How to Simulate Energy Savings of Non-Residential New Construction Savings by Design Program in California

Zhiqin Zhang and Amit Kanungo, DNV GL
Peter Jacobs, Building Metrics Inc.

ABSTRACT

In California, EnergyPro is a state-approved energy simulation tool specifically to demonstrate performance compliance for new construction projects. This tool follows the Title 24 Alternative Calculation Method (ACM) Manual to determine the time dependent valuation of energy of standard and proposed buildings. EnergyPro also has been widely adopted by the Investor Owned Utilities (IOUs) to simulate energy savings of new construction projects under the Savings By Design (SBD) program. The SBD program uses Title 24 and Title 20 or industry standard practice as its reference to determine energy savings. The differences between these two EnergyPro applications have contributed significant inconsistencies to the implementation and evaluation of the SBD program. At present, there is no document available to guide energy savings simulations for the SBD program. This void has led to confusion and discrepancies among program implementers and applicants.

This paper clarifies the differences between the compliance and non-compliance applications as well as their impacts on energy savings simulations. Additionally this paper proposes a SBD simulation to estimate the energy savings of the SBD program. This method generates standard and proposed DOE2.1E input files by combining the input files created by EnergyPro and it runs both SBD input files with the DOE2.1E engine in the command prompt. A new construction example project is used to illustrate the application of the proposed SBD run. While these discussions focus on the California SBD program, they can provide useful insights for managers of new construction programs in other jurisdictions.

Introduction

Savings By Design (SBD) is California's nonresidential new construction energy efficiency program, administered statewide and funded by utility customers through the Public Purpose Programs surcharge applied to gas and electric services. SBD is administered by four IOUS: PG&E, SCG, SCE, and SDG&E. SBD programs represent a significant portion of the statewide energy savings portfolio. According to the 2010-2012 Custom Program Evaluation Research Plan (Itron and KEMA, 2011), in 2010, the total energy savings claims of the SBD programs were 132.7 GWh, 28 MW, and 1.64 million therms. These savings claims represent 3.4%, 4.0%, and 3.7% of the electric energy, electric demand and gas therms savings claim for 2010 in the statewide portfolio.

SBD adopts two performance-based design approaches: the Whole Building Approach and the System Approach (CPUC, 2014). The Whole Building Approach requires a comprehensive tool capable of conducting hourly energy simulations of the proposed new building design. This allows comparison of interactive effects of different energy efficiency measures. The Whole Building Approach is suitable for large, complex projects or for projects containing innovative energy design features. The System Approach uses a simple, performance-based modeling tool to quickly estimate typical energy savings of recommended measures. The tools adopted by both approaches utilize the Title 24, Part 6 (CEC, 2008a) and/or Title 20 (CEC, 2010) or industry standard practices as a reference baseline for comparison.

The California Energy Commission (CEC) approved EnergyPro and eQUEST to demonstrate that new construction meets Title 24 mandatory design and maximum energy budget requirements. Both tools conduct compliance analyses strictly following the Nonresidential Alternative Calculation Method (ACM) Approval Manual (CEC, 2008b). This manual specifies the CEC approval process for nonresidential compliance software and defines the assumptions and procedures of the reference method against which the compliance tool will be evaluated. In accordance with the ACM Approval Manual, EnergyPro uses the Title 24 performance compliance module (referred to as a compliance run) to simulate the time dependent valuation (TDV) annual energy consumptions of both the standard and proposed buildings. TDV, as the name implies, values energy differently depending on the time it is used. Compared to source energy, the TDV energy consumption more closely reflects the market for electricity, gas, propane and other energy sources. To comply with Title 24, each regulated new construction project must consume less TDV energy than the corresponding standard building.

Although EnergyPro is approved for compliance analysis purposes, it has also been widely used to estimate SBD project energy savings and incentives. The TDV energy savings percentage compared to the standard building is used to determine electricity and natural gas incentive rates (CPUC, 2014). To be eligible for SBD incentives, the TDV energy consumption of the proposed design must be at least 10% less than that of the standard design. The higher the percentage, the higher the incentive rate is. This design reflects the increasing difficulty to achieve deeper energy-efficiency improvements. For eligible projects, another module, named NR Performance non-compliance run (referred as non-compliance run)is used to estimate annual building energy consumptions and gross energy savings. Both compliance and non-compliance runs create standard and proposed building description input files, and both runs use the DOE-2.1E engine to conduct hourly energy simulations.

