In Praise of Prescriptive Codes, Rules of Thumb and Design Guidelines: How Do We Compare With 50% AEDG?

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ABSTRACT

Commonly accepted wisdom is that prescriptive building requirements cannot be sufficiently responsive to the site or occupancy to form the basis of low energy buildings. As a result, some have called for the elimination of prescriptive codes altogether and for building codes to be outcome-based and would have compliance rely entirely upon whole building performance software or post-construction monitoring. Some also consider prescriptive approaches to inhibit creativity and innovation. This paper makes the argument that prescriptive codes often contain the results of expert judgment supported by detailed parametric simulations and reviewed by a panel of experts; this level of expertise, innovation, and effort is often not available for the 73% of nonresidential buildings with floor areas below 10,000 sf. Even when the performance approach is used to comply with building energy codes, the prescriptive code forms the baseline and provides a good starting place for energy efficiency and highlights measures that might otherwise be overlooked.

Design guidelines are often developed to acquaint and teach designers how to apply new technologies so that outcomes are repeatable and predictable. After design guidelines help transform a market, they can be the basis of prescriptive codes. This paper contains a comparison of how closely selected energy codes come to approximating advanced energy guidelines. The mandatory and prescriptive requirements in 2013 Title 24, 2013 CALGreen, ASHRAE 90.1-2010 and 189.1-2011 are compared with the 50% Advanced Energy Design Guidelines. The gaps between the energy codes and the energy guidelines are discussed along with limitations of energy codes to address all types of efficiency measures.

Introduction

As modern industrialized societies become increasingly aware of the societal costs of inefficient use of energy (environmental, distribution capacity constraints, consumer cost etc.), the demand for more stringent building energy codes has also risen. As an example, Figure 1 illustrates that the stringency of the ASHRAE Standard 90.1 national energy code for commercial buildings has reduced energy consumption targets by approximately 40% over the last 20 years. The concern by some in the energy efficiency community is that we are starting to hit the law of diminishing returns and that traditional prescriptive energy codes are not going to be sufficient if we expect to hit some of the more ambitious targets such 50% of the 2004 ASHRAE 90.1 standard or Zero Net Energy.

This line of reasoning posits that prescriptive codes are generic and cannot be tailored to the site, the specific occupancy or the wide array of energy technologies. As a result some have called for codes that are completely performance based (i.e. the proposed building is modeled using a whole building energy simulation software and the simulated energy consumption is compared to a particular energy target). Of course, the performance based approach is available as an option at the discretion of the building owner and design team.

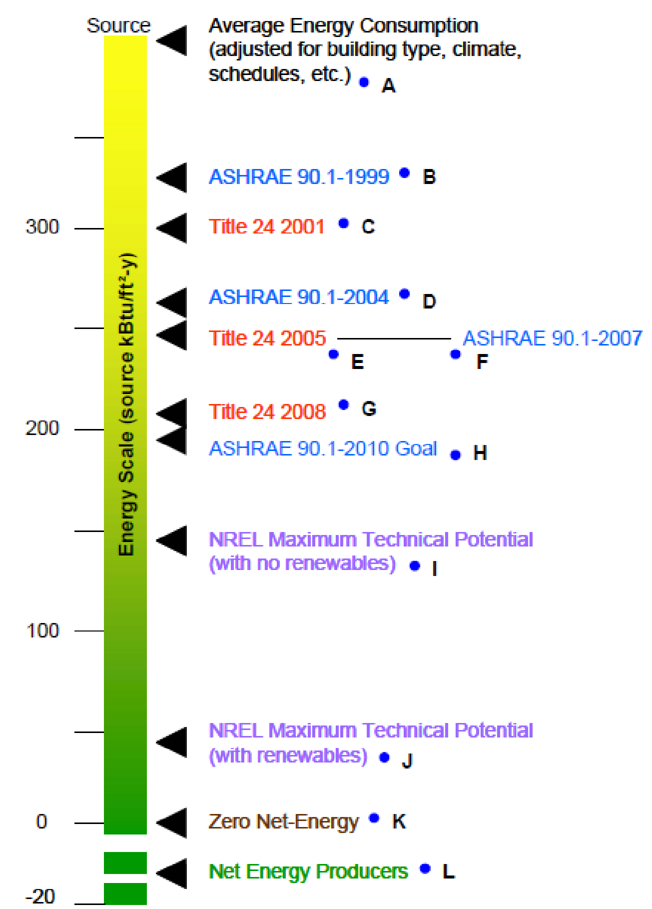


Figure 1. Increasing Stringency of Energy Codes (AEC, SCE 2009)

Other energy efficiency advocates feel that even the simulation models are not sufficient for achieving the actual energy savings targets, and have proposed "outcome-based" energy codes. Outcome based energy codes do not necessarily require compliance documentation outside of the target efficiency threshold and a promise to stay beneath these limits. Their concern is that simulation models present idealized equipment operation and that the simulation models cannot keep up with advanced energy efficiency technologies. In addition such outcome based codes can regulate plug loads and appliances though this format. It also gives a reasonable assurance that over the period that outcome is measured that equipment is performing correctly. This moves towards a continuous disclosure and benchmarking of building performance.

Outcome based standards can be defined in many ways but one method as presented in a number of proposals to the IgCC (International green Construction Code) is in terms of a zero Energy Performance Index (zEPI) value. The zEPI is defined as percentage of energy consumption relative to the median energy consumption of the stock of buildings that existed at the year 2000. In the United States this is median energy consumption of a given building type as contained in the 2003 CBECS (Commercial Buildings Energy Consumption Survey) database maintained by the US Department of Energy (EIA 2003).

