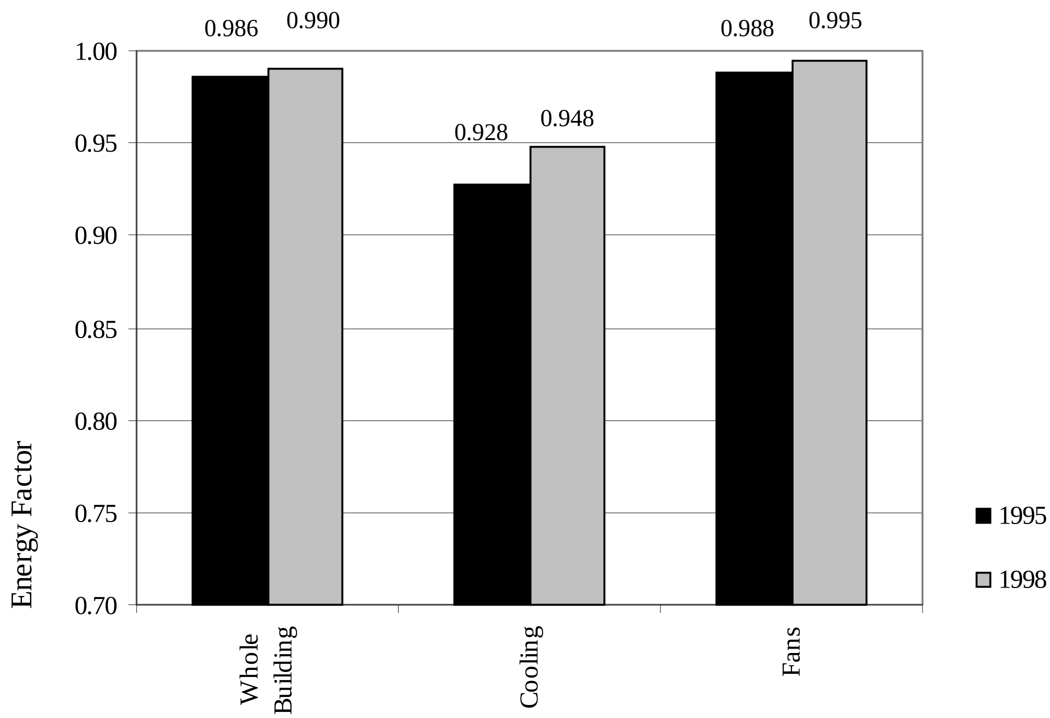

Figure 45: Average HVAC Parametric Energy Factor by End Use and T-24 Baseline

Table 11 shows the percentage of sites with reduced energy consumption due to HVAC measures, the average energy factor, the error bound, and the sample sizes.

	End Use	Sites Better Than Motors Parametric	Average Value	Error Bound	Sample Size
1995 T-24	Whole Building	56.5%	0.986	0.006	667
	Cooling	58.2%	0.928	0.031	637
	Fans	11.6%	0.988	0.007	656
1998 T-24	Whole Building	56.1%	0.990	0.004	667
	Cooling	58.2%	0.948	0.023	638
	Fans	8.4%	0.995	0.005	656

Table 11: HVAC Parametric Energy Factor by End Use and T-24 Baseline

Figure 46 shows the distribution of buildings by energy factor using the 1995 T-24 baseline by end use.

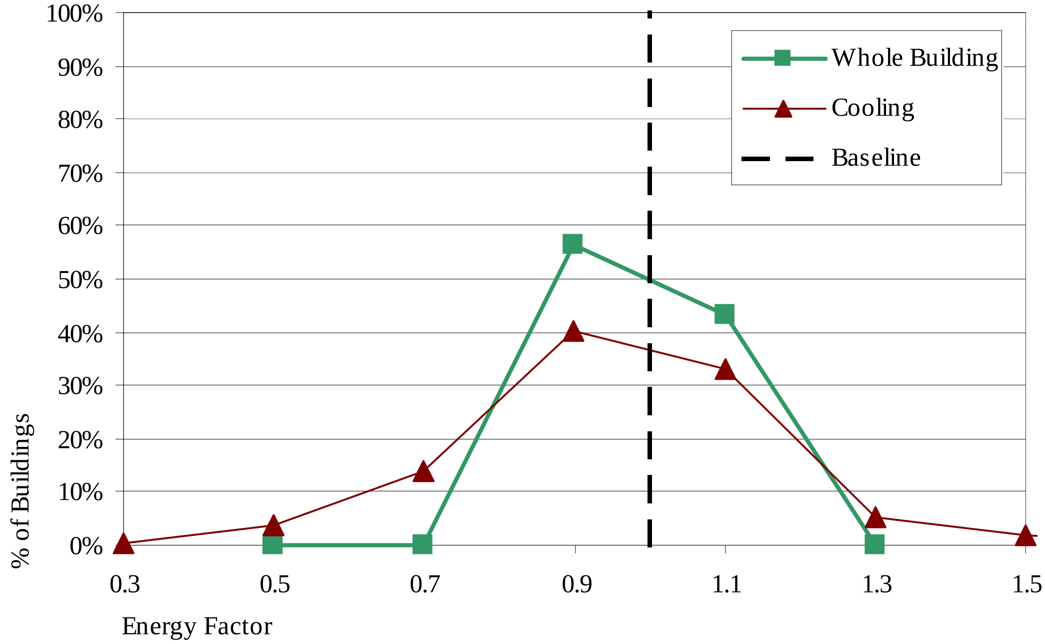

Figure 46: HVAC Parametric Energy Factor by End Use - 1995 T-24 Baseline

Figure 47 shows the distribution of buildings by energy factor using the 1998 T-24 baseline by end use.

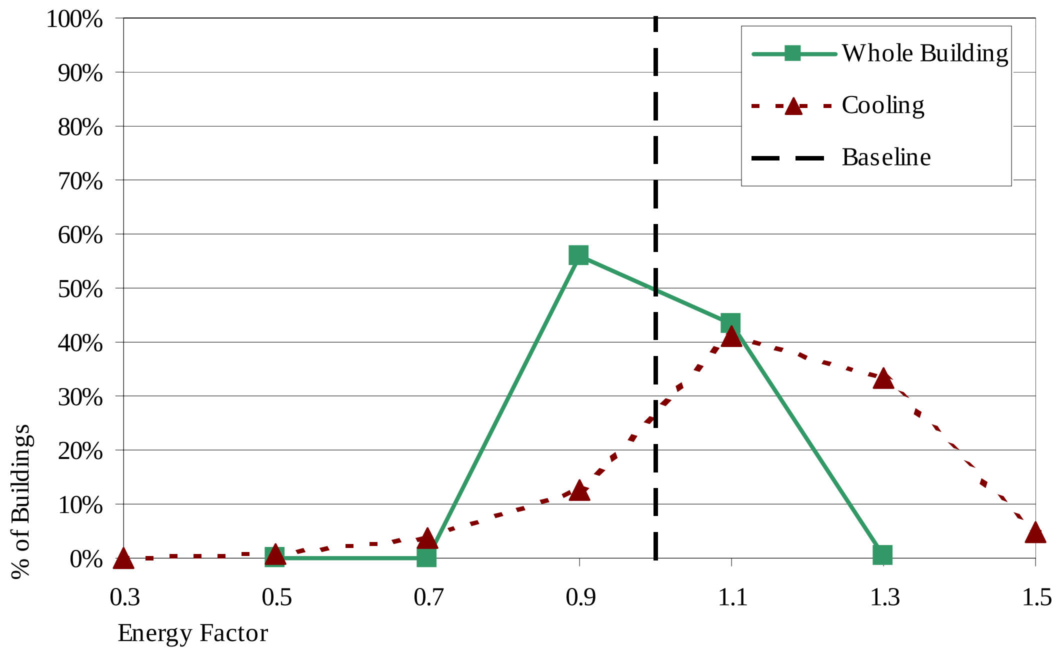

Figure 47: HVAC Parametric Energy Factor by End Use - 1998 T-24 Baseline

Cooling Results Using 1998 Sample

This section of the report contains the results for the cooling end use using only the 148 1998 sites. As mentioned previously, in the original Baseline study a distinct trend in the cooling efficiency was found between the 1994, 1996, and 1998 sites. The 1998 sites were summarized in the original report, along with the other years where possible. This section is provided to maintain consistency between the original study and this follow-on study.

Figure 48 and Figure 49 show the percentage of overall cooling savings due to each measure type relative to each T-24 baseline. In comparing Figure 48 to Figure 14, which show the cooling savings using all 667 sites, the only noticeable change between the 1995 T-24 is that lighting constitutes about 10% less savings and shell about 7% more savings in Figure 48.

In comparing Figure 49 to Figure 15, the major difference is that shell savings increase by 10% and LPD savings decrease by 11% in Figure 49.

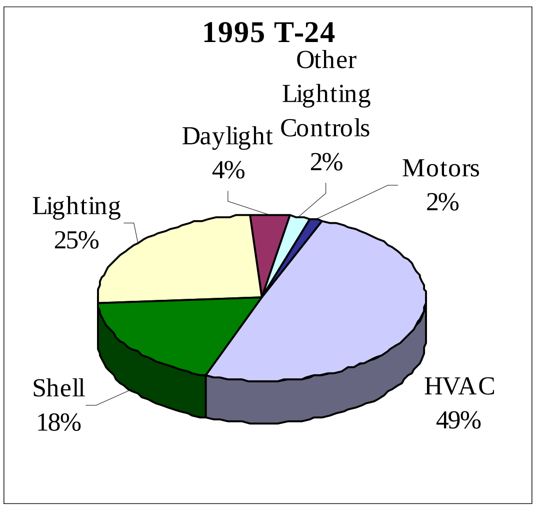

Figure 48: Percentage of Savings for Cooling End Use by Parametric Run Relative to 1995 T-24

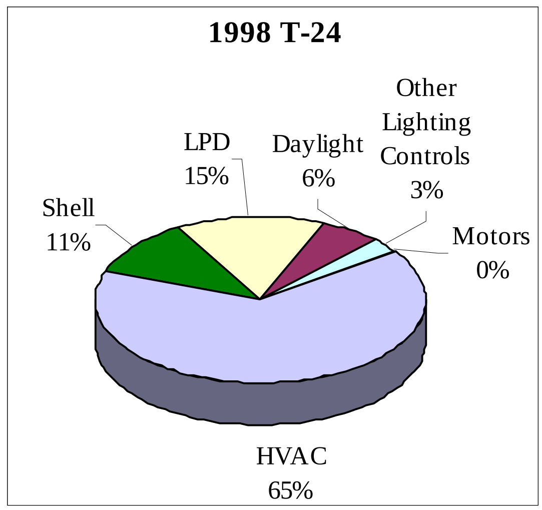

Figure 49: Percentage of Savings for Cooling End Use by Parametric Run Relative to 1998 T-24

The cooling end use savings are shown below in Figure 50 as a percentage of the whole building baseline. An increase of approximately 1% in the data from all 667 sites is seen in the overall savings relative to both baselines for these 1998 sites.

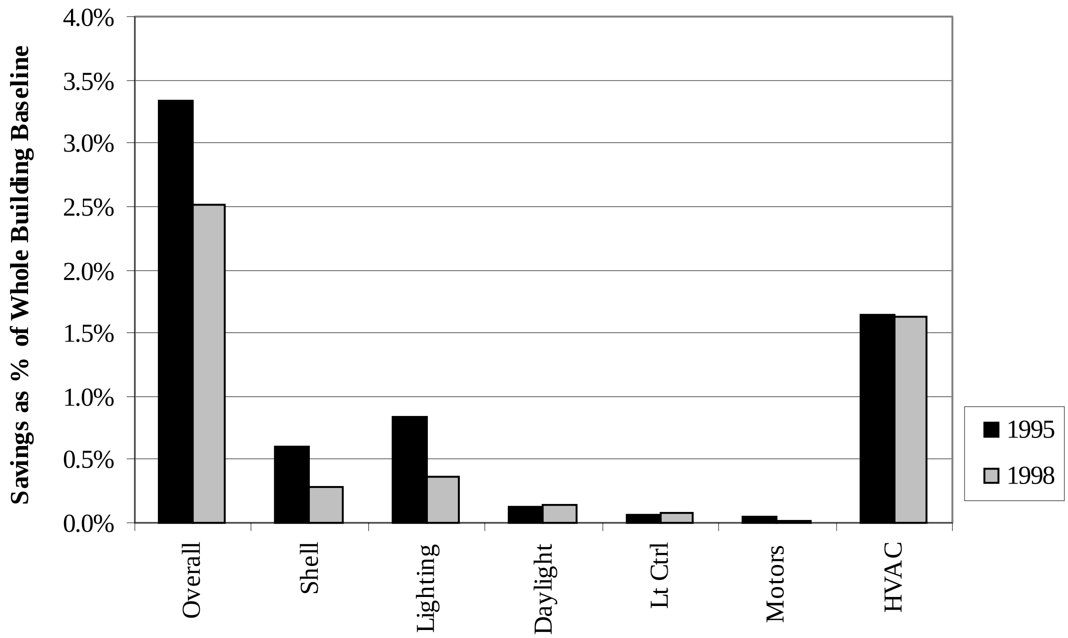

Figure 50: Cooling End Use Savings as a Percentage of Whole Building Baseline

Figure 51 shows the average cooling end use energy factor for all parametric runs and the overall energy ratio for cooling. The average energy factor for the 1998 sites is about 0.7 lower than the energy factor for the 667 sites relative to both baselines.