Considering the differences between building code compliance analysis and SBD building energy savings analysis, it is not appropriate to directly use a compliance tool for SBD program energy savings purpose. In practice, the compliance run has been loosely used by most applicants and implementers to estimate energy savings, which has contributed to significant inconsistencies in the savings estimates. Additionally, the baseline system created by the non-compliance run does not strictly follow the ACM manual. The lack of a modeling document for SBD programs has led to inconsistencies among SBD implementers and applicants.

This paper discusses the difference between the EnergyPro compliance run and non-compliance run and compares their impacts on energy savings estimations. In addition, this paper proposes a SBD run to estimate the energy savings of SBD program. This different run creates new standard and proposed building DOE2.1E input files by combining the input files created by EnergyPro and it uses the DOE2.1E engine to simulate both created SBD input files. We use a sample new construction project to illustrate the proposed SBD run.

Energy Simulation Method

Differences Between Compliance Run and Non-compliance Run

To avoid inconsistency in the energy savings estimations using EnergyPro, it is necessary to clarify the differences between the compliance run and non-compliance run. Figure 1 compares the two simulation runs and describes how they are different in various categories such as run period, weather data, HVAC system type, equipment efficiency, schedules, artificial loads, LPD in unconditioned spaces, LPD in conditioned spaces, and envelope. The artificial loads category covers all internal loads except for space lighting. The categories in the red circle are treated differently in the compliance run and non-compliance run.

	Compliance		Non-compliance	
	Standard	Proposed	Standard	Proposed
Run period	1991	1991	Present	Present
Weather data	CZ	CZ	CZ/custom	CZ/custom
HVAC system type	T-24	As built	As built	As built
Equipment Efficiency	T-24	As built	T-24	As built
Schedules	T-24	T-24	As built	As built
Artificial loads	T-24	T-24	As built	As built
LPD in uncondi. spaces	0	0	As built	As built
LPD in condi. spaces	T-24	As built	T-24	As built
Envelope	T-24	As built	T-24	As built

Figure 1. Comparison between compliance run and non-compliance run for EnergyPro.

Run period. Compliance run uses 1991 calendar year (CEC, 2008b, 2-57) as a fixed calendar, while non-compliance run chooses the current year indicated by the user's computer clock. This difference may lead to only negligible changes to annual kWh and therms savings between the two simulation runs, but it could introduce a significant impact on calculations of the peak demand reduction.

In California, the California Energy Efficiency Protocol (CPUC, 2006) is used to estimate peak demand impact. The guideline establishes peak as it is currently defined in Database for Energy Efficient Resources (DEER). DEER defines peak kW for weather sensitive measures as the average grid-level impact for the measure between 2 pm and 5 pm during the three consecutive weekdays containing the weekday with the hottest temperature of the year. These three days vary by climate zone (J. J. Hirsch, 2006) and the dates are based on a 1991 reference year for defining workdays. If the run period is not 1991 reference year, the peak days selected by EnergyPro could fall into weekends or holidays, leading to a significant discrepancy on peak demand calculations. Therefore, the 1991 reference year should always be used for SBD on-peak demand estimation.

Weather data. California divides the state into 16 climate zones (CZ) and each climate zone has a standard 8,760 hour weather file. Compliance run applies the weather data of the climate zone in which the building is located to both the standard and proposed design. For non-compliance run, there are two options for the user. If custom weather data is provided and selected by the user for simulations, this custom weather data will be used for hourly simulation. Otherwise, standard climate zone weather data will be used. To be consistent among different projects, it is appropriate to use correct climate zone weather data to conduct SBD energy savings simulation.

