energy design resources

The 2005 update increases the scope of the Title 24 Standards to include unconditioned spaces and outdoor lighting. The revised Standards also increase the efficiencies for envelope, HVAC, lighting and hot water heating.

San Mateo Police Facility, an exemplary Savings By Design building that had 30 percent better energy performance than the 2001 Standards, still exceeds the 2005 Standards by a good margin (23 percent). However, the Standards do affect the building construction practices, add performance verification requirements for lighting and HVAC measures installed, and encourage measures that save peak energy.

# TITLE 24 AND SAVINGS BY DESIGN

## Understanding the Impacts of the 2005 Standards

The 2005 version of California's Energy Efficiency Standards for Residential and Nonresidential Buildings, commonly known as Title 24, went into effect October 1, 2005. Building plans submitted after this date must meet the requirements of these updated Standards, which span envelope, lighting, heating, ventilation and air conditioning (HVAC) and domestic water heating measures.

This publication explores the latest changes to Title 24 and how they relate to the Savings By Design (SBD) program criteria. Savings By Design offers services and incentives to help architects and building owners make cost-effective decisions that improve the energy efficiency of their buildings. To be eligible for SBD design team incentives, a building must use 15 percent less energy than the minimum requirements of Title 24.

To illustrate the effects of the 2005 Standards and SBD program criteria on a building's design and construction, we will consider the San Mateo Police Facility, a high performance building that filed for compliance under the 2001 Title 24 Standards.

## THE SAN MATEO POLICE FACILITY BUILDING

When it came time to replace the City of San Mateo's 45-year old Police Facility, city and police department leaders charged their design team with making it as energy efficient as possible. Leach Mounce Architects and Green Building Studio, an energy efficiency consultant, used an integrated design approach and energy analysis tools to help the City meet these goals.

The energy analysis tools promoted by the Energy Design Resources Web site proved critical to the design development process. Based on the energy savings and cost-effectiveness analysis done using these tools, Green Building Studio recommended a package of measures that would enable the building design to achieve its energy savings goals. While plans for the 43,300-square-foot facility are still undergoing final construction documentation, the completed building is expected to exceed SBD program goals and achieve the LEED Green Building Rating System's Silver certification. Key features are shown in Tables 1 through 3.

| Description | Base Case (Title 24 -2001) | Preliminary Design |
|---|---|---|
| Net Conditioned Area (Sq.ft) | 43,262 | |
| Roof R-value/U-factor | R-19 / 0.057 U-factor | R-19 w. **Cool Roof**/ 0.043 U-factor |
| Exterior Wall R-value/U-factor | R-11/ 0.189 U-factor | **R-19**/ 0.145 U-factor |
| Window Type | Dbl Pane, Lt Tint (Non-North): Dbl Pane, Clear (North) | |
| U-factor (including frame) | 0.81 | **0.29** |
| Solar Heat Gain Coefficient (SHGC) | 0.61 (North)<br>0.41 (Non-North) | **0.38**<br>**0.38** |
| Window Area (Sq.ft) | 5,529 (20.3% WWR) | |
| Skylight Area (Sq.ft) | 177 Sq.ft | |

*TABLE 1 — ARCHITECTURAL SYSTEM FEATURES*

| Description | Base Case (Title 24 -2001) | Building Design |
|---|---|---|
| Lighting Power Density (LPD) | | |
| Office Spaces | 1.3 W/Sq.ft | **0.86** W/Sq.ft |
| Garage | Not covered by 2001 T24 | **0.15** W/Sq.ft |
| Lighting Controls | | |
| Occupancy Sensors | Not required, but compliance credit given for sensors in offices, storage spaces. | **Installed in all offices, storage rooms and ancillary spaces** |
| Daylighting Controls | Not required, but compliance credit given for sensors in daylit spaces. | **Installed in all perimeter office spaces, and core spaces with skylights** |

*TABLE 2 – LIGHTING SYSTEM FEATURES*

| Description | Base Case (Title 24 -2001) | Building Design |
|---|---|---|
| HVAC System Type | Packaged DX,<br>constant air volume | Packaged DX,<br>**variable air volume** |
| RTU Cooling Equipment Efficiency (EER)<br><br>ACU Split Units Cooling Equipment Efficiency (EER) | 9.2 EER air-cooled<br><br>10.3 EER | **14 EER** evaporative condensers units 1 and 2<br><br>**12 EER** units 1 & 2;<br>EER 12.1 EER unit 3 |
| Motor Efficiency | High efficiency | **Premium efficiency** |
| Heating Boiler Efficiency | 75% Efficient Gas Fired Boiler | **93% efficient Condensing Boiler** |
| Garage Ventilation | Not covered by 2001 Title24 | **CO sensor based ventilation controls** |

*TABLE 3 — HVAC SYSTEM FEATURES — FINAL DESIGN*

This combination of measures produced an overall energy savings of slightly more than 30 percent compared to a design that meets the minimum requirements of the 2001 Title 24 Standards, as shown in FIGURE 1.