One definition of zEPI as follows:

zEPI = EUIa / EUIr

Where,

EUIa = Actual Annual Energy Use Index for the building expressed in source kBtu/sf·yr
EUIr = Reference Annual Energy Use Index for the building use and occupancy in same climate zone

The following is the text explaining the rationale of a proposal to the IgCC for the inclusion of an outcome based path that would have set a zEPI score of 51% based on the first 24 months' worth of energy bills relative to the median Energy Use Intensities by building type and climate of the 2003 CBECS database. (AIA et al. 2011) *For 35 years, since the first energy codes, there has been no consideration in the codes for how buildings actually perform – only criteria prescribing how they are to be designed and constructed. The provisions in virtually all energy codes and standards are based on a number of prescribed criteria that must be satisfied by specific products, materials and components of a building. The closest these documents come to actual performance of a building is a simulation of how a building as designed is expected to perform compared to the same identical building but assumed to just meet the provisions in the code. In effect this creates a custom energy budget for each and every building based on a prescriptive foundation.*

Unfortunately many of those criteria do not allow for application of new technologies such as innovative window materials or creative design approaches such as passive solar, building form and shape, and orientation. In order to establish an actual EUIa for a building the code must provide a methodology for measuring and expressing the energy use of a building and subsequently be able to compare it to the target EUIr as part of the compliance verification process….

This proposed outcome procedure is unique and offers communities the option to gain valuable experience and knowledge with a method and accurate results far beyond the traditional procedures of design for energy conservation. An analogy can be made between the outcome based requirements for a building to the purchase and use of an automobile. When purchasing a vehicle you are given information about the vehicles performance in its specifications and the mileage that is anticipated for its operation. However, your personal performance and mileage may be quite different. Only by checking your mileage are you able to know whether what was stated is being achieved.

Similarly, when the traditional energy codes and standards are used, when the building is completed and is occupied there is no way to know whether the decisions for a specific design or material or orientation resulted in actual energy savings. This proposed outcome approach provides a real target, allows design options and flexibility and then provides real answers as to whether what was planned has been achieved in a way that has never been done before.

One of the advantages of a zEPI based standard is that it is silent on the measures used and as a result might be possible to hit extremely low energy targets without directly violating federal appliance efficiency preemption restrictions placed on building codes (see Chase et al. 2012). This is also compatible with a "top-down" approach to energy codes where policy goals are set and it is up to the individual designer to figure out how to comply.

This paper is concerning itself with the benefits of prescriptive codes rather than addressing the shortcomings of other approaches however the following issues must be addressed by these other innovative code approaches.

Performance Standards

A performance standard is compared against some baseline, where a "Passing" building is one that uses no more simulated energy than the baseline building. Traditionally this baseline has a "custom budget" that is based upon applying prescriptive requirements to the proposed building model. But this baseline could be based upon a target EUI as is the case with the zEPI approach. The challenge with the zEPI approach is capturing how well the proposed building matches the "typical" building in the EUI database. Should infill buildings that have their form somewhat constrained by the site be penalized for selecting a site with less than ideal orientation? Conversely for a site with a long east-west axis, should the building have inefficient features because it has been blessed with an ideal site? What is the baseline for fairly atypical occupancies where statistically valid median energy consumption figures are not available for every climate zone?

A statutory challenge for a performance standard that is not based upon a prescriptive baseline is demonstrating that the proposed budget is cost-effective or “feasible.” Some building efficiency codes such as California’s Title 24, part 6 were authorized by a statute that required that the code “shall be cost-effective when taken in their entirety and when amortized over the economic life of the structure compared with historic practice”[1]. Showing cost-effectiveness and feasibility are key criteria for determining which measures are added to this building efficiency standard. The detailed cost-effectiveness analysis has been a critical element in the argument refuting that the proposed energy code is unwarranted and is harmful to the local economy.

Outcome Based Standards

The same issues associated with documenting cost-effectiveness applies to outcome based standards that use zEPI benchmarks. However the opportunities for continuous commissioning associated with this approach are appreciated. Nonetheless a key concern is the enforceability of an outcome based standard. What does one do when a building doesn’t comply with an outcome based standard? What is the basis for recourse for a design-build project? Within the 2 year period, the building may have changed hands more than once. That this approach might be pursued in addition to the more traditional prescriptive and performance method would result in a building regulation that is akin to continuous commissioning. Another barrier to outcome based codes is that current energy codes only apply to design and construction up to the point of occupancy. Building energy codes will need to change their purpose and scope to cover post-occupancy similar to fire codes which allow for periodic inspections of systems after a certificate of occupancy is issued for a building.

When someone sells a product, there is an expectation in the United States that there may be some form of regulation at time of sale as there is for various appliances in terms of energy efficiency and other features such as safety. However, there is no history of periodic regulatory requirements on many products (outside of periodic emissions inspections on cars). Even time of sale efficiency regulations as clearly beneficial as the efficiency regulations for incandescent lamps met stiff resistance by a segment of the population that does not want “Big Government telling me what type of light bulb I can use.” An outcome based code that has a government review of one’s energy consumption “Big Brother snooping on my energy usage” and levying penalties based on use could, in general, result in a larger backlash against energy codes.

If the penalty is levied on the occupant rather than the owner or on the current owner rather than the original owner, this leads us back to the original problem of split incentives that energy codes are very effective at addressing. If the penalty is levied on the original owner rather than the occupant, the owner may be penalized for excessive energy consumption that is the result of occupant behavior. Alternatively, if the penalty is levied on the occupant (currently the default situation via high utility bills) some of this consumption is due to the how the building was originally designed – exactly the split incentive that prescriptive and performance energy codes are good at addressing. Potentially an outcome based code may be better suited towards an owner-occupied building or somehow normalized to (to occupied hours) so that it is more independent of occupant behavior.

A market based alternative to Outcome-Based Standards would include requirements for disclosing energy bills prior to leasing or selling property – better yet a bill summary as

[1] § 25402 (CA Public Resources Code 2009)

compared to benchmarked value could be part of the building summary posted in a MLS (Multiple Listing Service) prior to the customer even seeing the property. Besides the pressure this would place on existing properties to conduct energy upgrades, it would help differentiate newer properties that are complying with modern energy codes from the rest of the market where about half of the market was constructed before there was any energy code.