HVAC system type. The baseline HVAC system types selected by the compliance run and non-compliance run could be totally different. Based on the building type, system type, and proposed heating source, the compliance run selects a standard HVAC system in accordance with Table N2-13 (CEC, 2008b, 2-61), while the proposed HVAC system is based on the user-input HVAC system. In contrast, the non-compliance run always applies the user-input HVAC system in both the standard and proposed buildings. For example, considering a three-story office building with a proposed built-up VAV and gas boiler reheat system, the baseline system in the compliance run will be System 1 – packaged VAV with gas boiler heat system. HVAC system type has a significant impact on HVAC system energy consumption. The difference between the baseline HVAC system types could lead to dramatic differences in energy savings estimate. It is more reasonable to use a Title 24 standard HVAC system in the baseline design so the advanced HVAC system in the proposed design can be credited by SBD program incentives.

Equipment efficiency. Generally speaking, both the compliance run and non-compliance run apply the minimum equipment efficiencies in the standard building and apply user-input efficiencies in the proposed building. The minimum performance rating of each type of HVAC equipment is presented inTitle 24 or Title 20. Because the standard system in the non-compliance run is different from that in the compliance run, the equipment efficiencies in both standard buildings could be different. Clearly, this could lead to differences in energy savings estimate for SBD projects.

Schedules. The schedules section covers operation schedules and setpoint schedules modeling hourly variations in occupancy, lighting power, receptacle power, process load, DHW load, fan stage, and heating and cooling setpoint reset. Compliance run applies Title 24 standard operation schedules in Table N2-8 through Table N2-12 (CEC, 2008b, 2-52) to both the standard and proposed buildings. The type of operation schedule is selected from Table N2-7 (CEC, 2008b, 2-50) based on the selected occupancy type. In contrast, non-compliance run applies user-input schedules to both the standard and proposed buildings. If user-input schedules are not provided, Title 24 standard operation schedules will be selected.

Title 24 provides only one type of standard nonresidential occupancy schedule for all buildings other than retail. However, one size does not fit all and different buildings could have different schedules. The differences in building schedules can have a significant impact on the energy savings, especially for seasonal buildings such as schools and recreation centers where as-built design schedules typically have larger variations. Applying one type of occupancy schedules to all nonresidential buildings could skew SBD energy simulations for those buildings with special schedules. Allowing the user to apply different schedules is consistent with the current SBD program, and can be important for buildings that operate differently from the standard schedules.

Artificial loads. In this paper, the term artificial loads covers receptacle load, occupant load, service water heating, process lighting, and process load, but excludes space lighting, which is discussed separately. Similar to the Schedules, in the compliance run, standard design and proposed design shall use the same Title 24 standard artificial load assumptions based on Table N2-5 or Table N2-6 (CEC, 2008b, 2-34). In the non-compliance run, the standard design and proposed design shall use the identical user-input load assumptions. If users do not input the assumptions, EnergyPro will use the default values. The actual artificial loads could be quite different from the default values. Although the energy consumptions of these artificial loads will cancel each other out, it can impact HVAC energy consumptions if the performance of the standard and proposed HVAC systems is different. To make simulated energy savings closer to actual realized savings, it is reasonable to select actual artificial load values based upon professional judgment or collected information.

LPD in unconditioned spaces. Compliance run simulates unconditioned spaces in the standard building exactly as it does in the proposed building. However, for parking garages, unconditioned commercial and industrial storage spaces, lighting power is set at zero and is excluded in the energy budgets (CEC, 2008b, 2-11). Lighting is still required to meet the prescriptive requirements for these spaces. The non-compliance run, in contrast, will include the standard baseline LPD value and proposed user-input LPD value for these unconditioned spaces in the standard and proposed design, respectively. If lighting control energy efficiency measures are implemented in these unconditioned spaces, the compliance run will not reflect corresponding lighting power savings, but the compliance run will. Therefore, the compliance run could underestimate energy savings for buildings with such unconditioned spaces.