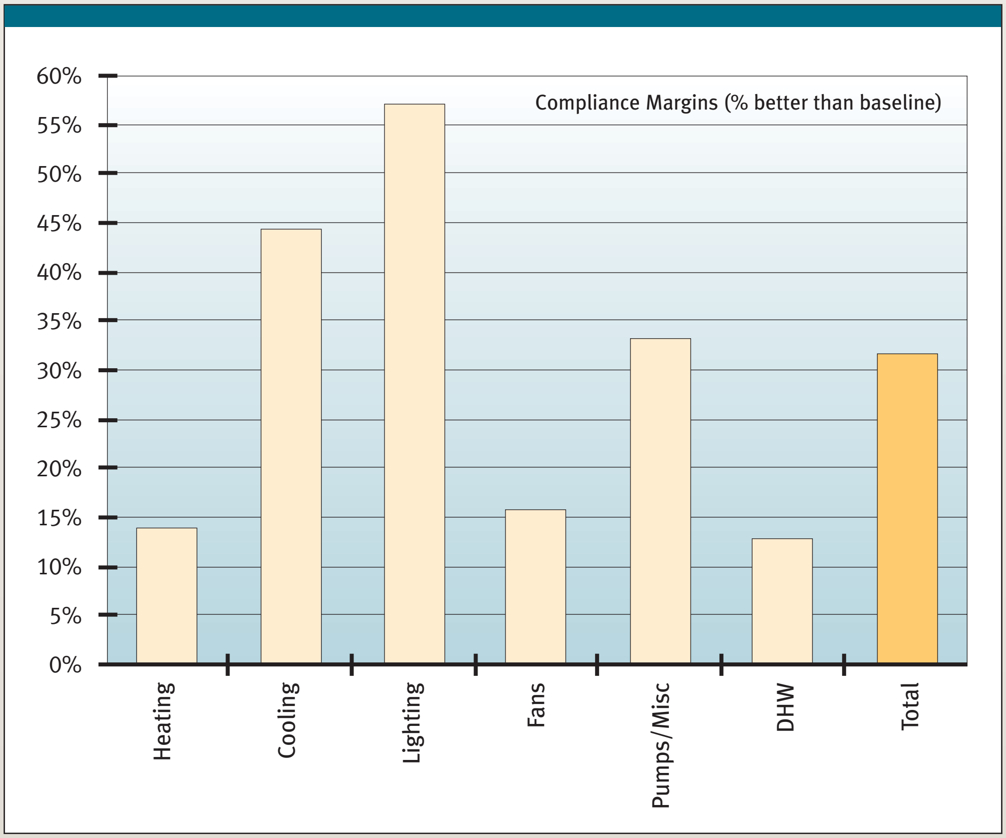


*FIGURE 1: COMPLIANCE MARGINS COMPARED TO 2001 TITLE 24 STANDARDS*

## 2005 TITLE 24 CODE CHANGES

The 2005 Title 24 Standards introduced various changes to the envelope, mechanical and lighting requirements for nonresidential buildings. Some are slight alterations of existing measures, while others make significant changes to the way the Standards value energy efficiency.

This section explores a few of the more notable changes introduced in 2005.

### Expanded Scope

A mandate from the California legislature led to an expansion of the scope of the Standards to include an additional space type and an additional application type: unconditioned buildings or spaces, and outdoor lighting for buildings. For buildings such as the San Mateo Police Facility, this means that unconditioned garages and outdoor lighting are now regulated by the Standards, whereas they were not before.

### Time Dependent Valuation (TDV)

The basis of the space conditioning energy budget calculations for the standard and proposed building has been changed to a Time Dependent Valuation model. This model values on-peak electricity consumption higher than off-peak consumption. On-peak consumption occurs on hot summer afternoons when electricity demand is high, excess capacity is low, and electricity prices are highest. This substantially increases the importance of measures that reduce peak electricity consumption relative to measures that affect energy use in off-peak periods.