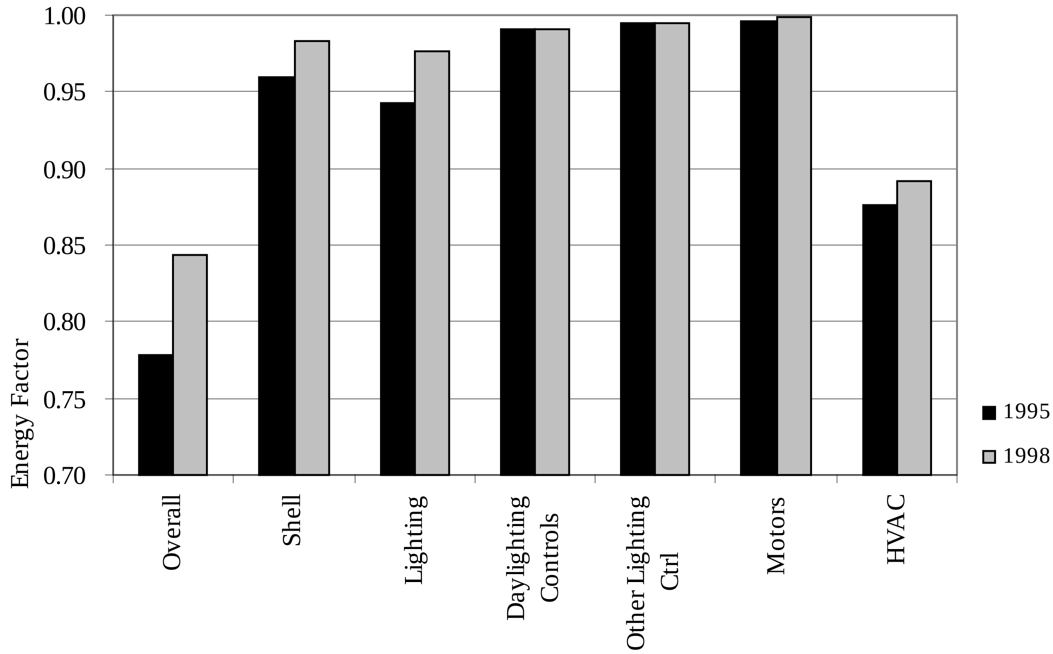

Figure 51: Average Cooling End Use Energy Factor for each Parametric Run

7. Lighting by Space Type

This section of the report contains the results from the Lighting Power Density and lighting technology analyses by space type. In the previous Baseline report, the LPD and lighting technologies were analyzed at the building level, and not by space type. These analyses were completed with the goal of obtaining a better understanding of the technologies being installed, and the lighting levels being achieved among the various building and area types. The lighting technologies by space type explore the potential of expanding the saturation of lighting controls and efficient lighting technologies.

In this section of the report, the following analyses are presented by space type:

- LPD - Average, Distribution, and LPD Ratio (LPDs were compared to new 1998 Title 24 baseline requirements),
- Fixtures - % of Lighting Connected Load, % of Spaces,
- Lamps and Ballasts - % of Lighting Connected Load, % of Spaces, and
- Lighting Controls - % of Lighting Connected Load, % of Spaces.

There are a total of 39 codes that were used to categorize the space types in the buildings[9]. Only those space types that account for at least 1% of the total square footage are included in the tables. The following table shows the breakdown of space types by total area (SqFt), percentage of total area, and cumulative percentage of total area. The grayed space types in Table 12 are the 15 types that will be summarized in the body of the report.

Table 12 also shows that although 15 space types represent 93% of the total square footage, three space types represent 70% of the new construction square footage. These predominant space types are 'Office' (37.1%), 'Retail sales/showroom' (22.3%), and 'Classrooms' (10.6%). This is not surprising, since the data used in these analyses are limited to offices, retail establishments, schools, and public assembly buildings. Notice that the majority of the space types each account for less than one percentage of the total surveyed square footage.

[9] A total of 667 buildings were used in the overall lighting analyses by space.

Rank	Space Type	% of Total Area	Cum. % of Total Area
1	Office	37.1%	37.1%
2	Retail sales, showrooms	22.3%	59.4%
3	Classrooms	10.6%	70.0%
4	Storage, warehouse	3.3%	73.3%
5	Gymnasiums	2.9%	76.1%
6	Library	2.7%	78.9%
7	Motion picture theater	2.5%	81.4%
8	Churches/chapels	2.2%	83.6%
9	Cnvntns, conf., meetings	1.9%	85.5%
10	Auditorium	1.6%	87.1%
11	Main entry lobby	1.4%	88.5%
12	Bank/financial institution	1.4%	89.9%
13	Computer center	1.2%	91.0%
14	Malls, arcades, atria	1.1%	92.1%
15	Gnrl comm, industrial	1.1%	93.2%
16	Kitchen	0.8%	94.0%
17	General area	0.8%	94.8%
18	Locker room	0.5%	95.3%
19	Dining	0.5%	95.8%
20	Day care	0.5%	96.2%
21	Laboratory	0.3%	96.5%
22	Courtrooms	0.3%	96.8%
23	Swimming pools	0.2%	97.1%
24	Performance theater	0.2%	97.3%
25	Exhibit	0.2%	97.5%
26	Auto repair workshops	0.2%	97.7%
27	Grocery	0.2%	97.9%
28	Bars, lounges, casinos	0.2%	98.1%
29	Prcsn comm, indstrl	0.1%	98.2%
30	School shops	0.1%	98.3%
31	Medical,clinical, dentist	0.1%	98.4%
32	Patient room/ nursery	0.0%	98.4%
33	Pharmacy	0.0%	98.4%
34	Hotel lobby	0.0%	98.4%
35	Hotel guest rooms	0.0%	98.5%
36	Barber, beauty shops	0.0%	98.5%
37	Occ. physical therapy	0.0%	98.5%
38	Commercial dry cleaners	0.0%	98.5%
39	Other spaces not listed	1.5%	100.0%

Table 12: Total Area (SqFt), Percentage of Total Area, and Cumulative Percentage of Total Area by Space Type

Table 13 shows the carefully selected sub-sample of buildings used in each type of analysis. The approach was established in the previous Baseline study. For the analyses by building type and overall, all 667 sample buildings consisting of 2,329 spaces were used. When comparing ownership types, the sample sites from the 1995 SDG&E impact evaluation were dropped because the ownership status of these sites was not known.

In comparing participants to non-participants, the 1998 sample was dropped since it was originally restricted to non-participants. In looking at time trends, the program participants were excluded in order to provide a comparison between the 1994, 1996, and 1998 data. The 1995 sites were also dropped because that part of the sample was small and out of phase with the rest of the sample.

	1994		1995		1996		1998		
Type of Analysis:	**Participant**	**Non-Participant**	**Participant**	**Non-Participant**	**Participant**	**Non-Participant**	**Participant**	**Non-Participant**	**Total Number in Sample**
Building Type	232	224	50	19	444	458	39	863	2329
Ownership Type	232	224	0	0	444	458	39	863	2260
Participant vs. Non-Participant	232	224	50	19	444	458	0	0	1427
Time Trends	0	224	0	0	0	458	39	863	1584

Table 13: Sample Sizes of Spaces

Lighting Power Density

Table 14 shows the average LPD by space type and building type. The 'Office' building type has the lowest average LPD among all of the building types.

Space Type	Office	Public Assembly	Retail	School	Overall
Office	1.1	1.3	1.0	1.3	**1.1**
Retail sales, showrooms	1.2	1.8	1.8	1.6	**1.8**
Classrooms	2.0	1.1	1.1	1.4	**1.4**
Storage, warehouse	0.8	0.9	0.9	1.1	**0.9**
Gymnasiums	0.9	1.3	0.0	1.3	**1.3**
Library	1.3	0.8	0.0	1.5	**1.3**
Motion picture theater	0.0	1.0	0.0	0.0	**1.0**
Churches/chapels	0.0	1.3	0.0	1.2	**1.3**
Cnvntns, conf., meetings	1.3	1.7	0.5	0.9	**1.6**
Auditorium	2.0	1.3	0.0	1.4	**1.4**
Main entry lobby	1.5	1.4	2.1	1.3	**1.4**
Bank/financial institution	1.0	0.0	1.4	0.0	**1.0**
Computer center	0.7	1.1	1.2	1.1	**0.8**
Malls, arcades, atria	0.0	1.4	1.3	0.0	**1.3**
Gnrl comm, industrial	1.4	0.6	0.0	0.8	**1.4**
Overall	**1.1**	**1.4**	**1.7**	**1.4**	**1.4**

Table 14: Average LPD by Space Type and Building Type

Figure 52 shows the average LPD by space and ownership type for office, retail, and classroom spaces. Not surprisingly, the average LPD in owner occupied spaces in all but retail spaces is lower than public and speculative development.

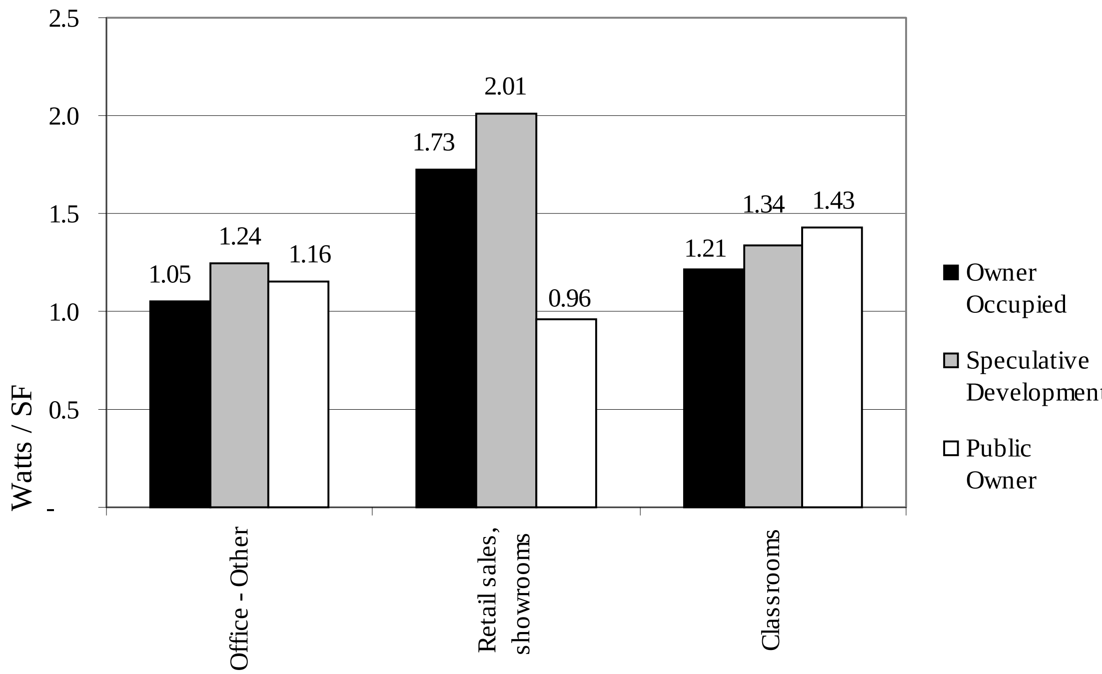

Figure 52: Average LPD by Ownership Type and Space Type

Figure 53 shows the distribution of spaces by LPD and building type. Note that the public assembly buildings tend to have lower LPDs than the other building types. Retail buildings tend to have higher LPDs.