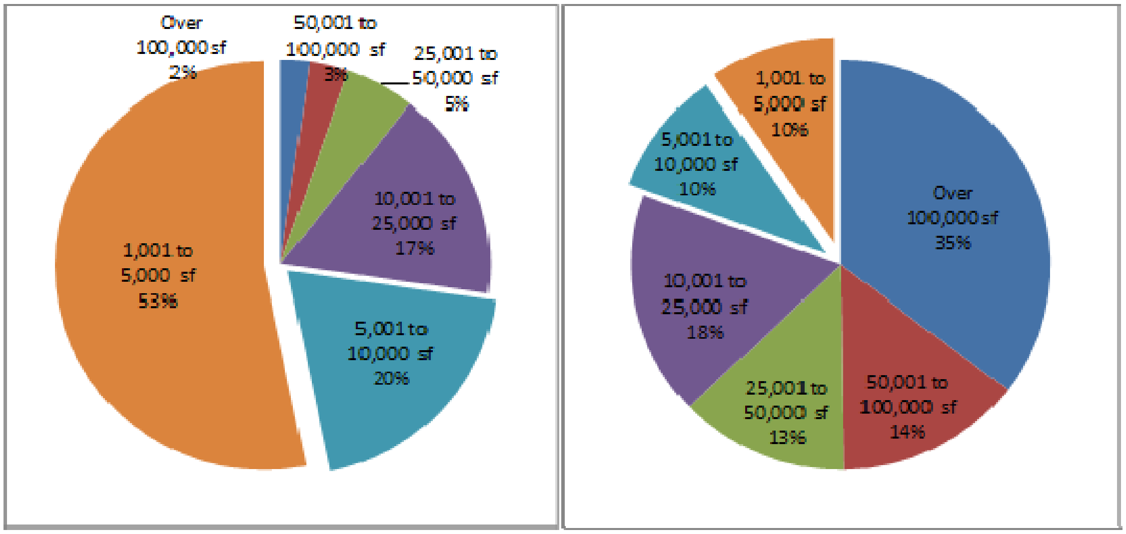
Where an outcome based standard is truly warranted is in a green building rating. Presumably the owner and the occupants are all motivated to share in the glory of a well-designed, well-maintained and well-operated building with low energy consumption. The brand of a certified "green" building is weakened by rated buildings that are not maintaining high levels of energy efficiency and indoor environmental quality. Turner & Frankel (2008) describe such a scenario where some LEED rated buildings performed worse that the minimum energy code baseline.

Prescriptive Code Expertise

When energy codes are developed, there is a lot at stake. A single measure can literally save consumers billions of dollars over the course of the life of one year's new and retrofit construction. As a result when energy codes are developed there is a tremendous amount of technical expertise brought to bear on the development of standards. In addition the code development occurs within the crucible of attention focused on the new code by affected industries. Many of the affected industries are also dedicating considerable resources towards promoting code change proposals or at least reviewing code change proposals. This isn't to say that illogical code requirements never make their way into codes or that all measures are driven purely by cost-effectiveness and net present value savings to the consumer, but there is a lot of attention given to these very important standards. There are literally tens of thousands of person-hours that go into developing national or state standards. For example for the ASHRAE 90.1-2010 Standard, there were 37 people listed on the Standing Standard Project Committee 90.1 (SSPC 90.1) that represented 85 people on the various subcommittees. In addition, the standard was reviewed by another 29 people on the ASHRAE Standards Committee. These committee members are carefully selected by this technical society of their technical capability and in a manner that provides diversity to the committees. Similarly for the development of the 2013 version of the Title 24 building efficiency standards, the California Statewide Codes & Standards program hired 22 consultant firms to develop the CASE (Codes and Standards Enhancement) code change proposals. The work of the ASHRAE 90.1 committee and the Title 24 CASE authors are exposed to public scrutiny though the public review process.

In contrast to the huge amount of effort that goes into national and state energy standards, the amount of effort that can go into optimizing an individual building's energy feature is limited. As shown in Figure 2(a), of the total number of commercial buildings in the US building stock, 73% of buildings are less than 10,000 sf in area. Given that design fees are often based on a $/sf basis, design time is extremely limited on these small buildings. As a result, it is unlikely for typical buildings to have sufficient budget for detailed parametric performance analyses that would allow for optimizing for the specifics of the site, occupancy etc.

Figure 2. US commercial building stock: Number of Buildings and Total Area (EIA 2003)



a) Fraction of building number
4.8 M buildings (US)

b) Fraction of total building area
71.6 Billion sf (US stock)

Even though small buildings make up the majority of code submittals, Figure 2(b) illustrates that these small buildings with floor areas less than 10,000 sf are only 20% of the total floor area of all buildings. Additionally, Figure 2(b) shows that the 2% of building projects which are over 100,000 square feet in area account for 35% of the total commercial floor space. For these large buildings with higher design budgets, and where even relatively small changes to the project can have relatively large cost or energy impacts, the performance approach seems like a natural fit with these highly engineered buildings.

However, even with a large building that has plenty of design budget to investigate optimal design approaches where does one start? Does the designer start with single glazed clear windows and old style multi-zone HVAC systems that control temperatures by mixing hot and cooled air? The prescriptive standard can be used as a rule of thumb for starting reasonably close to what we expect will be a reasonable outcome whether we are just trying to meet code or creating a high performance building.

Prescriptive codes can be helpful in terms of which requirements they exempt or exclude. Some requirements are specifically written to apply to certain occupancies or have some threshold value before they apply. These caveats help identify if the measure under consideration is likely to have low savings for the particular building type being designed. Occupancy sensors are required in classrooms and small offices which are intermittently occupied and are not impacted by having lights turned off during periods when they are vacant. In contrast occupancy sensor control of lights are not required in retail spaces where turning the lights off in portions of the store that are not occupied might discourage shoppers from going to that part of the store.