LPD in conditioned spaces. The compliance run and non-compliance run use the same approach to the LPD in conditioned spaces (Title 24 for standard, As-built for proposed) and this approach is appropriate for SBD simulations. If lighting compliance is not performed, the standard design lighting power level is the same as the proposed design lighting level based on Table N2-5 (CEC, 2008b, 2-34). Otherwise, the standard design lighting level is determined from either the whole building or area category method based on Table N2-6 (CEC, 2008b, 2-35) and the proposed lighting level is based on the user-input values. Note that if a user chooses to input a custom lighting LPD value to the standard design, this value will apply to the standard building no matter which run is selected. This option should be allowed only if the target occupancy area is not regulated by Title 24, for example, an operating room in a hospital.

Envelope. Generally speaking, both the compliance run and non-compliance run treat the envelope in a similar way. The determination of the standard and proposed envelope design is appropriate for SBD simulations. The standard envelope design is selected based on class of building, type of construction, climate zone and other factors in accordance with Title 24. The thermal performance of the selected standard envelope has been tabulated in advance. The user needs to input the proposed envelope design information into the model.

SBD Energy Savings Simulation

Building energy code compliance analysis is different from SBD energy simulation. The former is to ensure that the TDV energy consumption of the proposed design will not exceed that of a reference building under standard operations including standard schedules and artificial loads. The latter measures the energy performance improvement between the proposed building and a reference building under actual operating conditions. This difference could lead to significant discrepancies in building energy simulations.

The comparisons above show that neither of the standard building models created by the compliance and non-compliance run is appropriate for use as the baseline model for the SBD program. The compliance run uses Title 24 standard operation schedules and control setpoints in both the baseline and post-retrofit models, even though these schedules may not reflect actual building operation and control. The reasonable schedules used in both the standard and proposed design for SBD simulations should be the building's as-built design schedules. As-built design schedules are synonymous with "as planned" (full design occupancy and typical planned building schedules). As-built is different from the standard or reference Title 24 schedules. The as-built schedules are also different from the "as-observed" schedules, which can only be collected during evaluation and used for calibration purposes.

	Compliance		**Non-compliance**		**Proposed SBD**	
	Standard	Proposed	Standard	Proposed	Standard	Proposed
Run period	1991	1991	Present	Present	1991	1991
Weather data	CZ	CZ	CZ/custom	CZ/custom	CZ	CZ
HVAC system type	T-24	As built	As built	As built	T-24	As built
Equipment efficiency	T-24	As built	T-24[1]	As built	T-24	As built
Schedules	T-24	T-24	As built	As built	As built	As built
Artificial loads	T-24	T-24	As built	As built	As built	As built
LPD in uncondi. spaces	0	0	As built	As built	As built	As built
LPD in condi. spaces	T-24	As built	T-24	As built	T-24	As built
Envelope	T-24	As built	T-24	As built	T-24	As built

Note 1: Equipment minimum efficiency associated with the as-built system instead of the T-24 system

Figure 2. Proposed new SBD energy savings simulation method.

To be consistent among individual projects and with DEER peak definition, a 1991 reference year and California climate zone weather data should be used for SBD energy savings and peak demand reduction calculations. An advanced HVAC system design is normally associated with additional capital cost, with the benefit of energy. To encourage and incentivize customers to go the extra mile on HVAC system design, it makes more sense to use standard HVAC system design in the SBD standard building. The artificial loads in the actual building may be quite different from the Title 24 standard schedules. Considering that artificial loads contribute to the space heat gains, it is preferable to use actual artificial loads instead of default loads in the SBD standard and proposed design. Energy savings credit should be given to energy efficient lighting measures for parking garages and unconditioned commercial and industrial storage spaces because this is consistent with the current SBD program.

Based on the considerations above, this paper proposes a separate SBD run to simulate energy savings of the SBD program. This SBD method is compared with the compliance run and non-compliance run in Figure 2. For the proposed SBD energy run, mandatory requirements by Title 24and/or Title 20 must be met in the standard and proposed design. The proposed SBD run ensures energy simulations are consistent with the SBD program and among different SBD projects.

Workaround of the SBD Run

At present, EnergyPro cannot directly conduct the proposed SBD run by creating the proposed SBD standard and proposed input files. This paper introduces a workaround procedure to simulate energy savings following the SBD run proposed above.