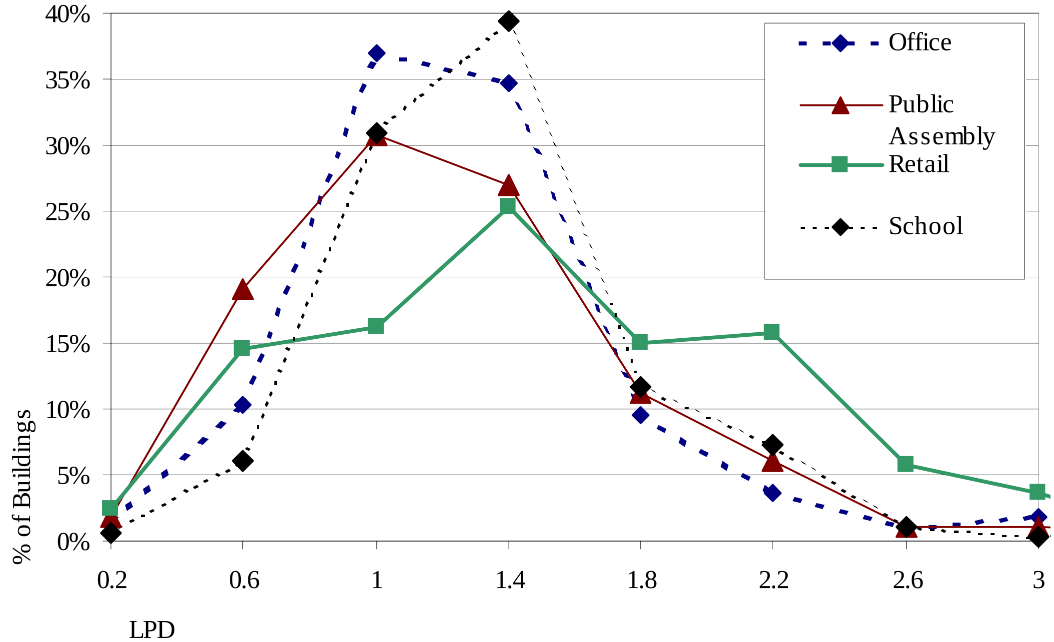

Figure 53: LPD Distribution of Spaces by Building Type

Table 15 shows the LPD ratio for each T-24 baseline by space type. The LPD ratio was calculated as follows:

$$\frac{(Watts / Square\ Feet)_{Installed}}{(Watts / Square\ Feet)_{T\text{-}24\ Baseline}}$$

The average LPD ratio indicates the percentage of lighting wattage that was saved relative to baseline. For example, office spaces installed 29% less wattage than 1995 T-24 baseline and 12% less than 1998 T-24 baseline. Also, the overall average LPD ratio increases from 1995 T-24 baseline to 1998 T-24 baseline by 0.14 indicating a reduction in energy savings brought on by the more stringent 1998 code requirements. Compared to the five space types having an 1995 LPD ratio exceeding 1.0, seven space types have 1998 LPD ratios exceeding 1.0 indicating that two additional spaces have a higher installed LPD than the 1998 Baseline LPD, and their installed LPD is lower than the 1995 Baseline LPD.

Space Type	1995 LPD Ratio	1995 Error Bound	1998 LPD Ratio	1995 Error Bound
Office	0.71	0.04	0.88	0.04
Retail sales, showrooms	0.82	0.05	0.91	0.05
Classrooms	0.70	0.05	0.88	0.06
Storage, warehouse	1.47	0.18	1.47	0.18
Gymnasiums	0.66	0.07	1.32	0.14
Library	0.66	0.06	0.88	0.07
Motion picture theater	0.99	0.10	1.09	0.11
Churches/chapels	0.57	0.07	0.60	0.08
Cnvntns, conf., meetings	1.02	0.27	1.02	0.27
Auditorium	0.71	0.11	0.71	0.11
Main entry lobby	0.89	0.08	0.95	0.08
Bank/financial institution	0.58	0.07	0.75	0.09
Computer center	0.48	0.22	0.48	0.22
Malls, arcades, atria	1.04	0.30	1.04	0.30
Gnrl comm, industrial	1.09	0.25	1.18	0.28
Overall	**0.77**	**0.03**	**0.91**	**0.03**

Table 15: LPD Ratio by Space Type

Figure 54 shows the average LPD ratio by space type for each of the T-24 baselines. Notice that the majority of space types have LPD ratios under 1 for each T-24 baseline. However for storage, other space, conference rooms, malls and general commercial/industrial spaces the LPD ratio is over 1 for both T-24 years. This indicates that for these space types, the wattage installed is more than allowed. This could happen in cases where the overall building complies with LPD code, but individual spaces within the building have LPD ratios greater than 1. The new code should impact these space types. However, for the other space types shown that have a 1998 LPD ratio lower than 1, the new code probably will not have a significant impact on their lighting choices.

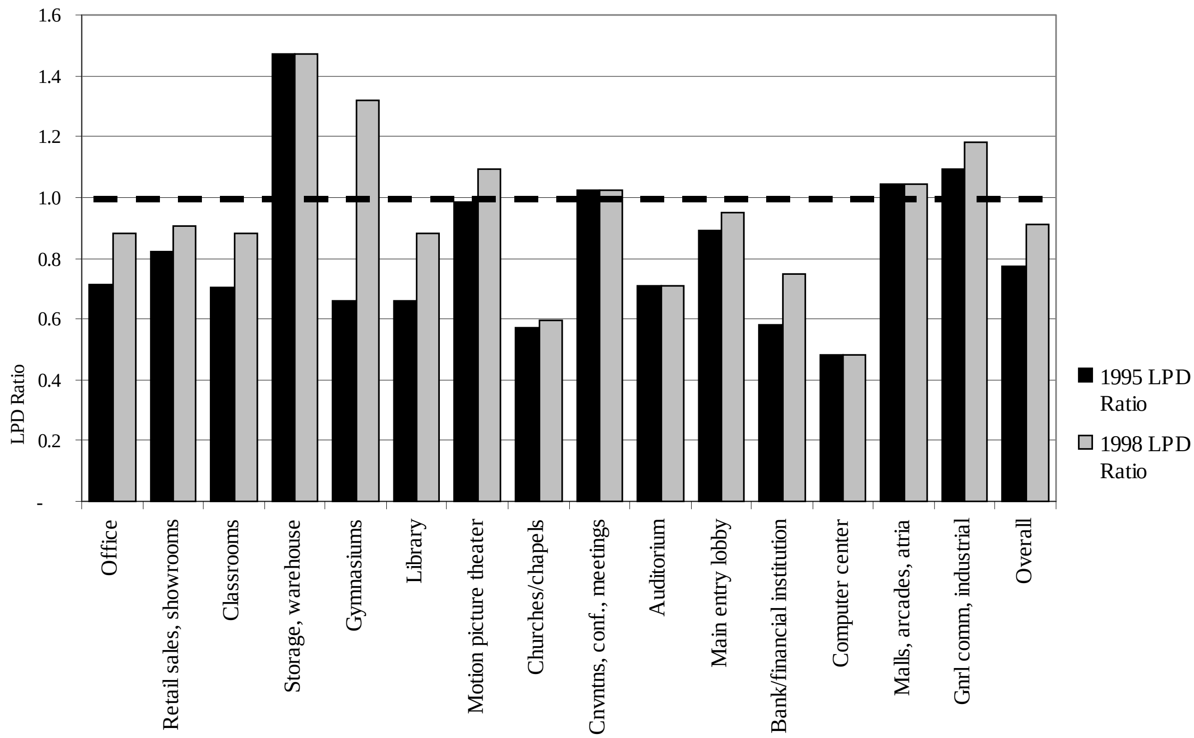

Figure 54: Average LPD Ratio by Space Type

The following table summarizes the space types by building type. Table 16 shows the sample size, the percentage of sites better than baseline, the average value of the LPD ratio, and the error bounds associated with each value. The table indicates that 80% of spaces within schools have an LPD better than 1995 T-24 baseline LPD.

Building Type	Sample Size	Spaces Better than Baseline	Average Value	Error Bound
Office	827	79.8%	0.71	0.03
Public Assembly	435	71.0%	0.85	0.13
Retail	423	61.9%	0.84	0.05
School	644	80.0%	0.73	0.04
Overall	2,329	74.8%	0.77	0.03

Table 16: Space 1995 T-24 LPD Ratio by Building Type

Table 17 shows the sample size, the percentage of sites better than baseline, the average value of the LPD ratio, and the error bounds associated with each value. The table shows that only 64% of spaces within schools have an LPD better than 1998 T-24 baseline LPD.

Building Type	Sample Size	Spaces Better than Baseline	Average Value	Error Bound
Office	827	65.1%	0.87	0.04
Public Assembly	435	60.4%	1.01	0.15
Retail	423	49.0%	0.92	0.05
School	644	63.8%	0.92	0.05
Overall	2329	61.1%	0.91	0.03

Table 17: Space 1998 T-24 LPD Ratio by Building Type

Figure 55 shows the LPD ratio distribution by T-24 baseline year. It is easy to see that the majority of spaces have lower LPD ratios at the 1995 T-24 baseline as opposed to the 1998 T-24 baseline.

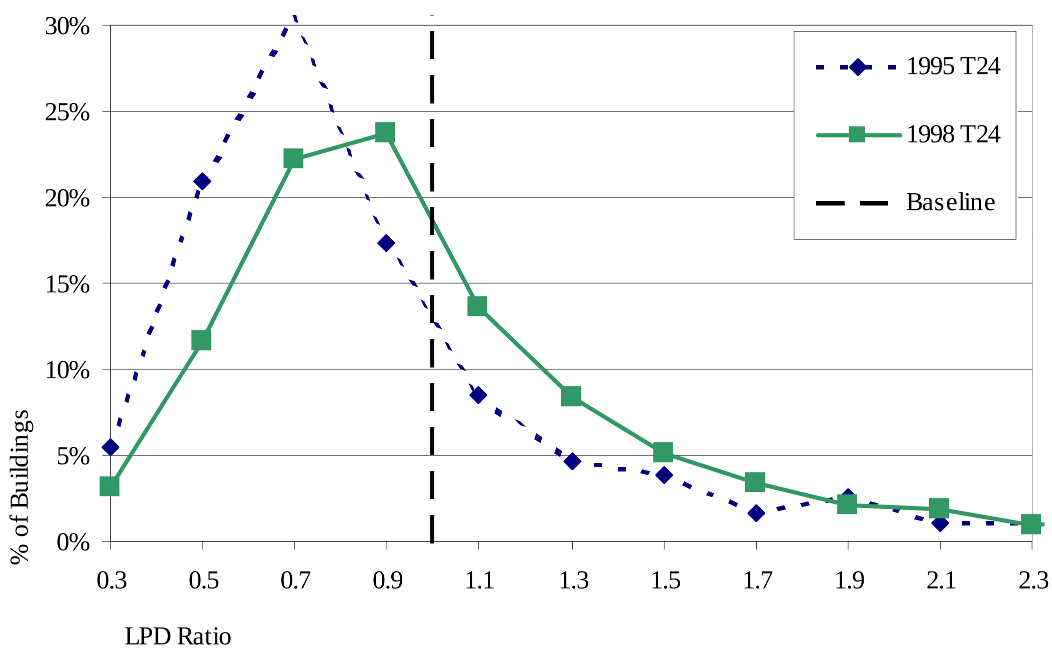

Figure 55: LPD Ratio Distribution by T-24 Year

Figure 56 shows the 1995 LPD ratio distribution of spaces by building type. The figure shows that LPD ratios over 1.2 are not very common for any of the four surveyed space types. In fact, most of the LPD ratios are less than one indicating better than 1995 T-24 baseline conditions for most buildings in all four building types.