The committees that develop prescriptive codes are very cautious to exempt a code requirement where it may have a safety implication. These exemptions help the designer avoid or have some other incompatibilities with building operation. For example, occupancy sensors in stairwells are required to be bi-level and automatic on rather than manual on/off; as this helps avoid a safety hazard.[2]

Prescriptive Codes Transforming Markets

For all their inflexibility, prescriptive codes have one other beneficial attribute; they can transform markets. Prescriptive codes set efficiency baselines for a variety of products whether they be envelope components or lighting products (most mechanical equipment efficiencies are fixed by federal appliance efficiency regulations which preempt an additional building efficiency regulation). The two products that were designed specifically in response to the 2005 Title 24 standards are bi-level occupancy sensors and automatic daylighting controls with a setpoint that can be calibrated. The CASE team had discussed with lighting controls manufacturers that research had indicated that more energy could be saved with a multi-level occupancy sensor and that efforts were under way to provide lighting control credits for such a control. The occupancy sensor control manufacturers indicated they could build such a control with the existing technology and they brought this technology to the market in response to the control credit. Prior to 2005 Title 24, some photocontrols had only a "high-lo" adjustment setpoint control without any way to distinguish the relative setpoint along the continuum between high and low settings. This was exacerbated by some controls having a logarithmic relationship between setpoint control adjustments (rotation of calibration knob) and the setpoint! These controls were difficult to calibrate and thus were undermining the benefit of the control. The photocontrol manufacturers agreed that they could all produce controls that "have a setpoint control that easily distinguishes settings to within 10% of full scale adjustment."[3] This requirement forced the redesign of a number of photocontrol interfaces.

When prescriptive codes are adopted, the state or local government frequently provides training on the new standard. Processional societies such as AIA, ASHRAE, and IESNA train their membership. Energy utilities have also been a traditional source of training for new code updates. The private sector also provides training. Manufacturers of building products develop marketing materials touting that their product is compliant with the new code. The end result is that designers specify products that meet the new code and because of cost pressures many of these specified products are minimally compliant with the new code.

A number of manufacturers design a product around what is minimally compliant with the prescriptive requirement. The competitive pressures of selling a similar product result in commoditization and the resulting economies of scale and lower margins associated with the commodity product. The ultimate result is a lower price for a relatively high efficiency building component. The loss of margins spurs companies to develop and commercialize the next premium efficiency product and thus this cycle of increasing the stringency of energy codes helps drive new product innovation.

[2] §9.4.1 ASHRAE 90.1-2010

[3] §119(e) 2005 California Title 24, part 6.

Advanced Design Process Savings by Design Program

Savings By Design (SBD) is a California statewide energy efficiency program administered by many of the California utilities (PG&E, SCE, SDG&E, SCG and SMUD) that has been operated since 2000. The program is targeted at non-residential new construction building projects and is designed to encourage building owners and their design teams to design high performance, energy efficient buildings. The primary focus of the program is to encourage the deep savings that results from integrated building design where all the key design decision makers (owner, architect, engineers, interior designer, etc.) are designing the building together rather than sequentially. Decisions by the team are informed by whole building energy simulations so that choices made by the team have close to real time energy feedback from the building energy analyst. This extra effort up front yields significant savings over the long term. The incentives from the Savings By Design program are performance based – they are a function of how much energy is predicted to be saved by the building simulation. The larger the compliance margin, or the percentage of savings relative to the energy code, the larger the incentive rate (in $/kWh) rewarded by the program. These incentives are paid to the building owner and to the design team so that extra design time by designers is compensated. SBD also develops case studies that tout the benefits of integrated design and also serve as a marketing tool for the owner of the building.

After serving hundreds of design teams, the SBD program recognized that they were repeatedly providing similar types of design guidance. In addition, the SBD program had identified need in the design community for design tools and pattern guides for recurring design solutions for efficient buildings. This led to the formation of Energy Design Resources.

Design Guidelines

Energy Design Resources

The Energy Design Resources (EDR) website serves as a portal for accessing a valuable palette of energy design tools and resources that assist building owners, architects, engineers, lighting designers, and developers to design, build, and operate high performance, energy efficient buildings.

This library of resources was designed in tandem with the Savings By Design Program, to educate building owners throughout California and their design teams about new, innovative building technologies and processes, and to assist them to make decisions for incorporating these technologies and processes into their building projects to achieve higher building performance and greater energy efficiency.

Over the past decade, EDR has extended its reach worldwide, and has over 20,000 members who use its resources on a regular basis. Publications number approximately 300, and include: software tools, design briefs, design guidelines, and e-newsletters. Site users can search for information by design topics, technologies, or building type, and can easily download for free a wealth of knowledge on a variety of energy efficiency strategies and high performance design.

Much of the information provided on the EDR web site may be used to support the decision making process for the prescriptive pathway. Software tools (like SkyCalc and others) allow the user to make informed decisions to optimize design solutions. Design briefs, guidelines, and e-news articles provide users with the knowledge to make informed decisions on using technologies for their projects without having to do time-consuming, detailed analysis

50% Advanced Energy Design Guidelines (AEDG)

USDOE and ASHRAE have goals that a building designed to the future 2013 version of ASHRAE 90.1 will consume 50% less energy than ASHRAE 90.1-2004. The 50% AEDGs illustrate how one can could achieve these goals. These guidelines were collaboratively produced by ASHRAE, the American Institute of Architects (AIA), the Illuminating Engineering Society of North America (IESNA), and the U.S. Green Building Council (USGBC). As a guideline, the energy efficiency options are not constrained by federal preemption as are building codes.