In previous versions of Title 24, energy use estimates had a constant value regardless of whether the use was at night or day. TDV assigns higher value for on-peak savings, lower value for off-peak, and is neutral for savings that occur during both on- and off-peak hours.

In previous versions of Title 24, energy use estimates had a constant value regardless of whether the use was at night or day. TDV assigns higher value for on-peak savings, lower value for off-peak, and is neutral for savings that occur during both on- and off-peak hours.

To calculate the space conditioning energy budget, the energy use values for the proposed and standard designs are estimated for each hour. The difference between these values is multiplied by the TDV value for that hour. TDV values vary for each hour of the year and by energy fuel type (electricity, natural gas or propane), California climate zone, and building type (low-rise residential or nonresidential, high-rise residential or hotel/motel). A kilowatt-hour saved during a hot summer weekday afternoon hour is valued much more highly than a kilowatt-hour saved at night or other off-peak hours, as shown in Figure 2.

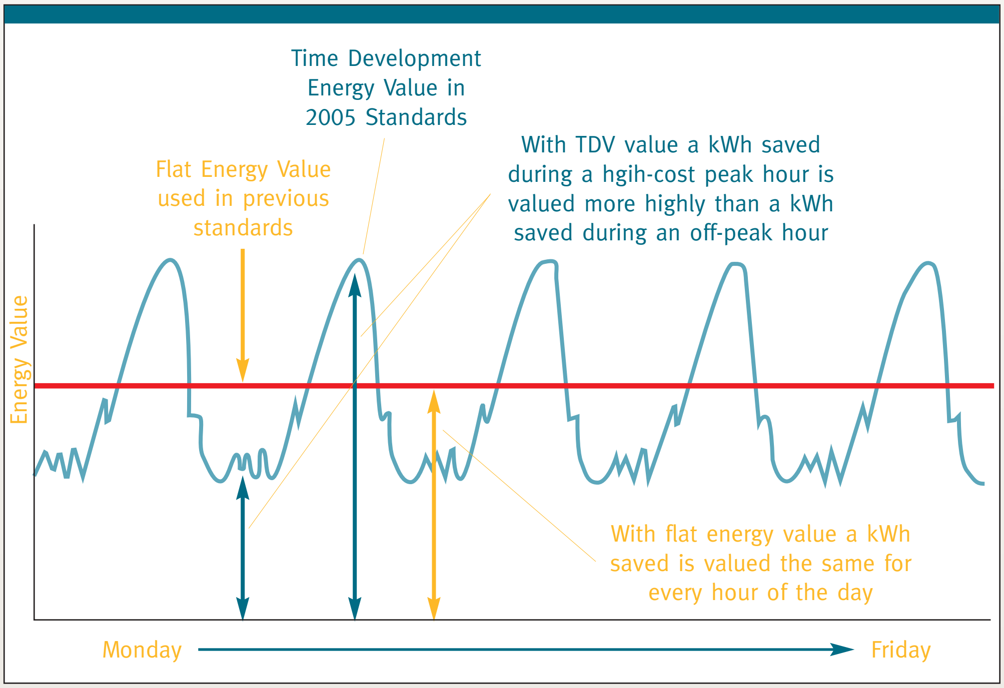


*FIGURE 2: TIME DEPENDANT VALUATION MODEL FOR ELECTRICITY*

## Building Envelope

Cool roofs are now required for nonresidential buildings with low-slope roofs, and are used to establish the standard budget in the performance method of compliance. This takes away the compliance credit one would have gotten in the 2001 Standards for installing a cool roof as an energy efficiency measure.

Ceiling insulation must be placed in direct contact with a continuous roof or drywall ceiling. Insulation placed on top of a T-bar ceiling is no longer recognized by code to have any insulating behavior. This affects construction practices for many nonresidential buildings.

Roofs with metal framing members or a metal deck must have continuous insulation either above the roof deck or between the roof deck and the structural members supporting the roof deck as specified. This affects construction practices for metal-framed buildings, which typically have not been built with continuous insulation. In the past, vinyl-backed fiberglass insulation was draped over the metal purlins before the metal deck was attached with metal screws. This installation method compresses the insulation at the supports, reducing its effectiveness.