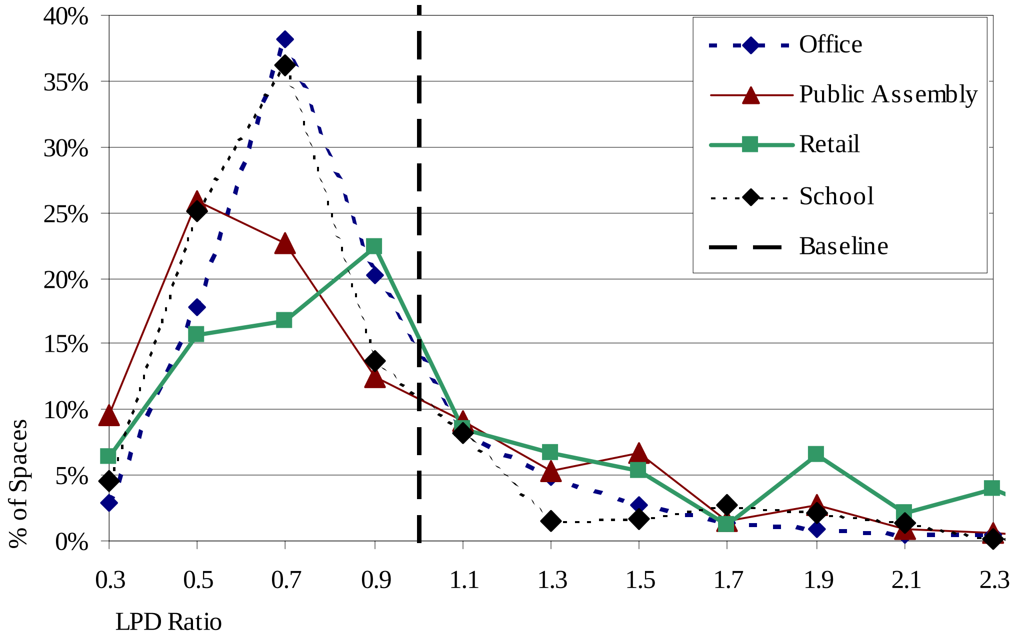

Figure 56: 1995 LPD Ratio Distribution by Building Type

Figure 57 shows the 1998 LPD ratio distribution of spaces by building type. Notice that the majority of the spaces within all building types have a 1998 LPD ratio below one. Even though the majority of spaces within the building types do have 1998 LPD ratios less than one, the figure indicates there are spaces within the building types, most notably retail, that have 1998 LPD ratios greater than one. Compared to the 1995 T-24 baseline, this is evidence that a greater percentage of spaces were designed short of the 1998 T-24 code. This finding verifies the potential for future lighting related energy and demand savings with the enforcement of the 1998 T-24 code revisions.

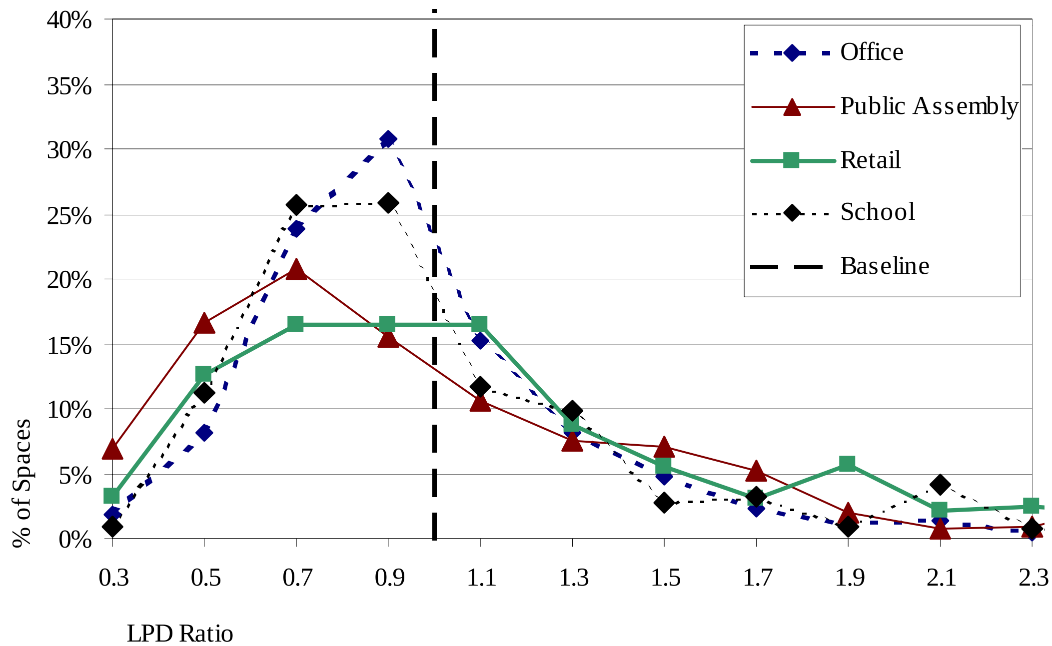

Figure 57: 1998 LPD Ratio Distribution by Building Type

Lighting Fixtures

Table 18 shows the percentage of spaces with each of the fixture types by space type. Not surprisingly, the most dominant type of lighting fixture is fluorescent. Almost 96% of office spaces have fluorescent fixtures, while over 93% of all spaces have fluorescent fixtures. The second most common lighting fixtures are compact fluorescent lamps, with over 36% of the spaces utilizing that technology. Even though the saturation of compact fluorescent lamps is greater than incandescent lamps, they are relatively close at 36.9% and 30.3% respectively. This indicates the potential for greater penetration of compact fluorescent lamps in the NRNC market. The high intensity discharge lamps, i.e. metal halide and high pressure sodium lamps, have a relatively low saturation in the spaces at 8.5% and 1.5% respectively. This is primarily because they have limited applications in NRNC. Mercury vapor, halogen, and biaxial lamps also have low saturation with 0.5%, 3.4%, and 4.2%, respectively, in all spaces using the technology.

Space Type	Biaxial	CFL	Exit Signs	Fluor.	Halogen	Sodium	Incan.	Metal Halide	Mercury Vapor	Sample Size
Office	5.2%	47.4%	17.7%	95.7%	2.6%	0.2%	24.5%	3.2%	0.2%	662
Retail sales, showrooms	10.6%	21.6%	40.1%	96.0%	8.3%	3.9%	60.5%	26.5%	1.7%	187
Classrooms	1.5%	22.9%	10.1%	99.8%	0.8%	0.7%	12.2%	2.7%	0.2%	387
Storage, warehouse	0.0%	4.6%	5.4%	95.4%	0.0%	1.9%	8.0%	8.2%	0.1%	134
Gymnasiums	4.8%	16.8%	21.6%	69.3%	0.0%	9.2%	32.8%	41.3%	4.5%	75
Library	5.0%	56.9%	14.0%	99.3%	7.0%	6.2%	33.0%	5.3%	0.0%	75
Motion picture theater	4.1%	75.2%	5.4%	84.8%	1.0%	0.0%	86.1%	6.0%	0.0%	49
Churches/chapels	1.9%	53.4%	32.1%	95.4%	22.1%	2.2%	69.1%	12.1%	0.0%	35
Cnvntns, conf., meetings	5.6%	41.6%	11.2%	94.9%	2.6%	0.0%	27.8%	5.9%	0.0%	73
Auditorium	0.7%	38.4%	23.7%	90.0%	0.4%	12.7%	89.0%	32.9%	0.7%	34
Main entry lobby	9.4%	61.5%	5.2%	75.8%	6.9%	0.0%	43.9%	18.7%	1.4%	103
Bank/financial institution	5.1%	66.6%	38.3%	100.0%	16.7%	0.0%	33.1%	0.0%	0.0%	20
Computer center	0.4%	12.2%	5.6%	100.0%	0.0%	0.4%	9.8%	0.4%	0.0%	44
Malls, arcades, atria	0.0%	7.2%	5.0%	97.8%	0.9%	0.0%	6.2%	9.2%	1.2%	9
Gnrl comm,	0.0%	0.0%	3.9%	94.5%	0.0%	0.0%	38.9%	13.7%	0.0%	15
Overall	**4.2%**	**36.9%**	**15.1%**	**93.6%**	**3.4%**	**1.5%**	**30.3%**	**8.5%**	**0.5%**	**2,329**

Table 18: Percentage of Spaces with Fixture Type by Space Type

Figure 58 shows the percentage of spaces within each building type that utilizes each of the fixture types. It is easy to see that fluorescent, compact fluorescent, incandescent, and exit signs are commonly found in the spaces.

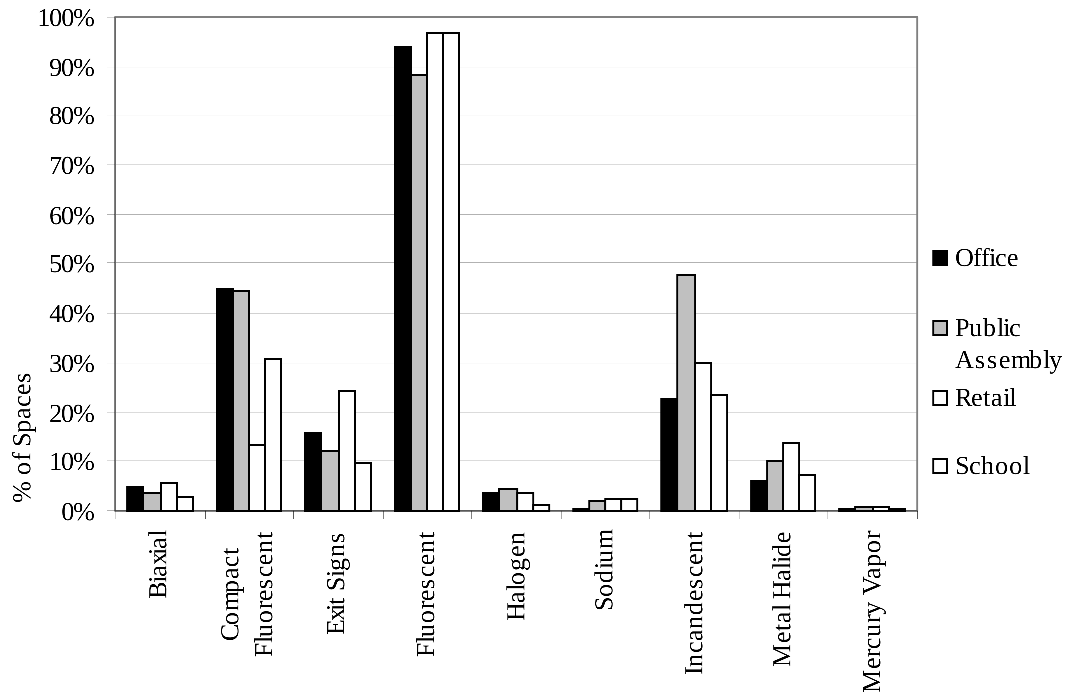

Figure 58: Percentage of Spaces with Fixture Type by Building Type

Table 19 shows the percentage of the total lighting connected load with each fixture type by space type. Fluorescent fixtures total only 67.4% of the load, while they are present in over 93% of spaces. Interestingly, compact fluorescent fixtures only make up 3% of the total lighting connected load, while they are present in over 36% of spaces. The low connected load for a significant number of spaces using compact fluorescent lamps is an indication of the superior efficiency of the technology, but most likely an indicator of the fact that in some cases, a small number of each technology are in installed in the spaces, thus making up a smaller percentage of the load.

The space types where incandescent fixtures control over 10% of the lighting connected load are 'retail', 'gymnasiums', 'motion picture theaters', 'churches/chapels', 'conventions, conference, meeting', 'auditoriums' 'main entry lobby' and 'general commercial & industrial'. The majority of those space types would be candidates for CFL replacement, with the exception possibly of 'retail' and 'main entry lobby' spaces that might rely on the color rendition of incandescent fixtures.