There are 50% AEDGs for medium and big box retail, small and medium offices, grocery stores, lodging, and K-12 schools. In addition at the AEDG web site there are other design guidelines including the 30% AEDGs as well as research reports that will be the basis for future AEDGs (ASHRAE 2012).

The AEDGs give guidance on integrated building design and identify key climatic considerations and design principles for each building type. Each AEDG also has a one page prescriptive summary for each ASHRAE climate zone with a list of measures that will result in a building being close to the 50% target. This prescriptive "cheat sheet" allows one to start out in the right ballpark when trying to achieve 50% savings and additional design evaluations will then allow one to narrow in on an appropriate mix of measures for their specific building.

Building Energy Efficiency Codes & Standards

Currently, all building energy codes in the US that we are aware of, have a prescriptive compliance path. Most of these codes also have a performance path. For new construction, an increasing percentage of buildings are using the performance approach as it allows more design flexibility and can result in code compliance for less construction cost. Most retrofits use a prescriptive approach as they frequently are only changing out one component and thus do not have the flexibility to make trade-offs.

Reach Codes Versus Minimum Codes

Historically energy codes were based on the concept of other building codes. They were minimum compliance codes with a "pass/no pass" answer if one complied or not. Over time, there has been a desire to exceed code and receive credit so as to differentiate the building from a minimally code compliant building. Reach codes are also adopted by cities and counties that see benefits (such as greenhouse gas mitigation) in requiring buildings that are above minimum codes.

In 2010 with the adoption of CALGreen or the California Green Building Standard (Title 24, part 11), California adopted the first statewide green building standard in the US. This green building standard, based loosely on other green standards that had come before, has two major components:

A mandatory section required of all buildings. The mandatory CALGreen requirements are primarily focused on water conservation, construction waste recycling, and reducing toxics from building materials. There are no mandatory energy provisions in CALGreen outside of complying with the state energy code.

1. A voluntary section that has more stringent requirements in all the areas covered by the mandatory portion of the standard and more stringent energy requirements than the Title 24 energy code. This voluntary "reach" section of CALGreen is used by cities who adopt more stringent energy codes for a number of reasons including as part of a Greenhouse Gas reduction plan. The voluntary reach portion of CALGreen has two voluntary tiers for reducing energy consumption below that of the state energy code. Nonresidential buildings that exceed the state energy code by 10% (in addition to other "green" measures) qualify for tier 1 and buildings that exceed code by 20% qualify for tier 2. To show that one has hit these energy targets, the California energy code performance software approach must be used. In addition to these energy targets the CALGreen reach standard has mandatory "prerequisites." The prerequisites include that the outdoor lighting power allowance must be 90% of that in the energy code and for large restaurants, water heating must be provided by a condensing water heater or with a solar water heater having a 15% solar fraction.

The ASHRAE 189.1 Standard for the Design of High-Performance Green Buildings is written in code language similar to the ASHRAE 90.1 Energy Standard for Buildings which the basis for the minimum commercial building code standard in the United States. ASHRAE 189.1 adopts all the energy efficiency measures in ASHRAE 90.1 plus a few extra measures that are more stringent. As an example, in the 2009 version of standard 189.1, the lighting power densities (W/sf) were 90% of those found in ASHRAE 90.1. These added measures are potentially a starting point if one wished to design a beyond code building.

Comparison of 50% AEDG to Energy Codes (T-24 and ASHRAE 90.1)

In preparation for research proposal development of the 2016 Title 24 energy codes, a comparison was conducted between the prescriptive portion of the 50% AEDG's (Design Strategies and Recommendations by Climate Zone) and the prescriptive requirements of the California Title 24, Part 6 energy code. These were also compared with the prescriptive requirements in ASHRAE 90.1-2010. These prescriptive requirements also form the basis of the baseline of the performance method in both California Title 24 and ASHRAE 90.1 energy codes.

The vast majority of the California population lives in the ASHRAE climate zone 3C (coastal) and 3B (dry) climate zones. By comparing the highlighted areas in the ASHRAE climate zone 3 map and the Title 24 climate zones in Figure 3, one can see that all of California is in ASHRAE climate zone 3except California Title 24 climate zones except CZ 1 (north coast), CZ 15 (low desert) and CZ 16 (mountains).[4]

Though an evaluation was conducted for all occupancies, the example presented here in

Table 1 is for the AEDG for Small to Medium Office Buildings. For brevity's sake, not all building features are described, just the most common ones.

[4] Also excluded from ASHRAE climate zone 3is Lake County in northern California, which is a small fraction of Title 24 climate zone 2.

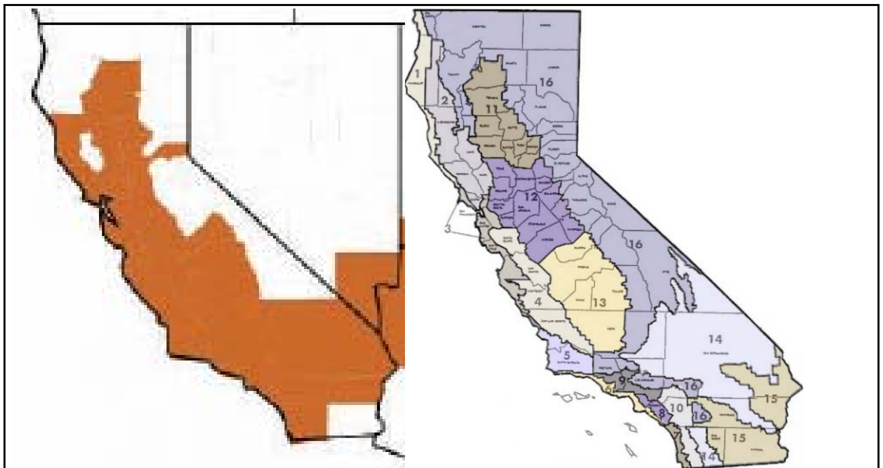


Figure 3. ASHRAE Climate Zone 3 and Title 24 Climate Zone Map

The AEDGs are guideline and since it is not code, the AEDGs are not constrained by the federal preemption requirements. Thus, the AEDGs can require higher AC, furnace and water heating efficiencies. Title 24 and ASHRAE 90.1 as energy codes are federally preempted from requiring higher equipment efficiencies of federally covered equipment except in the case where these higher efficiencies are part of an alternate path to a base option which has higher efficiencies for other components and minimum federal efficiencies (Chase et al.). Economizers, as add-on equipment, are not federally preempted and since they are a very cost-effective energy efficiency measure, the AEDG, ASHRAE 90.1-2010 and 2013 Title 24 all have similar economizer requirements.