When first developing a building model for program eligibility, the compliance run of EnergyPro should be used to estimate the baseline and post TDV energy use. The post-retrofit TDV energy should be at least 10% lower than the baseline TDV energy to be eligible for SBD incentives. For eligible projects, the next step is to switch from the compliance run to the non-compliance run. At this point, as-built design schedules and artificial loads would need to be manually input into EnergyPro. These inputs would be applied to both the standard and proposed input files of the non-compliance run. When running the compliance run and the non-compliance run together, EnergyPro will create compliance and non-compliance standard and proposed input files automatically. The following step is to manually create the SBD standard and proposed input files by combining the two parts. One part is the run period, weather data, HVAC system, and equipment efficiency from the compliance run input files. The other part is the schedules, artificial loads, and LPD in unconditioned spaces from the non-compliance run input files.

Since EnergyPro cannot directly run the created SBD standard and proposed input files, the user needs to change the name extension of both SBD input files from ".doe" to ".inp" and run both files with the DOE2.1E engine. This is the same simulation engine used by EnergyPro.

Please note that the eligibility of a project for SBD incentive and the incentive rates should still be established based on the TDV results of the EnergyPro compliance run. The proposed SBD run only applies to SBD energy savings simulations.

Project Example

To illustrate the application of the proposed SBD run, this paper uses a new office building as an example. The basic information of the new building design is first introduced, followed by the comparison of the DOE2.1E input files of the compliance run, non-compliance run, and proposed SBD run. Each run is paired with a standard input file and a proposed input file. The simulation results of the compliance run and non-compliance run are based on the outputs of EnergyPro NR Title 24 Performance module and NR Performance module, respectively. The DOE2.1E V136 engine is used to conduct the SBD run. The electricity and natural gas savings as well as on-peak demand reduction of each run are presented and analyzed at the end.

Building Information

The selected project is a two-story office building located at San Ramon, California. The climate zone is CZ 12 and the corresponding peak demand days are August 5 to 7, 1991. The total conditioned floor area is 17,000 ft^2, which is divided into three office zones and a corridor/restroom zone. There is an additional 5,000 ft^2 unconditioned storage space.

This building is designed with a built-up VAV system and each zone is conditioned by 40% VAV reheat boxes. The cooling coil supply air temperature is reset based on demand. An economizer based on differential dry-bulb temperature is designed to make full use of free cooling. The design airflow is 20,000 cubic feet per minute (CFM) and the rated brake horsepower of the variable speed fan is 20-hp. Chilled water is produced by a 40-ton air-cooled reciprocating chiller with a rated efficiency of 1.0 kW per ton. Hot water is produced by a gas-fired boiler with a rated efficiency of 80%. In addition, advanced lighting systems are installed to lower space LPD to 0.7 W/ft^2 for the office areas and to 0.3 W/ft^2 for the storage space. Other energy efficiency measures include DCV in one zone, a cool roof, high performance glazing, and a heat pump (HP) domestic hot water (DHW) heater.

Based on the simulation results of the EnergyPro compliance run, the TDV energy usage of this building is 15.1% below that of the standard building. Therefore, this project is eligible for SBD incentives.

Comparison of the DOE2.1E Input Files

Table 1 compares the standard and proposed model DOE2.1E input files for the compliance run, non-compliance run, and SBD run. The inputs in the green colored cells for the compliance and non-compliance columns are identical to those for the SBD column. This table shows that the inputs of the SBD run is a combination of the inputs from the compliance run for run period, HVAC system, and equipment efficiency, and the inputs from the non-compliance run for schedules, artificial loads, and LPD in unconditioned spaces. These three runs share the same inputs for weather data, LPD in conditioned spaces, and envelope.