Space Type	Biaxial	CFL	Exit Signs	Fluor.	Halogen	Sodium	Incan.	Metal Halide	Mercury Vapor	Sample Size
Office	1.9%	5.4%	0.2%	87.7%	0.1%	0.1%	4.0%	0.6%	0.0%	662
Retail sales, showrooms	0.5%	0.8%	0.1%	48.3%	1.1%	0.2%	14.4%	34.5%	0.2%	187
Classrooms	0.2%	2.3%	0.1%	94.4%	0.1%	0.2%	2.1%	0.6%	0.0%	387
Storage, warehouse	0.0%	0.2%	0.1%	79.4%	0.0%	5.2%	1.2%	13.6%	0.3%	134
Gymnasiums	0.1%	2.2%	0.2%	28.8%	0.0%	4.9%	15.3%	39.3%	9.2%	75
Library	0.8%	6.6%	0.1%	85.2%	1.2%	0.3%	3.3%	2.5%	0.0%	75
Motion picture theater	0.3%	3.8%	0.1%	19.9%	0.0%	0.0%	73.1%	2.8%	0.0%	49
Churches/chapels	0.3%	3.4%	0.5%	50.1%	4.3%	1.6%	34.2%	5.5%	0.0%	35
Cnvntns, conf., meetings	0.7%	7.9%	0.2%	52.1%	0.4%	0.0%	35.3%	3.5%	0.0%	73
Auditorium	0.0%	5.4%	0.1%	44.5%	0.0%	2.2%	40.6%	6.8%	0.3%	34
Main entry lobby	4.2%	22.2%	0.1%	33.9%	1.2%	0.0%	31.4%	6.9%	0.2%	103
Bank/financial institution	0.2%	9.5%	0.3%	82.1%	1.7%	0.0%	6.2%	0.0%	0.0%	20
Computer center	0.1%	1.2%	0.0%	98.2%	0.0%	0.0%	0.3%	0.2%	0.0%	44
Malls, arcades, atria	0.0%	1.3%	0.1%	78.2%	1.6%	0.0%	4.6%	9.2%	4.9%	9
Gnrl comm, industrial	0.0%	0.0%	0.0%	82.0%	0.0%	0.0%	11.0%	7.0%	0.0%	15
Overall	**1.0%**	**3.6%**	**0.1%**	**67.4%**	**0.6%**	**0.4%**	**13.4%**	**12.9%**	**0.5%**	**2,329**

Table 19: Percentage of Lighting Connected Load with Fixture Type by Space Type

Figure 59 shows the percentage of the total connected lighting load with each fixture type by building type. Interestingly, in public assembly buildings the fluorescent lighting makes up only 39% of the total load while in the other building types it totals at least 50% of the load. Public assembly buildings seem to rely heavily on incandescent fixtures, while retail establishments have a much higher proportion of metal halides than the other building types. The saturation of metal halides in retail stores is most likely attributed to the abundance of big box/warehouse type retail stores that usually use low bay metal halide fixtures. It is assumed that the public assembly spaces are using incandescent lamps for their dimming capabilities and good color rendering.

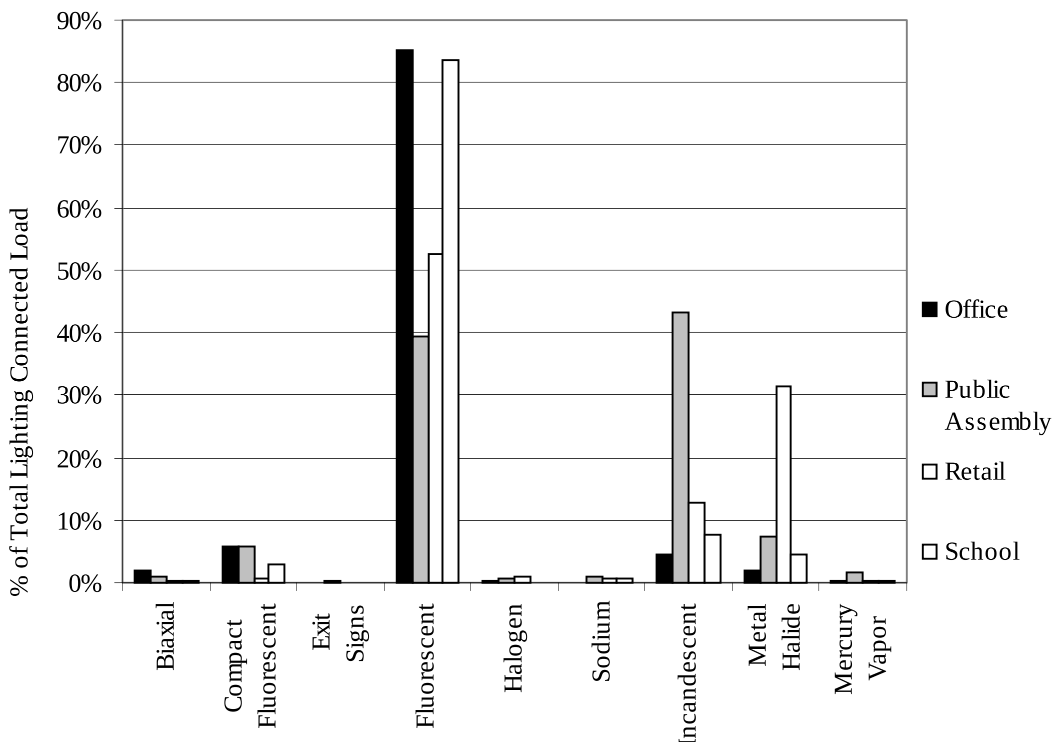

Figure 59: Percentage of Lighting Connected Load with Fixture Type by Building Type

Table 20 shows the percentage of the lighting connected load of each fixture type within LPD bins for 'Office-other' spaces. Overall, there are not any strong trends among the LPD bins.

Installed LPD Bins	Biaxial	Compact Fluorescent	Exit Signs	Fluorescent	Halogen	Incandescent	Metal Halide	Sample Size
LPD < 0.7	0.0%	6.6%	0.2%	88.6%	0.1%	4.1%	0.5%	42
LPD 0.7-0.79	0.0%	2.3%	0.1%	96.1%	0.1%	1.1%	0.3%	40
LPD 0.8-0.89	0.0%	7.2%	0.6%	89.5%	0.6%	1.6%	0.5%	47
LPD 0.9-0.99	0.7%	5.4%	0.5%	90.2%	0.7%	2.2%	0.3%	64
LPD 1.0-1.09	3.3%	7.7%	0.1%	85.0%	0.1%	3.6%	0.1%	88
LPD 1.1-1.19	1.3%	6.9%	0.2%	88.5%	0.0%	2.5%	0.5%	77
LPD 1.2-1.29	1.7%	5.9%	0.2%	89.2%	0.1%	2.2%	0.5%	78
LPD 1.3-1.39	2.7%	4.2%	0.1%	88.6%	0.1%	3.2%	1.1%	45
LPD 1.4-1.49	13.9%	4.6%	0.1%	78.5%	0.0%	1.7%	1.2%	47
LPD 1.5-1.59	2.3%	3.8%	0.1%	84.5%	0.0%	7.4%	1.8%	39
LPD 1.6-1.79	0.3%	6.5%	0.0%	83.4%	0.1%	9.5%	0.1%	34
LPD > 1.8	0.9%	2.0%	0.1%	87.8%	0.2%	8.0%	0.9%	61

Table 20: Percentage of Lighting Connected Load with Lighting Fixtures within LPD Ranges among Office Spaces

Table 21 shows the percentage of the lighting connected load of each fixture type within LPD bins for 'Retail, showroom' spaces. We see a higher percentage of metal halide, incandescent, and halogen fixtures in those retail spaces with high LPDs. Its interesting to notice that the percentage of load utilizing incandescent fixtures is also relatively high for the spaces within the lowest LPD bins.

Installed LPD Bins	Biaxial	Compact Fluorescent	Exit Signs	Fluorescent	Halogen	Sodium	Incandescent	Metal Halide	Mercury Vapor	Sample Size
LPD < 1.0	0.0%	2.9%	0.1%	54.6%	2.3%	0.0%	13.8%	25.2%	1.1%	17
LPD 1.0-1.19	0.2%	0.3%	0.1%	89.8%	0.0%	0.0%	8.7%	0.8%	0.0%	13
LPD 1.2-1.39	0.1%	0.4%	0.0%	95.3%	0.1%	0.0%	2.7%	1.3%	0.0%	20
LPD 1.4-1.59	1.0%	0.2%	0.1%	51.6%	0.1%	0.0%	3.5%	43.4%	0.0%	40
LPD 1.6-1.79	0.6%	0.1%	0.1%	38.5%	0.8%	0.0%	1.5%	58.5%	0.0%	23
LPD 1.8-1.99	0.6%	3.0%	0.2%	64.6%	1.4%	1.4%	26.8%	2.0%	0.0%	17
LPD 2.0-2.19	0.4%	1.3%	0.1%	70.9%	6.0%	0.0%	2.6%	18.8%	0.0%	19
LPD > 2.2	0.3%	0.5%	0.0%	25.2%	0.6%	0.0%	27.3%	45.3%	0.6%	38

Table 21: Percentage of Lighting Connected Load with Lighting Fixtures within LPD Ranges among Retail Spaces

Table 22 shows the percentage of the lighting connected load of each fixture type within LPD bins for 'Classroom' spaces. Among the classroom spaces with low LPDs, it is evident that there was a higher percentage of lighting connected load associated with compact fluorescent fixtures than those with high LPDs. Also, those spaces that utilize more compact fluorescent fixtures tend to have a lower percentage of fluorescent fixtures.

Installed LPD Bins	Biaxial	Compact Fluorescent	Exit Signs	Fluorescent	Halogen	Sodium	Incandescent	Metal Halide	Sample Size
LPD < 0.8	0.0%	6.5%	0.1%	86.1%	0.1%	5.0%	1.0%	1.2%	31
LPD 0.8-0.99	0.0%	2.5%	0.1%	93.2%	0.2%	0.1%	0.6%	3.3%	52
LPD 1.0-1.19	0.0%	4.3%	0.1%	92.5%	0.1%	0.1%	2.8%	0.1%	66
LPD 1.2-1.39	0.1%	2.6%	0.1%	92.2%	0.1%	0.0%	4.2%	0.6%	79
LPD 1.4-1.59	0.6%	1.5%	0.1%	95.9%	0.0%	0.1%	1.7%	0.2%	73
LPD 1.6-1.79	0.4%	2.0%	0.1%	95.7%	0.0%	0.1%	0.6%	0.1%	30
LPD > 1.8	0.1%	0.9%	0.1%	97.2%	0.0%	0.0%	1.3%	0.5%	56

Table 22: Percentage of Lighting Connected Load with Lighting Fixtures within LPD Ranges among Classroom Spaces

Lighting Lamps and Ballasts

This section summarizes the lamp and ballast combinations by space type. Only T8, T12, and u-tube fluorescent lamps are discussed here since the fixture energy consumption can vary significantly with ballast selection.

Table 23 shows the percentage of spaces with each of the ballast types. In all the space types shown, the majority of spaces have T8 lamps with electronic ballasts. The second most common lamp/ballast combinations are T12 lamps with magnetic energy saving ballasts, with over 16% of the spaces containing this type of lamp/ballast combination. This indicates that people were still designing with the less efficient T12 lamps before the 1998 Title 24 standards became effective. However, since the majority of spaces were being designed with T8 lamps and electronic ballasts, it is evident that T8 technology had become common practice before becoming mandatory per the 1998 Title 24 standards.

Space Type	T8 Electronic	T8 Magnetic Energy Saver	T12 Electronic	T12 Magnetic Energy Saver	T12 Magnetic Standard	T9 Magnetic Standard	Sample Size
Office	76.6%	6.6%	7.1%	15.6%	6.8%	1.0%	627
Retail sales, showrooms	75.3%	17.9%	15.0%	26.5%	27.1%	4.7%	179
Classrooms	74.4%	5.6%	5.0%	13.0%	10.8%	0.2%	384
Storage, warehouse	71.8%	0.2%	8.0%	23.4%	9.0%	3.9%	127
Gymnasiums	69.0%	15.6%	4.6%	1.7%	14.5%	0.0%	50
Library	93.7%	5.0%	5.3%	3.6%	7.8%	0.0%	74
Motion picture theater	40.2%	0.0%	14.0%	1.2%	49.2%	0.0%	39
Churches/chapels	33.8%	0.0%	2.9%	56.1%	21.3%	0.0%	34
Cnvntns, conf., meetings	80.9%	2.9%	11.3%	9.9%	5.3%	0.0%	69
Auditorium	87.1%	0.7%	5.2%	20.8%	22.2%	0.0%	31
Main entry lobby	76.2%	3.9%	4.1%	16.0%	8.1%	0.0%	73
Bank/financial institution	88.4%	2.3%	12.6%	0.0%	6.0%	0.0%	20
Computer center	91.4%	0.8%	0.3%	0.9%	6.6%	0.0%	44
Malls, arcades, atria	11.5%	0.0%	1.2%	87.3%	0.0%	0.9%	8
Gnrl comm, industrial	60.5%	0.0%	1.7%	39.5%	5.7%	0.0%	13
Overall	**74.3%**	**5.6%**	**6.3%**	**16.7%**	**10.9%**	**0.9%**	**2,163**

Table 23: Percentage of Spaces with Fluorescent kW with Lamp and Ballast Type by Space Type

Figure 60 shows the percentage of spaces with each of the ballast types by building type. Over 60% of the spaces within each of the building types have T8 electronic ballasts. It is clearly evident that the most prevalent lighting technology is the T8 lamp with electronic ballast. It can also be seen that there are few lighting systems that utilize T12 lamps with standard magnetic ballasts.