Table 1. Comparison of 50% AEDG for Offices, 2013 Title 24 and ASHRAE 90.1-2010

Building Component	50% Office AEDG	2013 Title 24	ASHRAE 90.1-2010
Gas water heater	Condensing 90% eff	Federal min	Federal min
SWH Pipe ins <1.5”/>1.5” dia	Thickness 1”/1.5”	Thickness 1”/1.5”	Thickness 1”/1.5”5
AC eff	<65 kBtu, 15 SEER 65k – 240kBtu, 11.5 EER 240k – 760kBtu, 10.5 EER	Federal min	Federal min
Furnace Heating eff	Indirect condensing 80%	Federal min	Federal min
Fan W/cfm	Multi-zone 0.72 W/cfm Fan coil 0.3 W/cfm	CV 0.8 W/cfm, VAV 1.25 W/cfm, fractional = ECM	0.35 W/cfm (performance)
Economizer	54 kBtu, drybulb control	54 kBtu drybulb control	54 kBtu drybulb control
Duct Insulation	R-6.0	R-8.0	R-6
Roofs Above Deck Attic & Other Metal Building Solar Reflectance Index	R-25 c.i. (U-0.036) R-38 (U-0.027) R-19 + R-10 FC (U-0.052) SRI = 76	Wood U-0.039 to 0.075 Metal U- 0.069 Low slope SRI = 78	R-20 c.i. U-0.048 R-38, U-0.027 R-13+R-13, U-0.055 SRI = 64
Walls Mass (HC > 7 Btu/sf) Steel frame Wood framed Metal Building Below grade	R-11.4 c.i. (U-0.08) R-13 + R-7.5 c.i.(U-0.083) R-13 + R-3.8 c.i. (U-0.072) R-13 c.i. (U-0.072) R-7.5 c.i. (F-0.56)	Light mass U-0.177 to 0.44 Steel U-0.062 to 0.098 Wood/other U-0.059 to 0.11 Metal bld U-0.061 to 0.113	Mass R7.6 c.i. U-0.123 R-13 + R-3.8 c.i, U-0.084 Wood R-13, U-0.089 Metal R-19, U-0.084 Below grade C-1.140
Air barrier	Entire building envelope	Required CZ 10-16	Required in all climate zones
Windows WWR	20% to 40%	0% to 40%	0% to 40%
Windows U-factor (Btu/h·ft^2)	U = 0.60, metal U = 0.41 nonmetal	U = 0.36 fixed, U = 0.45 operable U = 0.41 curtain wall	U- 0.65, metal framing U-0.65 nonmetal framing U-0.60 metal curtain wall
Windows SHGC	0.25 metal and non-metal	0.25 fixed, 0.22 operable	SHGC ≤ 0.25 all
Window minimum VT	VT ≥ 0.275 =1.1 x 0.25 VT = LSG x SHGC	0.42 Fixed, 0.32 operable	NR
Window light-to-solar gain ratio	1.1	Fixed 0.42/0.25 = 1.68 Operable 0.32/0.22 = 1.45	NR
LPD	0.75 W/sf	Whole bldg = 0.80 W/sf 1 W/sf, small, 0.75 W/sf lg. Task – 0.3 W/sf exempted	Whole bldg 0.90 W/sf, Space 1.11 private, 0.98 open plan + 1 W/sf decorative allowance

Building Component	50% Office AEDG	2013 Title 24	ASHRAE 90.1-2010
24-hour egress lighting LPD	0.075 W/sf	0.05 W/sf	
Daylighting controls	Open offices primary and secondary zones	All spaces with > 120 W in primary sidelit zone and toplit zone. Secondary sidelit zones > 120 W	All enclosed spaces with primary sidelit zone > 250 ft^2 Toplit zones > 900 ft^2
Lighting Auto ON to 50%	private offices, conference break copy and, storage rooms	PAF of 0.2 for areas < 250 sf or any size classroom, conference or waiting room.	50% ON or manual on for all occupancies below.
Lighting Auto ON occupancy sensors	restrooms, electrical/ mechanical rooms, open and private office task lighting	Classrooms, conference rm, offices ≤250 sf, multi-purpose rooms < 1,000 sf	Classrooms, lecture, training, conference, copy, locker, fitting and break rooms, rest-rooms, 50ft^2 < storage < 1,000 ft^2 , offices < 250 ft2,
Partial OFF occupancy sensor		Warehouses, library stacks, corridors and stairwells, parking garages	Parking garages, stairwells
Desk plug load control	Occupancy sensor plug strip	50% of plugs controlled by time clock or occ sensor	50% of plugs controlled by time clock or occ sensor
Façade and landscape lighting	LPD = 0.075 W/ft^2 in LZ3 and LZ4, 0.05 W/ft^2 in LZ2	Façade 0.35 W/sf in LZ3, 0.18 W/sf in LZ2. Landscape exempt	Façade 0.15 W/ft^2 in LZ3, 0.10 W/ft^2 in LZ2.
Parking lots and drives	LPD = 0.1 W/ft^2 in LZ3 and LZ4, 0.06 W/ft^2 in LZ2	LPA = 0.09 W/sf in LZ 3, 0.045 W/sf in LZ2	LPD = 0.1 W/ft^2 in LZ3 and 0.06 W/ft^2 in LZ2
Walkways, plazas, and special feature areas	LPD = 0.16 W/ft^2 LZ3 and LZ4, 0.14 W/ft^2 in LZ2)	Parking lots + ornamental lighting = 0.13 W/sf in LZ3 and 0.065 W/sf in LZ2	LPD = 0.16 W/ft^2 in LZ3 and 0.14 W/ft^2 in LZ2