For both the performance and prescriptive methods, the 2005 Standards now require you to choose the construction assembly from a set number of assemblies included in Joint Appendix IV. You cannot build up an assembly U-factor for compliance using custom layers as was previously allowed. So you could no longer claim, for example, to have an R-100 insulation layer inside of a 2x8 wood-framed construction.

For both the performance and prescriptive methods, the 2005 Standards now require you to choose the construction assembly from a set number of assemblies included in Joint Appendix IV.

Limiting the choice to a set number of assemblies based on the R-value of continuous insulation and R-value of insulation inside the structural assembly, is in effect an energy efficiency measure, because a metal roof that does not have continuous insulation will perform poorly compared to one that does.

These default construction assemblies also include a greater framing percentage assumption, making the R-value for the same assembly slightly lower than in the previous Standards.

For fenestration, the most substantial change is that the west-facing window area is now limited to no more than 40 percent of the west-facing wall area. Similarly, the overall window area for all orientations is limited to no more than 40 percent of the total wall area.

For fenestration, the most substantial change is that the west-facing window area is now limited to no more than 40 percent of the west-facing wall area. Similarly, the overall window area for all orientations is limited to no more than 40 percent of the total wall area. These prescriptive requirements also form the basis for the standard budget in the performance method. So if the building has more than 40 percent west-facing glass (such as a building with an all-glass façade), it will have worse energy performance than the standard design. It would not comply with the Standards unless other energy efficiency features were included, such as high efficiency air conditioning systems, lighting controls, and so on.

Prescriptive maximum window and skylight U-factors have been slightly changed. However, these changes merely reflect the new National Fenestration Rating Council (NFRC) test procedures, and do not alter which windows or skylights comply with the Standards.

Labeling requirements for fenestration products have been enhanced and clarified. All factory-assembled windows must have NFRC ratings. The NFRC rated U-factor and SHGC values need to be displayed on the windows on a permanent label.

## Lighting Measures

The scope of the Title 24 Standards has been expanded to include outdoor lighting applications and lighting in unconditioned spaces such as parking garages. The lighting load in unconditioned spaces and outdoor lighting applications are prescriptive, but cannot be traded off with other building features.

For interior lighting, allowed lighting power densities for the Whole Building, Area Category and Tailored methods have been reduced from 2001 levels to account for improved lighting technologies. For office spaces, the lighting power density (LPD) is reduced from 1.3 watts per square foot (W/sq.ft) to 1.2 W/sq.ft.

The 2001 Standards provided generous Power Adjustment Factor (PAF) credits for standard occupancy sensors installed in small private offices (0.20), large open-office spaces (0.10), and storage areas (0.60). The 2005 Standards no longer give any performance credits for standard occupancy sensors in any spaces. Instead, if you wish to receive a PAF, you need to use bi-level or multi-level enabled occupancy sensors. These sensors are preconfigured to provide a minimum of three levels of lighting control (high/low/off), and include an optional capability to have a manual-ON control while maintaining an automatic-OFF functionality.

## HVAC Measures

Time Dependent Valuation (TDV) energy, which is most valuable at the hottest times of year, results in a greater importance placed on HVAC efficiency. Thus HVAC systems with a high energy efficiency ratio (EER) that are more efficient during the warmest parts of the year will have a bigger impact than in the previous Standards.

The 2005 Standards also allow the designer to claim compliance credits in the performance method for large air conditioning systems (capacities >135,000 Btu/h) with better than typical efficiency at high temperatures. If the air conditioner is more efficient at higher outdoor dry-bulb temperature than would be predicted from a standard efficiency curve and the EER rating at the ARI test condition (95º F), you can now specify the exact efficiencies of the unit at other temperatures.

Mandatory requirements for demand control ventilation have been expanded from only high occupancy spaces (>40 people per 1,000 sq.ft.) to moderate occupant densities (>25 people per 1,000 sq.ft.). Specifically exempted spaces include classrooms and spaces with unvented food preparation or containing combustion engines without a local exhaust ventilation system.

Prescriptive requirements for HVAC systems have become more stringent. The threshold for variable speed drives controlling fans serving variable air volume (VAV) systems has dropped from greater than 25 horsepower (hp) to 10 hp or greater. Static pressure sensors placement is specified so that controller set point is no greater than one-third the total design fan static pressure. When individual zone boxes are reporting back to a central control, the new Standards require that the static pressure set point be reset until the zone requiring the most pressure has its zone box almost completely open.