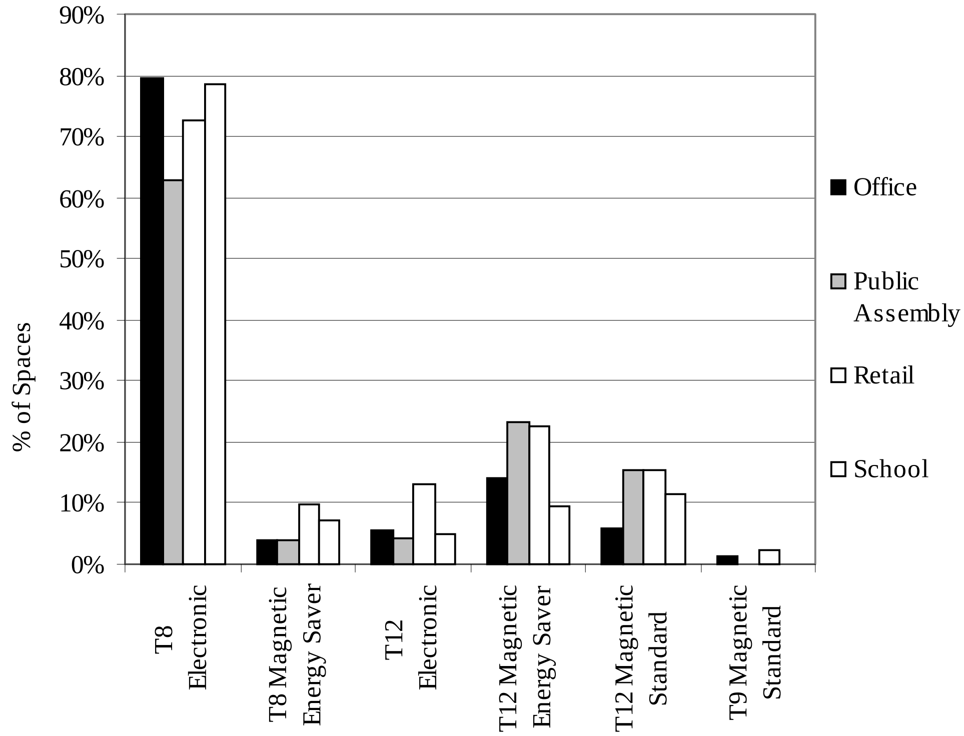

Figure 60: Percentage of Spaces with Fluorescent kW with Lamp Ballast Types by Building Type

Table 24 shows the percentage of the lighting connected load with each of the ballast types. Again, T8 electronic ballasts consist of the majority of the total lighting connected load, totaling over 69% of the lighting connected load in all the spaces. Interestingly, 84% of the lighting connected load in library spaces are T8 Electronic ballasts. Retail establishments have a much larger percentage of T12 Electronic ballasts at 17.1%, than the average of all the space types which is 6.6%.

Space Type	T8 Electronic	T8 Magnetic Energy Saver	T12 Electronic	T12 Magnetic Energy Saver	T12 Magnetic Standard	T9 Magnetic Standard	Sample Size
Office	80.4%	4.2%	1.6%	8.5%	5.2%	0.0%	627
Retail sales, showrooms	57.3%	4.9%	17.1%	11.2%	9.3%	0.2%	179
Classrooms	69.8%	4.2%	7.3%	10.6%	8.1%	0.0%	384
Storage, warehouse	47.2%	0.9%	10.1%	28.5%	13.3%	0.1%	127
Gymnasiums	59.3%	17.8%	4.0%	3.2%	15.7%	0.0%	50
Library	84.0%	2.4%	1.8%	1.7%	10.1%	0.0%	74
Motion picture theater	29.8%	0.0%	0.9%	0.1%	69.2%	0.0%	39
Churches/chapels	20.4%	0.0%	1.0%	52.5%	26.1%	0.0%	34
Cnvntns, conf., meetings	74.4%	1.4%	16.9%	5.8%	1.6%	0.0%	69
Auditorium	41.7%	0.1%	8.1%	10.5%	39.6%	0.0%	31
Main entry lobby	70.2%	1.0%	6.8%	15.2%	6.9%	0.0%	73
Bank/financial institution	85.1%	11.2%	3.6%	0.0%	0.2%	0.0%	20
Computer center	95.3%	0.9%	0.0%	0.2%	3.6%	0.0%	44
Malls, arcades, atria	47.9%	0.0%	2.2%	48.6%	0.0%	1.2%	8
Gnrl comm, industrial	43.9%	0.0%	0.1%	54.9%	1.1%	0.0%	13
Overall	**69.7%**	**4.1%**	**6.6%**	**11.7%**	**7.9%**	**0.1%**	**2,163**

Table 24: Percentage of Lighting Connected Load with Lamp Ballast Type by Space Type

Figure 61 shows the percentage of lighting connected load by lamp ballast type within each building type. In all building types, T8 lamps with electronic ballasts are used for at least 50% of the lighting connected load in the spaces.

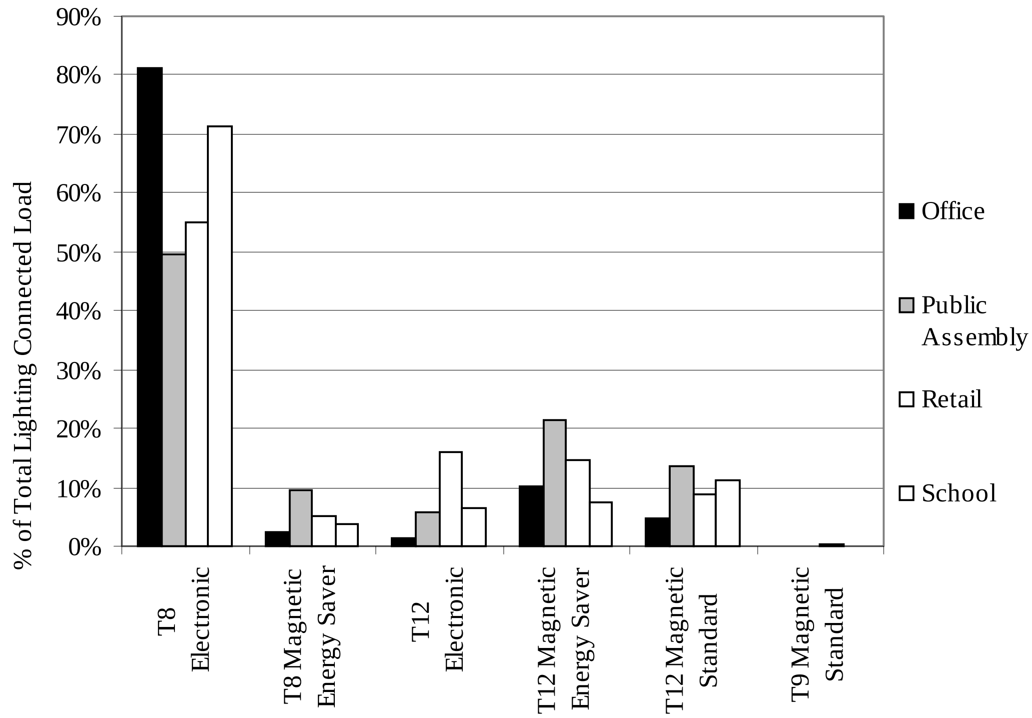

Figure 61: Percentage of Lighting Connected Load with Lamp Ballast Type by Building Type

Figure 62 shows the percentage of the lighting connected load with each ballast type by year. Not surprisingly, the apparent trend is that of an increasing use of T8 lamps with electronic ballasts and the decreasing use of T12 lamps with all types of ballasts.

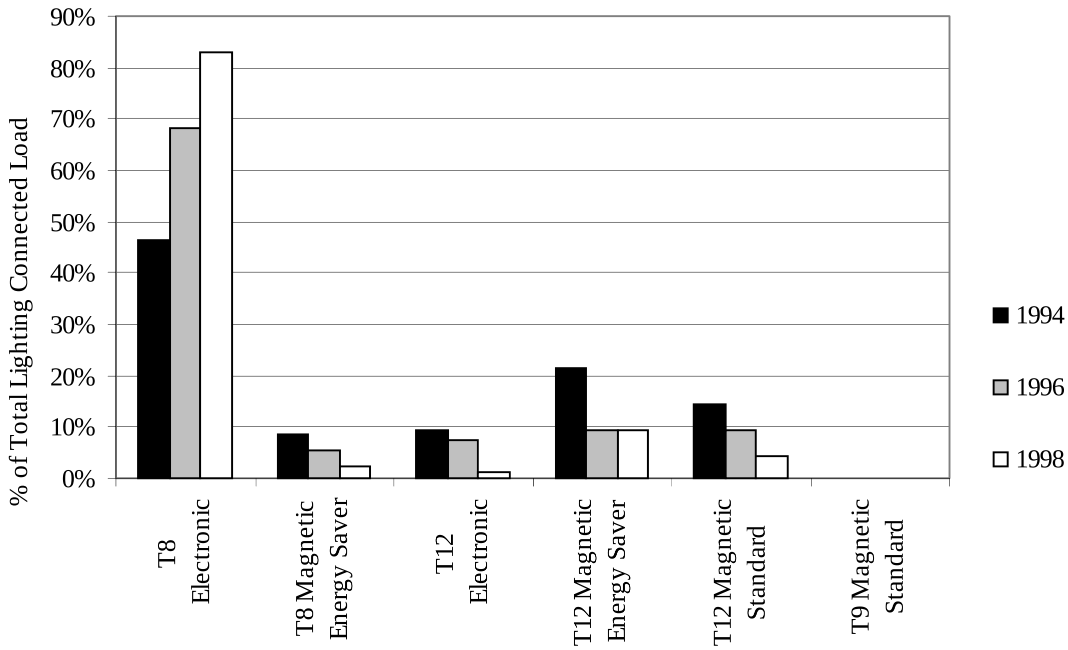

Figure 62: Percentage of Lighting Connected Load with Lamp Ballast Type by Year

Figure 63 shows the percentage of the lighting connected load with each ballast type by ownership type. There does not seem to be any apparent trend in the type of ballast installed by ownership type.

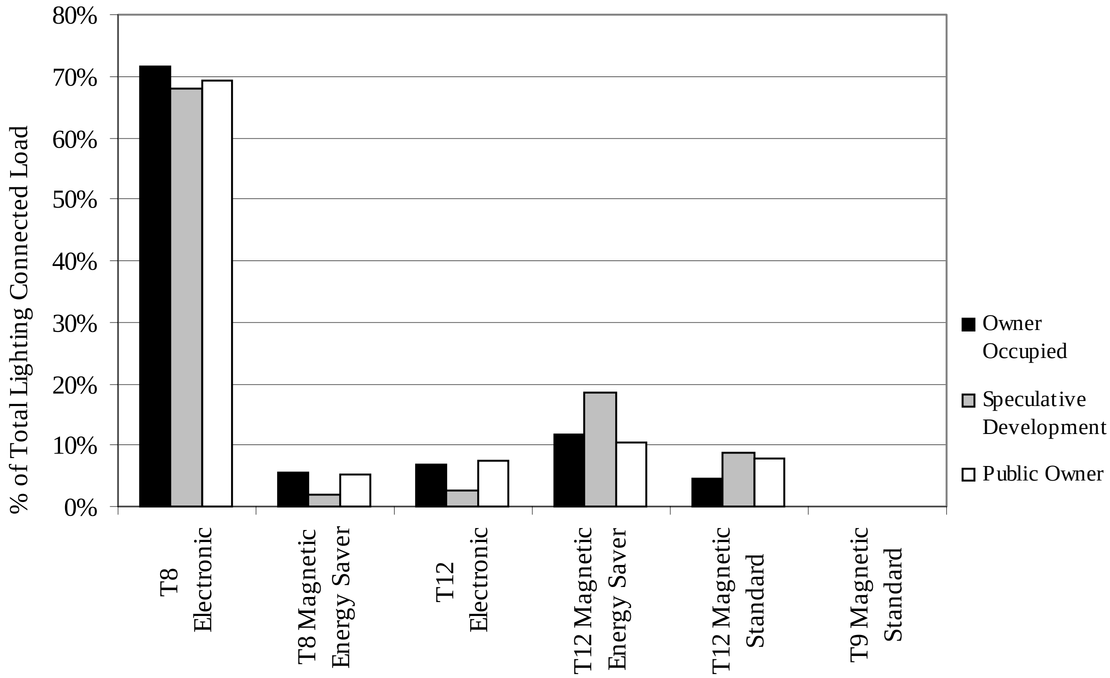

Figure 63: Percentage of Total Lighting Connected Load with Lamp Ballast Type by Ownership Type

Table 25 shows the percentage of the lighting connected load of each ballast type within LPD bins for 'Office-other' spaces. It is clear that among those office spaces with low LPDs, a higher percentage of T8 lamps with electronic ballasts are installed.