The discrepancies among the input files in Table 1 explain the differences in the energy simulation results. The EnergyPro non-compliance model is simulated in 2014, therefore the run period is 2014. The non-compliance run could use user-defined custom weather data if this option is selected by users. However, the SBD run should only use California standard climate zone weather data. The design space temperature reset schedule is more aggressive than the standard reset schedule. The as-built design night setback temperature is 95ºF for cooling and is 55ºF for heating, while the standard night setback temperatures are 60ºF and 77ºF, respectively. For the equipment efficiency category, although they are both based on Title 24or Title 20, the minimum chiller efficiency values of the non-compliance and the compliance runs are different for this project. This is because the standard equipment types of these two runs are different: one is an air-cooled chiller and the other is a water-cooler chiller. Compared to the proposed 150% heat pump DHW boiler, the standard DHW boiler is also a heat pump with a lower efficiency of 88.6%. This means there is no gas consumption for DHW. For the LPD in conditioned space and envelope categories, all three runs share the same standard inputs and the same proposed inputs.

Table 1. Summary of the standard and proposed model input files for the three runs

	Compliance		Non-compliance		SBD	
	Standard	Proposed	Standard	Proposed	Standard	Proposed
Run period	1991	1991	2014	2014	1991	1991
Weather	CZ12	CZ12	CZ12	CZ12	CZ12	CZ12
Schedules	T-24 Nonresidential schedules: Heating: 70ºF/60ºF Cooling: 73ºF/77ºF Fan: 6am to 8pm, Mon to Fri, 6am to 3pm, Sat Lights %: 5% to 85% Equipment %: 15% to 70% Occupant %: 0% to 65% DHW %: 0% to 90%		As-built design: Heating: 70ºF/55ºF Cooling: 74ºF/95ºF Fan: 5am to 7pm, Mon to Fri Lights %: 5% to 70% Equipment %: 5% to 50% Occupant %: 0% to 50% DHW %: 0% to 90%		As-built design: Heating: 70ºF/55ºF Cooling: 74ºF/95ºF Fan: 5am to 7pm, Mon to Fri Lights %: 5% to 70% Equipment %: 5% to 50% Occupant %: 0% to 50% DHW %: 0% to 90%	
Artificial loads[1]	T-24 for office >250 ft^2: Occupant density: 100 ft^2/occ Sensible heat: 250 Btu/hr-occ Latent heat: 200 Btu/hr-occ Receptacle load: 1.5 W/ft^2 Hot water: 120 Btu/hr-occ Ventilation: 0.15 cfm/ft^2		As-built design: Occupant density: 150 ft^2/occ Sensible heat: 255 Btu/hr-occ Latent heat: 225 Btu/hr-occ Receptacle load: 1.0 W/ft^2 Hot water: 100 Btu/hr-occ Ventilation: 0.13 cfm/ft^2		As-built design: Occupant density: 150 ft^2/occ Sensible heat: 255 Btu/hr-occ Latent heat: 225 Btu/hr-occ Receptacle load: 1.0 W/ft^2 Hot water: 100 Btu/hr-occ Ventilation: 0.13 cfm/ft^2	
LPD in unconditioned spaces (W/ft^2)	0.0	0.0	T-24 baseline: 0.6	As-built design: 0.3	T-24 baseline: 0.6	As-built design: 0.3
HVAC system type	T-24 standard: System 3 package VAV, gas boiler with reheat, air-cooled, 20% VAV box/Reheat	As-built design: Built-up VAV, gas boiler with reheat, air-cooled, 40% VAV box/Reheat	As-built design: Built-up VAV, gas boiler with reheat, water-cooled, 20% VAV box/Reheat	As-built design: Built-up VAV, gas boiler with reheat, air-cooled, 40% VAV box/Reheat	T-24 standard: System 3 package VAV, gas boiler with reheat, air-cooled, 20% VAV box/Reheat	As-built design: Built-up VAV, gas boiler with reheat, air-cooled, 40% VAV box/Reheat
Equipment efficiency	T-24 or T-20: Chiller: 3.05 IPLV HW boiler: 80% DHW boiler: 88.6% heat pump	As-built design: Chiller: 3.52 COP HW boiler: 80% DHW boiler: 150% heat pump	T-24 or T-20: Chiller: 4.45 COP CT EIR: 0.013 HW boiler: 80% DHW boiler: 88.6% heat pump	As-built design: Chiller: 3.52 COP HW boiler: 80% DHW boiler: 150% heat pump	T-24 or T-20: Chiller: 3.05 IPLV HW boiler: 80% DHW boiler: 88.6% heat pump	As-built design: Chiller: 3.52 COP HW boiler: 80% DHW boiler: 150% heat pump
LPD in conditioned spaces (W/ft^2)	T-24 standard: Office: 0.9 Corridor: 0.6	As-built design: Office: 0.7 Corridor: 0.55	T-24 standard: Office: 0.9 Corridor: 0.6	As-built design: Office: 0.7 Corridor: 0.55	T-24 standard: Office: 0.9 Corridor: 0.6	As-built design: Office: 0.7 Corridor: 0.55
Envelope	T-24: Cool roof: 0.55 reflectance /0.75 emittance /R25 Exterior wall: R17 Glazing: 0.470 U-factor/0.360 SHGC	As-built design: Cool roof: 0.68 reflectance /0.87 emittance /R30 Exterior wall: R19 Glazing: 0.564 U-factor/0.407 SHGC	T-24: Cool roof: 0.55 reflectance /0.75 emittance /R25 Exterior wall: R17 Glazing: 0.470 U-factor/0.360 SHGC	As-built design: Cool roof: 0.68 reflectance /0.87 emittance /R30 Exterior wall: R19 Glazing: 0.564 U-factor/0.407 SHGC	T-24: Cool roof: 0.55 reflectance /0.75 emittance /R25 Exterior wall: R17 Glazing: 0.470 U-factor/0.360 SHGC	As-built design: Cool roof: 0.68 reflectance /0.87 emittance /R30 Exterior wall: R19 Glazing: 0.564 U-factor/0.407 SHGC