Fan motors of series fan-powered terminal units are required to be electronically commutated or have a minimum motor efficiency of 70 percent.

Open cooling towers must be designed so that flow can be turned down to 33 percent of the design flow for the cell. Cooling towers with a combined rated capacity of 900 tons or greater must use propeller fans rather than centrifugal fans.

Chilled and hot water pumping serving more than three coils must be designed for variable flow. Pumps rated more than 5 hp must have variable frequency drives. Chillers and boilers are required to be designed so that equipment can be isolated to not allow flow through equipment when the equipment is shut off.

Small constant-volume duct systems (serving less than 5,000 sq.ft.) with more than 25 percent duct surface area in unconditioned or indirectly conditioned spaces must be sealed. Leakage must not be greater than 6 percent of fan flow, confirmed through diagnostic testing and field verification.

## Acceptance Testing Requirements and Field Verification of Measures

The 2005 Standards introduce a new set of mandatory performance verification criteria called Acceptance Testing Requirements. Acceptance testing is required for lighting and HVAC controls that are prone to incorrect calibration or failure.

The 2005 Standards introduce a new set of mandatory performance verification criteria called Acceptance Testing Requirements. Acceptance testing is required for lighting and HVAC controls that are prone to incorrect calibration or failure. These tests are to be carried out by a "responsible person," who typically would be a licensed architect, engineer, contractor or other person certified to inspect buildings under the Business and Professions Code. Most of these tests do not require third-party verification. Acceptance testing must be completed before the building official issues the certificate of occupancy.

New duct systems in unconditioned spaces are prescriptively required to have tested and field-verified sealed ducts. Typically the installer will test the tightness of ducts and fill out the MECH-5-A acceptance testing form. This measure must also be third-party verified by a certified HERS (Home Energy Rating Service) rater.

## SAN MATEO POLICE FACILITY UNDER THE 2005 STANDARDS

Clearly, the Standards are more stringent than before. Beyond requiring greater efficiency, the changes also affect the way compliance calculations are done in the performance method, as well as the way measures are installed and their performance verified.

How would these changes affect the design of a building such as the San Mateo Police Facility? As seen in FIGURE 3, the as-designed building was 32 percent better than a building that complied with 2001 Title 24 minimum requirements. Under the 2005 Standards, the same design is now 23 percent better than a minimally compliant building, a net reduction in compliance margin of roughly 9 percent. The measures that make the biggest difference in compliance margins are the TDV methodology, envelope construction assembly specification requirements, and lighting measures.