Installed LPD Bins	T8 Electronic	T8 Magnetic Energy Saver	T12 Electronic	T12 Magnetic Energy Saver	T12 Magnetic Standard	Sample Size
LPD < 0.7	80.3%	17.8%	1.5%	0.0%	0.4%	40
LPD 0.7-0.79	96.0%	0.9%	0.8%	2.3%	0.0%	38
LPD 0.8-0.89	96.5%	0.1%	1.1%	2.2%	0.1%	47
LPD 0.9-0.99	89.8%	0.0%	3.4%	5.9%	1.0%	64
LPD 1.0-1.09	97.5%	0.1%	0.2%	1.2%	1.0%	86
LPD 1.1-1.19	91.7%	3.6%	2.0%	2.0%	0.5%	75
LPD 1.2-1.29	86.4%	9.7%	0.7%	2.0%	1.3%	73
LPD 1.3-1.39	56.6%	2.3%	2.2%	31.9%	6.9%	42
LPD 1.4-1.49	64.3%	1.5%	3.1%	24.2%	6.9%	41
LPD 1.5-1.59	74.0%	9.4%	2.0%	11.8%	2.7%	35
LPD 1.6-1.79	87.1%	1.1%	3.4%	6.9%	1.4%	33
LPD > 1.8	29.6%	4.3%	1.4%	25.1%	39.6%	53

Table 25: Percentage of Lighting Connected Load with Ballasts within LPD Ranges among Office Spaces

Table 26 shows the percentage of the lighting connected load of each ballast type within LPD bins for 'Retail, showroom' spaces. The retail spaces utilizing a higher percentage of T12 Magnetic Standard ballasts tend to have a higher LPD. Those spaces with lower LPDs tend to utilize more T8 electronic ballasts. In most LPD bins either T12 or T8 lamps with electronic ballast tend to make up the larger percentage of connected load.

Installed LPD Bins	T8 Electronic	T8 Magnetic Energy Saver	T12 Electronic	T12 Magnetic Energy Saver	T12 Magnetic Standard	Sample Size
LPD < 1.0	81.1%	0.1%	3.1%	12.3%	3.4%	17
LPD 1.0-1.19	86.0%	0.0%	11.2%	0.1%	2.7%	12
LPD 1.2-1.39	85.2%	1.8%	10.1%	2.8%	0.0%	19
LPD 1.4-1.59	65.0%	6.5%	13.5%	8.4%	6.6%	37
LPD 1.6-1.79	45.6%	8.2%	19.9%	17.2%	9.1%	23
LPD 1.8-1.99	76.4%	0.7%	0.3%	20.0%	2.4%	17
LPD 2.0-2.19	1.2%	0.0%	0.0%	43.2%	55.5%	18
LPD > 2.2	34.5%	16.3%	0.1%	18.2%	30.9%	36

Table 26: Percentage of Lighting Connected Load with Ballasts within LPD Ranges among Retail Spaces

Table 27 shows the percentage of the lighting connected load of each ballast type within LPD bins for 'Classroom' spaces. It can be seen that classroom spaces with higher LPDs utilize more T8 lamps with magnetic energy saver ballasts and T12 lamps with magnetic standard ballasts than those classroom spaces with low LPDs.

Installed LPD Bins	T8 Electronic	T8 Magnetic Energy Saver	T12 Electronic	T12 Magnetic Energy Saver	T12 Magnetic Standard	Sample Size
LPD < 0.8	83.1%	0.0%	0.2%	10.3%	6.4%	30
LPD 0.8-0.99	80.2%	0.1%	4.4%	13.2%	2.1%	52
LPD 1.0-1.19	86.0%	0.0%	11.2%	0.1%	2.7%	66
LPD 1.2-1.39	85.2%	1.8%	10.1%	2.8%	0.0%	79
LPD 1.4-1.59	65.0%	6.5%	13.5%	8.4%	6.6%	73
LPD 1.6-1.79	45.6%	8.2%	19.9%	17.2%	9.1%	30
LPD > 1.8	54.2%	7.5%	0.2%	20.4%	17.6%	54

Table 27: Percentage of Lighting Connected Load with Ballasts within LPD Ranges among Classroom Spaces

Lighting Controls

This section of the report contains the results from the analyses of the lighting controls in the spaces of the buildings. Figure 64 shows the percentage of spaces using occupancy sensors by space type.

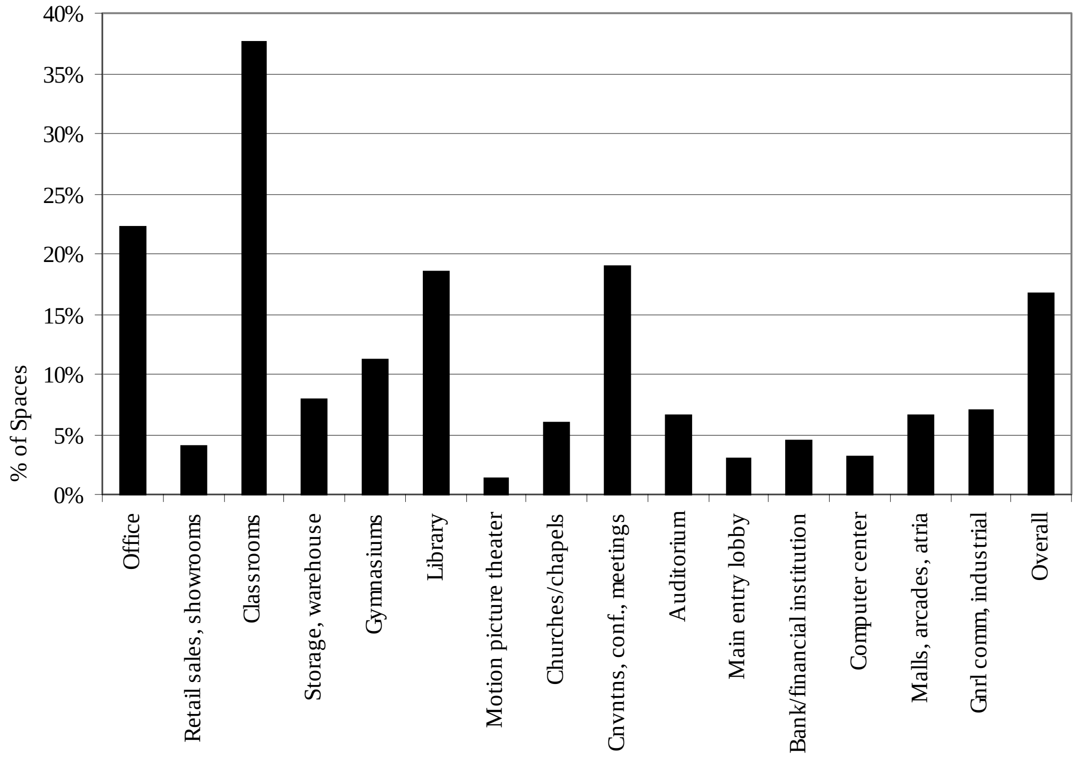

Figure 64: Percentage of Spaces with Occupancy Sensors by Space Type

Supporting the finding identified in the original baseline report that schools have the lowest average lighting ratio of 0.65 is the current finding that classrooms utilize occupancy sensors more frequently than the other spaces. Recall that these can be school, church, and/or community center classrooms. This prevalent utilization of the sensors in classrooms is a practical application because of the varying occupancy throughout the day and into the night. They are especially effective if the school does not conduct nighttime lighting sweeps to turn out the lights.

Among the known space types, office spaces follow classrooms in the percentage of the spaces controlled with occupancy sensors. Occupancy sensors were present in approximately 22% of the office spaces surveyed. It was observed on site that open area offices are less likely than closed individual offices to have the lighting systems controlled by occupancy sensors. Whether this is a decision based on technology limitations or unwillingness to install them in an area occupied by multiple persons was not determined during the on-site or telephone survey.

Several spaces have low utilization of occupancy sensors for explainable reasons. It was found that about 8% of storage/warehouse spaces implement occupancy sensors. This is understandable because of the long re-strike time for high intensity discharge lamps that are often installed in warehouses. Retail/showrooms depend on quality light with a high color-rendering index to showcase product and tend to not use occupancy sensors to ensure continuous illumination.

However, it was found that 8.21% of retail spaces do utilize stepped daylighting to take advantage of daylight and conserve energy. It was observed during some on-site visits that some retail institutions in California have incorporated this technology into nearly all of their new retail buildings. Security issues at banks and financial institutions are reason enough to ensure continuous illumination of the workspace and thus application of occupancy sensors is not typical.

Other than spaces where safety or technological concerns prohibit the use of the occupancy sensors as described above, there appears to be potential to increase the quantity of spaces that have occupancy sensors. As evident in Table 28, which shows the percentage of spaces with each lighting control type by space type, there is potential to expand the application of the other lighting controls as well. Where over 16% of the spaces have occupancy sensors, less than one percent of the spaces has any other advanced lighting control. Even though the saturation of advanced lighting controls is low overall, nearly all types of advanced controls were found in at least one of the office spaces.

Continuous dimming through daylight harvesting is the second most commonly utilized advanced lighting system. Overall, 0.96% of spaces employ this technology, while 2.4% of office spaces utilize the same technology.

Space Type	Occupancy Sensors	Continuous Dimming Daylight	Stepped Dimming Daylight	Lumen Maintenance	Combined Occ.Sensor and Daylight	Combined Occ.Sensor and Lumen Maint	Combined Daylighting and Lumen Maint.	Overall	Sample Size
Office	22.2%	2.41%	0.70%	0.16%	0.92%	0.52%	0.00%	24.22%	662
Retail sales, showrooms	4.0%	0.23%	8.21%	0.00%	0.00%	0.00%	0.00%	12.42%	187
Classrooms	37.7%	0.00%	0.07%	0.00%	0.32%	1.84%	0.19%	39.84%	387
Storage, warehouse	8.0%	0.00%	0.43%	0.00%	0.74%	0.00%	0.00%	9.12%	134
Gymnasiums	11.1%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	11.13%	75
Library	18.5%	0.78%	0.98%	0.00%	0.59%	2.36%	0.00%	21.07%	75
Motion picture theater	1.3%	0.00%	0.00%	0.87%	0.00%	0.00%	0.00%	2.17%	49
Churches/chapels	6.0%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.95%	35
Cnvntns, conf., meetings	19.0%	0.00%	0.00%	0.00%	6.87%	0.00%	0.00%	25.83%	73
Auditorium	6.5%	0.00%	0.00%	4.10%	0.00%	0.00%	0.00%	10.60%	34
Main entry lobby	3.0%	1.72%	0.46%	1.44%	0.00%	0.00%	0.00%	6.19%	103
Bank/financial institution	4.5%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.47%	20
Computer center	3.1%	0.47%	0.00%	0.00%	0.47%	3.77%	0.00%	7.38%	44
Malls, arcades, atria	6.5%	0.00%	2.17%	0.00%	0.00%	0.00%	0.00%	8.66%	9
Gnrl comm, industrial	7.0%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.00%	15
Overall	**16.73%**	**0.96%**	**0.89%**	**0.23%**	**0.65%**	**0.53%**	**0.02%**	**19.09%**	**2,329**

Table 28: Percentage of Spaces with Lighting Control Type by Space Type

Figure 65 again illustrates the finding that all lighting controls other than occupancy sensors are rarely used to reduce lighting demand and energy consumption in the spaces. It is evident in the graph that schools utilize occupancy sensors most frequently followed by offices, retail, and then public assembly. We can also observe the finding that stepped daylighting is the second most utilized advanced lighting control in retail establishments.