Notes: Artificial loads cover all internal loads except for space lighting.

Simulation Results

Table 2 shows the simulated annual energy consumptions for kWh, kW, and therms, respectively. Because of the significant differences shown in Table 1, the annual energy consumptions vary dramatically among the three runs. The gas consumptions of the non-compliance run and the SBD run are much higher than those of the compliance run, which could be due to lower artificial heat gains for the non-compliance and SBD runs.

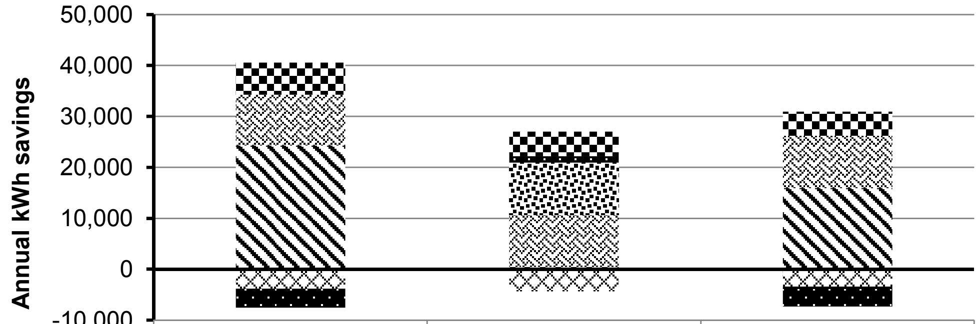
Table 2. Summary of annual energy savings for each run

Annual consumptions	Compliance		Non-compliance		SBD	
	Standard	Proposed	Standard	Proposed	Standard	Proposed
Total kWh	192,261	159,208	113,816	91,110	121,029	97,371
On-peak kW	68.3	54.7	44.5	39.7	57.8	45.6
Total therms	427	904	902	1,497	1,031	1,480
kWh savings	33,053		22,706		23,658	
kW savings	13.6		4.8		12.2	
Therms savings	-477		-595		-449	

Table 2 also shows the annual energy savings for each run. The natural gas savings numbers for all runs are negative, which indicates the proposed design consumes more natural gas than the standard design does. Several factors could have contributed to the negative gas savings, such as lower space LPD, higher reflectance of the cool roof, and less efficient window U-factor for the proposed design.