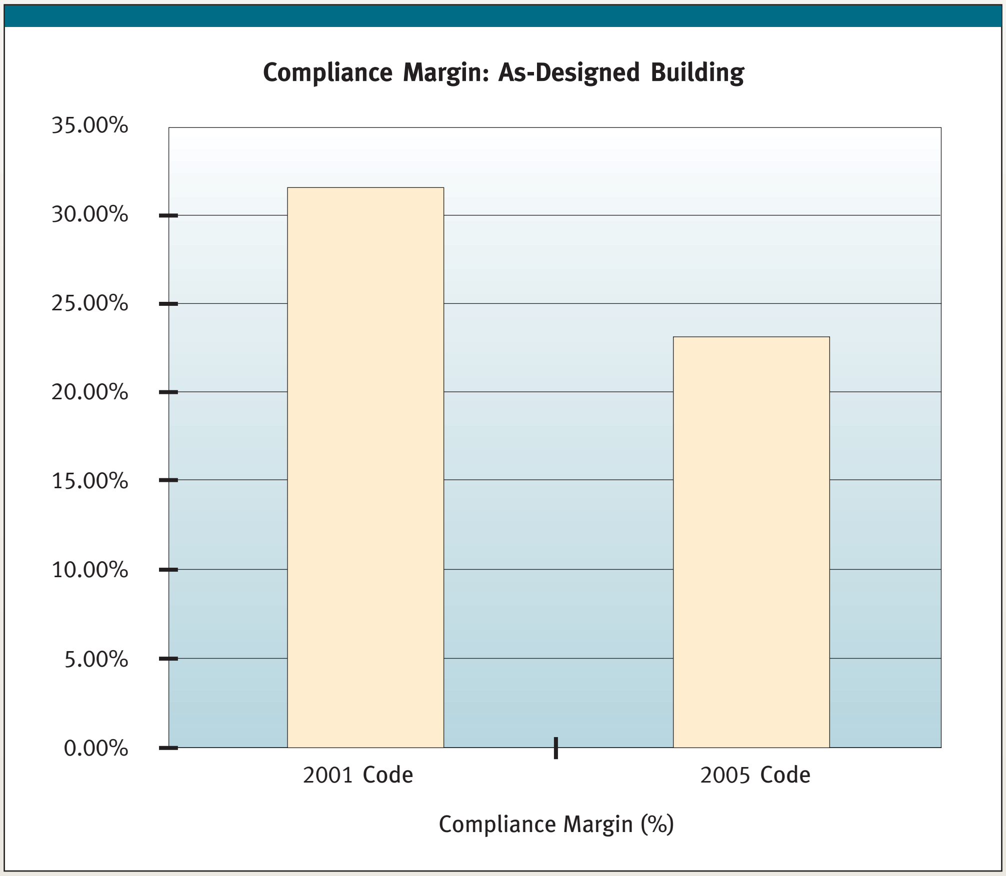


*FIGURE 3: COMPLIANCE MARGIN: AS-DESIGNED BUILDING*

As mentioned previously, you can no longer use a custom-built envelope construction assembly, and instead have to use an assembly from the Joint Appendix of the 2005 Standards. For this building, the closest assembly is a metal-framed 2x6 wall with R-19 cavity insulation and no continuous insulation on the outside. The overall R-value of this assembly is 5.5 (U-factor of 0.183), as compared to the R-value of 6.9 (U-factor of 0.145) as specified in the model under the 2001 Standards. Similarly, the closest construction assembly for a metal-framed flat roof has an overall R-value of 12.5 (U-factor of 0.08) in the 2005 rule-set as compared to an overall R-value of 24.5 (U-factor of 0.04) in the 2001 model.

The 2005 Standards reduce the LPD allowances as well as remove the PAFs for standard occupancy sensors. The credits for daylighting controls (which are installed in most spaces of this building) have been retained from the 2001 Standards.

THE AS-DESIGNED BUILDING WAS 32 PERCENT BETTER THAN A BUILDING THAT COMPLIED WITH 2001 TITLE 24 MINIMUM REQUIREMENTS. UNDER THE 2005 STANDARDS, THE SAME DESIGN IS NOW 23 PERCENT BETTER THAN A MINIMALLY COMPLIANT BUILDING, A NET REDUCTION IN COMPLIANCE MARGIN OF ROUGHLY 9 PERCENT.