Insulation requirements for Title 24 vary as there are 13 California climate zones that cover the same area as the ASHRAE climate zone 3. AEDG and ASHRAE 90. 1 roof insulation values are comparable and are more stringent than Title 24; this is an area for improvement in Title 24. The AEDG solar reflectance values are similar to Title 24; ASHRAE 90.1 has lower solar reflectances. Wall insulation values in AEDG and ASHRAE 90.1 are similar and are in the middle of the range for Title 24.

Both AEDG and ASHRAE 90.1 prescriptively require air barriers. California Title 24 only requires air barriers in the hotter climates (CZs 10-15 of the desert and central valley) and the very cold climate in the mountains (CZ16).

The solar heat gain coefficients are similar across all three standards. Both the AEDG and ASHRAE 90.1 have higher U-factors that the Title 24 U-factors which assumes that the windows are metal with thermally broken frames. Though great gains were made in the overall energy efficiency of ASHRAE 90.1-2010, improvements to the requirements for windows and opaque wall sections were stalled due to an appeal of the envelope addendum to ASHRAE 90.1.[5] Thus envelope efficiency upgrades are a huge opportunity for improvement in the next version of ASHRAE 90.1. The Title 24 requirements for visible light transmittance far outstrip those proposed in the AEDG. The California standard partially relies on tremendous improvements to low-e coatings that allow high visible light transmittance to solar heat gains ratios otherwise known as high LSG (light to solar gain) ratios. As shown in the table the California requirements effectively require LSG's in excess of 1.4. Higher LSGs are possible – this is an area that should be reviewed for update in both the AEDG's and ASHRAE 90.1.

[5] ASHRAE 90.1-2007 addendum bb. If this addendum were adopted, it was estimated to reduce regulated building energy consumption by 5% or around 15% of the potential savings during the 2007 to 2010 upgrade of ASHRAE 90.1.

The AEDG's recommend that interior lighting power densities (LPDs) of 0.75/W/sf are possible in offices. The ASHRAE 90.1 standard allows approximately 1 W/sf plus up to another 1 W/sf of added display and ornamental lighting in offices.[6] In addition, ASHRAE 90.1 exempts from the LPD calculation, furniture mounted task lighting that has an automatic shut-off control.[7] The California Title 24 LPDs for large offices have 0.75 W/sf lighting power density limit for the overhead lighting and exempts the first 0.3 W/sf of task lighting from the open office lighting power calculation.[8] The Title 24 LPD's for small offices are 1 W/sf with the assumption that smaller spaces can require more light to address the higher room cavity ratio of smaller offices.

Indoor lighting controls are roughly comparable between AEDG, ASHRAE 90.1 and Title 24.

When comparing Title 24 outdoor lighting power allowances (LPA) to the AEDG and ASHRAE 90.1 LPAs for hardscape, it must be recognized that the lighting power allowance in Title 24 is the sum of a Watts per sf of hardscape, Watts per linear foot of perimeter and a fixed added Watts per site. Both the AEDG and ASHRAE 90.1 have significantly lower allowed façade lighting power densities than Title 24. Feature lighting in AEDG and ASHRAE 90.1 has significantly higher allowance than in Title 24.

Comparison of 50% AEDG to Reach Codes (CALGreen and ASHRAE 189.1)

Similar to the previous section, a comparison is being made with the prescriptive recommendations for office buildings in the 50% AEDG for Small and Medium Office Buildings and the prescriptive requirements of CALGreen and ASHRAE 189.1-2011 Standard for the Design of High Performance Green Buildings. This prescriptive comparison is difficult because the "reach" energy portion of CALGreen is primarily a performance standard. As described earlier, the reach standard has a Tier 1 that is 10% more stringent and a Tier 2 that is 20% more stringent than the Title 24 energy code. For offices CALGreen has only one prescriptive prerequisite – a lighting power density that is 90% that of the Title 24, part 6 building energy code lighting power requirements. Thus, in Table 2, the gray cells in the CALGreen column represent a repetition of the Title 24 code requirements with the understanding that overall CALGreen tiers are 10% and 20% more stringent. Similarly the ASHRAE 189.1-2011 standard has a requirement for on-site renewable generation that on average reduces the total building energy cost by approximately 10%. Using the performance approach to the energy requirements in ASHRAE 189.1, one can choose to displace all of the renewable generation with energy efficiency measures that save as much energy cost. Thus by comparing the ASHRAE 189.1 and Title 24 prescriptive requirements, one can get a feel for the relative stringency of CALGreen Tier 1 and Standard 189.1 because both will use 10% less energy that what is represented by the prescriptive efficiency requirements.