If the savings for the SBD run are counted as 100% of savings, the compliance run overestimates kWh savings by 40%, kW by11%, and therms by 6%. In contract, the non-compliance run underestimates kWh by 4% for, kW by 61%, and overestimates therms by 33%. The DEER peak demand days for CZ 12 are Aug 5 to 7, which are working days in the 2014 calendar year. Therefore, the kW reduction discrepancies among the three runs are not due to the calendar change but to the differences in building loads and HVAC operations.

It seems that the non-compliance run and SBD run generate close results on electricity simulations. However, the end-use breakdowns of these totals reveal significant differences in where energy is used in the two runs. To take a closer look at the kWh simulation results, Figure 3 provides break down of kWh savings for each run. The DHW kWh savings for the compliance run are moderately higher than those for the other two runs because of moderately higher DHW demand. The chilled water pump power savings are negative for the compliance run and SBD run as an air-cooled package VAV system is selected in their baseline systems. There are no power savings on cooling towers or condenser water pumps in these two runs. In the non-compliance run, the baseline system is built-up VAV with a water-cooled chiller. Positive savings of 10,225 kWh show up in the Heat Rejection (HR) category representing power consumptions by cooling towers and condenser water pumps. The negative fan power savings are similar for all runs because the minimum airflow ratio of the VAV boxes is 20% for the standard design and 40% for the proposed design for all three runs. Due to slight differences in the lighting schedule, the indoor lighting savings in the compliance run are slightly less than those of the other two runs. Lastly, there are significant differences in cooling energy savings. The non-compliance run has similar standard and proposed HVAC systems, leading to minimal cooling power savings. The compliance run and SBD run share the same standard and same proposed systems, respectively. However, the compliance run adopts higher artificial loads, longer operation hours, and less aggressive night setback schedules, leading to higher cooling energy savings.



	Compliance	Non-compliance	SBD
Elec DHW	6,309	4,809	4,709
Elec Pumps	-3,744	1,254	-3,927
Elec HR	0	10,225	0
Elec Fans	-3,810	-4,311	-3,369
Elec InLight	9,984	10,283	10,277
Elec Cool	24,314	446	15,968

Breakdowns of kWh savings vs. the SBD standard design

Figure 3. Disaggregation of annual electricity energy savings for each run.

The analysis above indicates that due to the aforementioned differences in the model input files, these three run generate significantly different energy savings results. This example illustrates the differences between the compliance run and the non-compliance run and the significance of adopting the proposed SBD run to simulate energy savings for SBD projects.

Conclusion

SBD programs represent an essential and considerable contribution to California's energy efficiency portfolio. However, the energy savings simulation method for SBD programs has not been comprehensively discussed or clearly documented. This has led to confusion and inconsistency in the SBD program implementation and evaluation.

This paper provides side-by-side comparisons of the compliance run and non-compliance run of the EnergyPro simulation. The results indicate that neither is appropriate for estimating energy savings of SBD projects. To reasonably estimate SBD project energy savings, this paper proposes an SBD run based on the comparison findings. This SBD run creates SBD standard and proposed input files by combining the run period, where the standard run uses Title 24 standard for HVAC system, equipment efficiency, envelope and LPD in conditioned spaces, whereas the building schedules, artificial loads and LPD in un conditioned spaces use as-built design schedule. However, the proposed run uses as-built design for all the components of the building including the HVAC system, LPD in conditioned spaces, equipment efficiency, LPD in unconditioned spaces, envelope and artificial loads. Both the standard and proposed SBD runs should use 1991California Climate Zone (CZ) weather data for the simulation runs. In that way, the as-built design schedules are reflected in both in the standard and proposed conditions and the savings are attributed only to the lighting, equipment, and envelope design enhancements.

The proposed SBD energy simulation run is illustrated using a new construction example project. The simulation results and analysis indicate that the proposed SBD run is capable of reasonably capturing SBD project energy savings, while the compliance run and the non-compliance run could significantly overestimate or underestimate the energy savings.

The recommended SBD modeling process detailed above is a labor intensive process and can be very tedious. We recommend exploring modifications to the available simulation tools to automate the proposed SBD modeling process to estimate future SBD program energy savings .

These discussions focus on the California SBD program, but they can provide useful insights for managers of new construction programs in other jurisdictions.

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