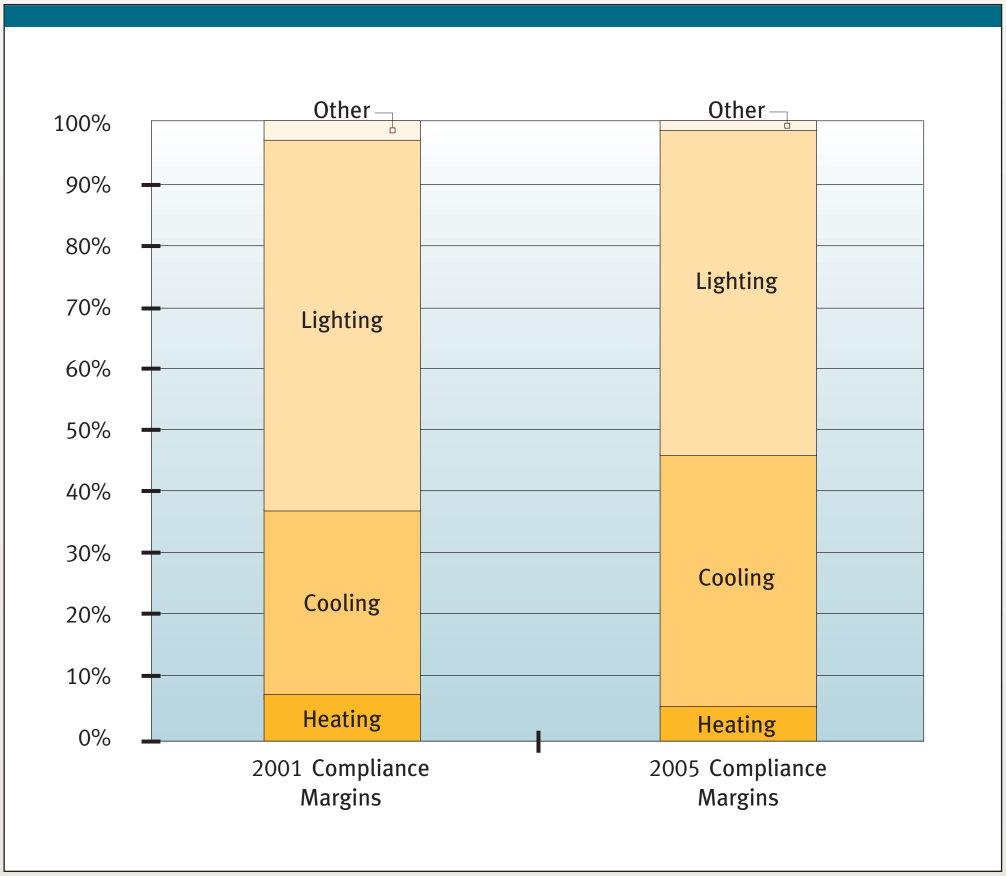


*FIGURE 4: COMPLIANCE MARGINS BY CATEGORY*

Figure 4 shows the difference in the compliance margins by category for the San Mateo Police Facility under both the 2001 and 2005 Title 24 Standards. Each bar shows the relative contribution of each energy use category to the total compliance margin (percentage of energy savings above the Title 24 Standards).

Under the 2001 Standards, for this building lighting energy savings was the largest contributor (about 60 percent), cooling energy savings the next biggest (about 30 percent), while heating was about 7 percent of the total energy savings.

Under the 2005 Standards, lighting is still the largest contributor to savings, but at a slightly lower value of 53 percent. Cooling energy savings is a bigger contributor (41 percent versus 30 percent in 2001), while heating contributes less to savings than under the 2001 Standards (5 percent versus 7 percent in 2001). This is partially due to the TDV requirements in the 2005 Standards, which assign more value to energy used during peak electricity generation periods such as summer afternoons and less value to energy used during off-peak periods such as winter nights.