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[6] ASHRAE 90.1-2010 §9.6.2(a)
[7] Ibid Exception (p) to §9.2.2.3
[8] 2013 Title 24 exception to §140.6(a):

Table 2. Comparison of 50% AEDG for Small & Med. Office, 2013 CALGreen and ASHRAE 189.1-2011

Building Component	50% Office AEDG	2013 CALGreen	ASHRAE 189.1-2011
Roofs Above Deck	R-25 c.i. (U-0.036)		U-0.039 R-25 ci
Attic & Other	R-38 (U-0.027)	Wood U-0.039 to 0.075	U-0.021 R-49
Metal Building	R-19 + R-10 FC (U-0.052)	Metal U- 0.069	U-0.035 R-19 + R-11 liner
Solar Reflectance Index	SRI = 76	Low slope SRI = 78	
Walls Mass (HC > 7 Btu/sf)	R-11.4 c.i. (U-0.08)	Light mass U-0.177 to 0.44	R-9.5 c.i. U-0.104
Steel frame	R-13 + R-7.5 c.i.(U-0.083)	Steel U-0.062 to 0.098	R-13 + R-5 c.i. U-0.077
Wood framed	R-13 + R-3.8 c.i. (U-0.072)	Wood/other U-0.059 to 0.11	R-13 + R-3.8 c.i. U-0.064
Metal Building	R-13 c.i. (U-0.072)	Metal bld U-0.061 to 0.113	R-13 + R-6.5 c.i. U-0.079
Below grade	R-7.5 c.i. (F-0.56)		R-0 C-1.140
Windows U-factor (Btu/h·ft^2)	U = 0.60, metal U = 0.41 nonmetal	U = 0.36 fixed, U = 0.45 operable	U = 0.55, metal U = 0.45 nonmetal
Windows SHGC	SHGC = 0.25 all	0.25 fixed, 0.22 operable	SHGC = 0.25 all
Window minimum VT	VT ≥ 0.275 =1.1 x 0.25 VT = LSG x SHGC	0.42 Fixed, 0.32 operable	EA > 0.1 When WWR = 50%, Approx. VT > 0.2
Window overhangs			E, W, S, PF > 0.5
24-hour egress lighting LPD	0.075 W/sf	0.05 W/sf	0.1 W/sf
Economizer	>54 kBtu, drybulb control	>54 kBtu drybulb control	>33 kBtu drybulb control
Submetering and data storage		Services > 50 kVA loads disaggregated	HVAC > 100 kVA All other > 50 kVA
LPD Whole Bldg	0.75 W/sf	0.80	95% x 0.9 = 0.86
LPD Small Office		1.00	95% x 1.11 = 1.05
LPD Open Plan Office		0.75	85% x 0.98 = 0.83
Renewables		NR	Single story - 20 kWh/m2 All other- 32 kWh/m2
Façade in LZ 3	0.075	90% x 0.35 = 0.32 W/sf,	95% x 0.15 = 0.14 W/ft^2
Parking lots and drives LZ 3	0.100	90% x 0.09 = 0.08 W/sf	95% x 0.1 = 0.095 W/ft^2
Performance Budget		Tier 1: 90% of T-24 performance budget Tier 2: 80% of T-24 performance budget	

Shaded areas are required by Title 24 and referenced by CALGreen

Key findings of Reach Code Comparison

- AEDG and ASHRAE 189.1 have equivalent roof insulation requirements that are significantly more stringent that CALGreen
- Wall insulation requirements are comparable
- CALGreen window U-factor are more stringent (lower U-factors)
- CALGreen window VT requirements are more stringent (higher VT)

- Window SHGCs are comparable
- ASHRAE 189.1 has window overhangs; this is missing from both the AEDG prescriptive recommendations and CALGreen
- Allowed 24 hour lighting (egress) is twice as high in ASHRAE 189.1 as in Title 24 and CALGreen. All values are lower than current practice.
- ASHRAE 189.1 has a lower size threshold (33 kBtu/h) for when economizers must be used than the 50% AEDG, ASHRAE 90.1 or CALGreen (54 kBtu/h)
- Both ASHRAE 189.1 and CALGreen have prescriptive disaggregation of loads and submetering requirements. The 50% AEDG does not have any prescriptive guidelines though in the body of the text submetering is briefly discussed.
- The lighting power density recommendation in the 50% AEDG for small and medium offices matches relatively closely the prerequisite mandatory LPD in CALGreen. The LPD's in ASHRAE 189.1 are significantly higher
- The Title 24 lighting power allowances for façade lighting are significantly higher than those in the 50% AEDG's as well as ASHRAE 90.1. Thus for CALGreen even with a 10% reduction they are still very high.
- The parking lot lighting allowances are pretty comparable across all three guidelines. Parking lots make up for the lion's share of outdoor lighting not including street lighting.

Overall the AEDG and these two reach codes are very similar with each one having different areas where they are relatively more stringent. Rationalizing the differences between these three guides for designing high efficiency buildings will be very useful as they are updated to account for new technologies and new policy initiatives.

Conclusions

To paraphrase Mark Twain, *"The reports of the death of the prescriptive energy codes are greatly exaggerated."*

Prescriptive energy codes still have a useful place in the range of tools that are available to the energy efficiency policy implementers. Undoubtedly, performance standards offer the promise of yielding greater savings for less building cost; especially when cutting-edge advanced technologies are contemplated. However, the effort to find the ideal match of building characteristics tuned to the building's site, and occupancy may be excessive for the vast majority (73%) of buildings that are less than 10,000 sf. Carefully constructed prescriptive codes might actually be close to the Pareto Principle that 80% of the savings are achieved with 20% of the effort by first adopting the principles of prescriptive codes and for owners that want to have a high performing building to consider the prescriptive guidelines in the 50% AEDGs or reach codes.

Performance codes or outcome-based codes do not give any direct guidance to designers on where to start. Prescriptive codes and prescriptive guidelines for advanced buildings give an unambiguous starting point for designers who are evaluating efficiency options. This global optimum helps identify the likely "neighborhood" of optimal design features that the designer can optimize in a local optimum for their particular building.

Finally this paper evaluates the 50% AEDG's and the EDR guidelines and compares them to the 2013 California Title 24, and the ASHRAE 90.1-2010 energy codes. A similar comparison is conducted between these guidelines and the 2010 CALGreen and ASHRAE 189.1-2011 reach codes. The gaps identified between the prescriptive guideline and these prescriptive codes help set a research and advocacy agenda for updating these codes.

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