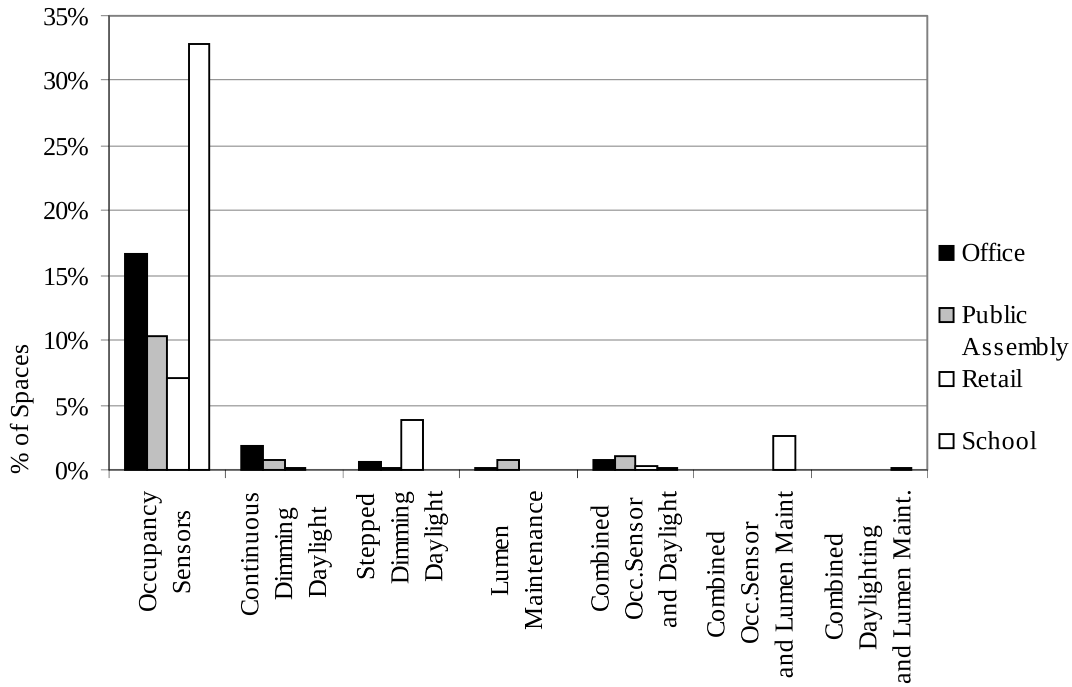

Figure 65: Percentage of Spaces with Lighting Control Type by Building Type

Table 29 shows the percentage of lighting connected load with lighting control types by space type. Again it can be seen that occupancy sensors are the most dominant type of lighting control. However, it should be noted that occupancy sensors control approximately 12% of the total lighting connected load, indicating that the majority of lighting is controlled manually. With 11.6% of the total connected load being controlled in 16.7% of the surveyed spaces, it can be determined that a small proportion of the lights in the spaces are controlled with occupancy sensors. Nineteen percent of the lighting connected load in retail spaces is controlled by stepped dimming daylight systems.

Space Type	Occupancy Sensors	Continuous Dimming Daylight	Stepped Dimming Daylight	Lumen Maintenance	Combined Occ.Sensor and Daylight	Combined Occ.Sensor and Lumen Maint	Overall	Sample Size
Office	17.1%	0.6%	0.1%	0.0%	0.4%	0.4%	18.6%	662
Retail sales, showrooms	0.4%	0.3%	19.1%	0.0%	0.0%	0.0%	19.9%	187
Classrooms	38.9%	0.0%	0.0%	0.0%	0.0%	3.6%	42.6%	387
Storage, warehouse	10.8%	0.0%	0.5%	0.0%	0.9%	0.0%	12.3%	134
Gymnasiums	4.6%	0.0%	0.0%	0.0%	0.0%	0.0%	4.6%	75
Library	8.1%	0.5%	1.0%	0.0%	0.1%	1.6%	11.3%	75
Motion picture theater	0.5%	0.0%	0.0%	0.7%	0.0%	0.0%	1.2%	49
Churches/chapels	5.4%	0.0%	0.0%	0.0%	0.0%	0.0%	5.4%	35
Cnvntns, conf., meetings	12.7%	0.0%	0.0%	0.0%	5.4%	0.0%	18.1%	73
Auditorium	2.3%	0.0%	0.0%	3.6%	0.0%	0.0%	5.8%	34
Main entry lobby	3.5%	0.3%	0.9%	0.2%	0.0%	0.0%	4.9%	103
Bank/financial institution	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	1.2%	20
Computer center	0.3%	0.1%	0.0%	0.0%	0.3%	4.4%	5.1%	44
Malls, arcades, atria	34.1%	0.0%	0.3%	0.0%	0.0%	0.0%	34.4%	9
Gnrl comm, industrial	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	15
Overall	**11.6%**	**0.4%**	**5.8%**	**0.1%**	**0.3%**	**0.6%**	**18.7%**	**2,329**

Table 29: Percentage of Lighting Connected Load with Lighting Control Type by Space Type

Figure 66 illustrates the percentage of lighting connected load that utilizes each of the lighting control types by building type. The figure further illustrates which space types are utilizing a specific lighting control. Observed from the figure is that classrooms utilize occupancy sensors and lumen maintenance controls more frequently and that retail spaces utilize stepped day lighting more frequently than the other spaces. Office spaces are the only space type applying the majority of advanced controls in at least a few of the spaces surveyed.

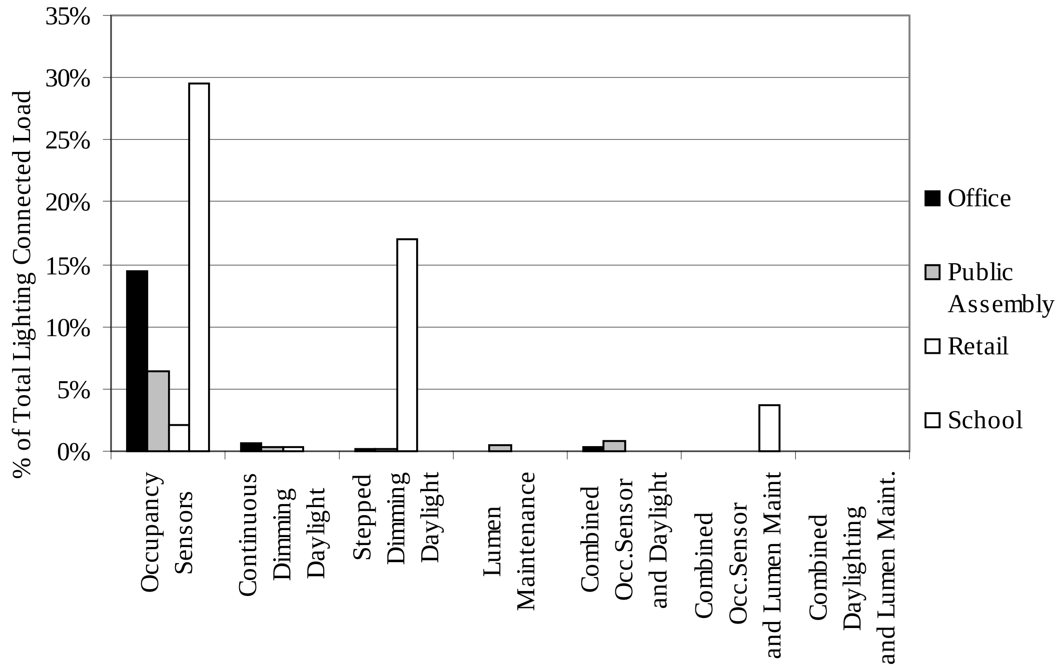

Figure 66: Percentage of Lighting Connected Load with Lighting Control Type by Building Type

Table 30 shows the percentage of the lighting connected load using lighting controls within LPD bins for 'Office-other' spaces. Not surprisingly, among those office spaces with lower LPDs, a larger percentage of their connected lighting load is controlled by occupancy sensors or other advanced controls than those with higher LPDs.

Installed LPD Bins	Occupancy Sensors	Continuous Dimming Daylight	Combined Occ.Sensor and Daylight	Combined Occ.Sensor and Lumen Maint	Sample Size
LPD < 0.7	14.3%	1.8%	0.0%	0.0%	42
LPD 0.7-0.79	3.6%	0.0%	0.0%	0.0%	40
LPD 0.8-0.89	21.4%	0.0%	0.0%	0.0%	47
LPD 0.9-0.99	24.6%	0.2%	0.0%	0.0%	64
LPD 1.0-1.09	21.6%	0.3%	0.0%	0.6%	88
LPD 1.1-1.19	19.8%	1.1%	2.6%	2.1%	77
LPD 1.2-1.29	18.8%	2.5%	0.0%	0.0%	78
LPD 1.3-1.39	14.5%	0.0%	0.0%	0.0%	45
LPD 1.4-1.49	21.5%	0.0%	0.7%	0.0%	47
LPD 1.5-1.59	18.2%	0.0%	0.0%	0.0%	39
LPD 1.6-1.79	6.0%	0.0%	0.0%	0.0%	34
LPD > 1.8	16.9%	0.1%	0.7%	0.0%	61

Table 30: Percentage of Lighting Connected Load with Lighting Controls within LPD Ranges among Office Spaces

Table 31 shows the percentage of the lighting connected load using lighting controls within LPD bins for 'Retail sales, showrooms' spaces. Here we can see the LPD ranges for the retail establishments that take advantage of daylight harvesting using stepped dimming controls. The type of retail establishments that utilize the stepped dimming controls are big box retailers. In contrast to the more popular control, occupancy sensors, stepped daylighting controls have a higher amount of connected load than do the occupancy sensors.

Installed LPD Bins	Occupancy Sensors	Continuous Dimming Daylight	Stepped Dimming Daylight	Sample Size
LPD < 1.0	0.3%	0.0%	0.0%	17
LPD 1.0-1.19	0.3%	0.0%	0.5%	13
LPD 1.2-1.39	0.4%	0.0%	1.0%	20
LPD 1.4-1.59	1.4%	2.1%	26.4%	40
LPD 1.6-1.79	0.7%	0.0%	35.1%	23
LPD 1.8-1.99	0.0%	0.0%	0.0%	17
LPD 2.0-2.19	0.0%	0.0%	0.0%	19
LPD > 2.2	0.1%	0.0%	26.6%	38

Table 31: Percentage of Lighting Connected Load with Lighting Controls within LPD Ranges among Retail Spaces

Table 32 shows the percentage of the lighting connected load using lighting controls within LPD bins for ‘Classroom’ spaces. Interestingly, the occupancy sensor usage does not seem to be related to the LPD. Using the Title 24 area category method and whole building method of lighting compliance, Title 24 allows 1.6 and 1.4 watts/sqft respectively. The equivalent lighting bins in Table 32, e.g. 1.2-1.79 watts/sqft, are more likely to have occupancy sensors than the LPD bins outside these ranges. This may be the result of designers using lighting control credits to obtain an adjusted LPD that is compliant with standards, using either more fixtures or less efficient fixture combinations.

Installed LPD Bins	Occupancy Sensors	Combined Occ.Sensor and Lumen Maint	Sample Size
LPD < 0.8	55.6%	0.0%	31
LPD 0.8-0.99	36.7%	0.0%	52
LPD 1.0-1.19	27.5%	14.1%	66
LPD 1.2-1.39	59.1%	5.0%	79
LPD 1.4-1.59	52.9%	0.0%	73
LPD 1.6-1.79	51.7%	0.0%	30
LPD > 1.8	23.7%	0.0%	56

Table 32: Percentage of Lighting Connected Load with Lighting Controls within LPD Ranges among Classroom Spaces

8. Summary

The following are some of the key findings of this study:

- As expected, the 1998 Title 24 standards raised the bar for new-building energy efficiency. But buildings built between 1994 and 1998 generally met or exceeded the higher standards. More specifically, these buildings were on average almost 8% more efficient than the 1998 baseline. By contrast, these same buildings were about 14% more efficient than the 1995 baseline. So typical practice led the improvement in standards.
- Under both the new and prior standards, the majority of the savings were in the lighting end use. Relative to the 1998 baseline, the lighting end use had almost 5% of the 8% savings. By contrast, relative to the 1995 baseline, the lighting end use had over 11% of the 14% savings. The remaining savings were about equally split between the cooling and fan end uses.
- Under the new baseline, lighting power density measures account for 4% of the 8% savings, daylight controls account for 0.8% and other lighting controls another 0.7%, for a total of 5.5% of all savings. This includes the interactive effects of the lighting measures. The remaining savings come from motor measures (1.2%) HVAC measures (0.9%), and shell measures.
- About two-thirds of the savings in the cooling end-use are due to HVAC measures. Most of the remaining cooling savings are due to the indirect effect of lighting measures.
- Under the 1998 baseline, most of the savings in the fan end use are due to motor measures.

The report also provides a detailed analysis of lighting technologies by type of space. Some key findings are:

- Lighting controls are connected to less than 20% of the total connected lighting load.
- Fluorescent fixtures provide 67% of all lighting connected load. 70% of this load is served by T8 lamps and electronic ballasts. But almost 12% of this load is served by T12 lamps and Energy Server ballasts.
- Moreover, incandescent fixtures provide over 13% of all lighting connected load.

These results suggest there is substantial room for expanding the saturation of lighting controls and efficient lighting technologies.