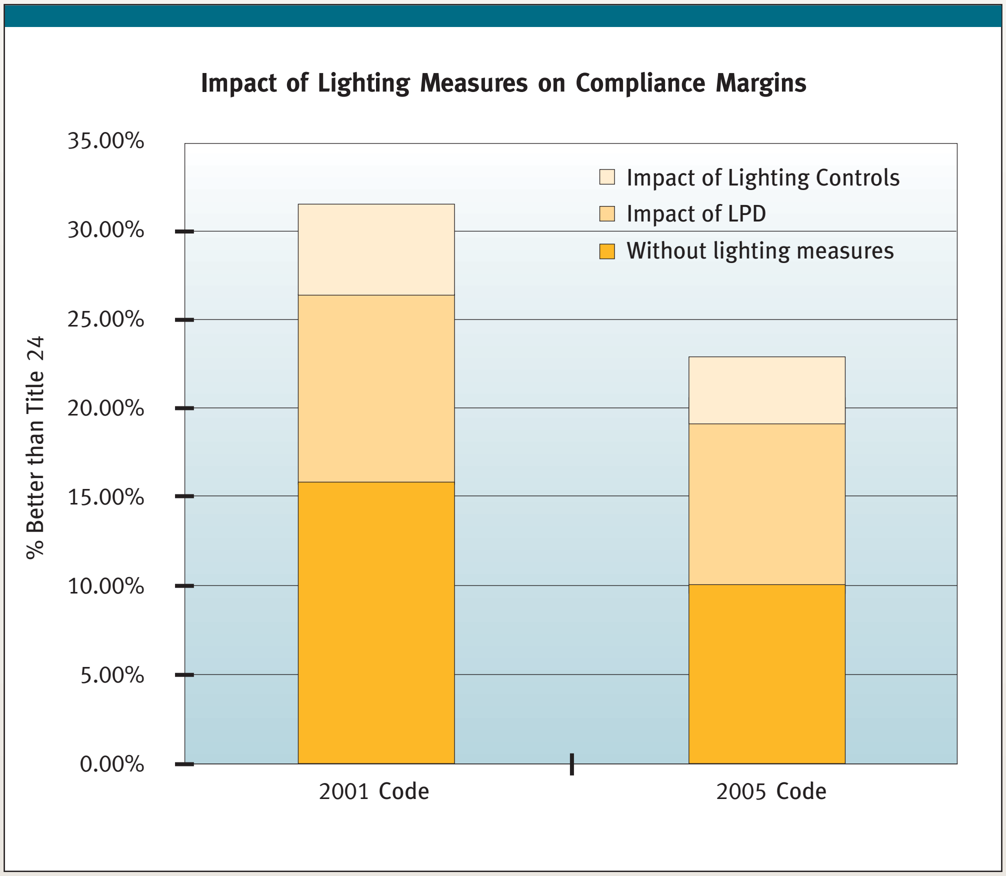


*FIGURE 5: IMPACT OF LIGHTING EFFICIENCY ON COMPLIANCE MARGINS*

As seen in Figure 5, without the reduced LPD of 0.86 W/sq.ft_ and occupancy and daylighting controls, the compliance margin is 16 percent better than code in 2001, but only 10 percent better than code in 2005. At this compliance margin, the building would meet SBD's threshold for owner incentives (10 percent better than code) but would not qualify for design team incentives (15 percent better than code). The reduced compliance margin without lighting controls is due to a combination of factors, including TDV (heating energy is valued less under TDV), the reduced R-values of the proposed construction assemblies, and the new prescriptive requirement for cool roofs.

Thus, to meet the SBD requirement for design team incentives (15 percent better than code) without the use of lighting controls, the building would have to include other energy efficiency measures. Since the climate of San Mateo is mild, and the heating system already quite efficient (93 percent efficient condensing boiler), the savings would have to come from cooling energy and domestic hot water savings. Further, to achieve the compliance margins and energy savings of about 30 percent better than code that would potentially qualify the building for a LEED Silver rating, multi-level enabled automated lighting controls would be essential.

To illustrate this, let's assume that the building designers increase efficiencies as below:

- Increase roof and wall insulation to R-19 insulation in frame with R-10 continuous insulation, and floor insulation of R-10
- Increase the EER of the split DX cooling equipment to EER 14
- Use a condensing boiler for domestic hot water heating (93 percent efficient)
- Use economizers on all air-conditioning units

A combination of these measures added to the existing design of the building (minus the lighting measures) yields an overall compliance margin of 15 percent better than 2005 Title 24. This would enable the building to just meet the requirements of the SBD program for design team incentives. If we then add low LPD (0.86 W/sq.ft_), multi-level enabled occupancy sensors to the office and storage spaces, and daylight-based controls for all areas with windows or skylights, the building achieves a compliance margin of 30 percent better than 2005 Title 24, which would potentially qualify it for a LEED Silver rating.

ENERGY DESIGN RESOURCES (EDR) HAS DEVELOPED A TRAINING MODULE ON THE 2005 TITLE 24 PROVISIONS, AND ONE SPECIFICALLY ON THE OUTDOOR LIGHTING PROVISIONS IN 2005 TITLE 24. BOTH ARE AVAILABLE AT WWW.ENERGYDESIGNRESOURCES.COM

## CONCLUSION

The 2005 Standards change the way energy efficiency is evaluated, with Time Dependant Valuation (TDV) as one of the main underlying changes. With TDV, measures that save energy on-peak (high EER) will get more energy savings, resulting in a greater compliance margin than would measures that save energy off-peak.

The Standards also change the way envelope assemblies and fenestration are modeled in the performance calculation software, increase lighting efficiency requirements through lower LPD values, and provide progressive PAFs for multi-level lighting controls instead of simple occupancy sensors. The scope of the Standards has also increased: they now also govern unconditioned and outdoor lighting spaces.

The Standards introduce a series of Acceptance Testing measures that will help ensure that the HVAC and lighting systems are installed correctly and will achieve their intended savings. While this is not a direct increase in efficiency, it will have the net effect of improving building performance. Similarly third-party verification of measures such as duct sealing will help ensure that the building achieves its stated energy efficiency goals.

For an exemplary building like the San Mateo Police Facility, these changes would not make it unduly difficult to meet the SBD goals. However, the Standards will have an impact on some construction practices (such as continuous insulation in the envelope), will change the way energy efficiency measures are valued (with more impact for peak-saving measures), and will promote the use of the latest lighting and HVAC controls technology for most buildings that just met the SBD program goals under the previous Standards.