Residential Building Code Compliance: Implications for Evaluating the Performance of Utility Residential New Construction Programs

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Knowing how well builders comply with (or exceed) energy-related building codes is critical for completing a sound evaluation of utility residential new construction programs and for determining the actual cost-effectiveness of these programs. Obtaining credit from utility regulators for additional energy savings from code compliance in participant houses as a result of the utility program is one of the key options available for utilities for improving the cost-effectiveness of these programs.

In this paper, we examine residential building energy code compliance and specific code violations in three states (California, Oregon and Washington). We then compare residential building energy code compliance for program participants and nonparticipants as well as estimates of the energy savings impacts from noncompliance. We also point out some of the methodological limitations of these studies which limit our ability to generalize from these studies.

We show that homes may fall below residential building energy codes based on a prescriptive path due to noncompliance with prescriptive components and also that homes participating in utility RNC programs may have higher frequency and levels of building compliance compared to nonparticipating homes. We expect these differences (as well as the energy implications of noncompliance) to be greater in those states with less experience and expertise in building energy codes and energy code compliance. Accordingly, we believe utility RNC programs in other states could be more cost-effective if utility regulators recognize the role of RNC programs in increasing compliance by participants with existing state building codes.

INTRODUCTION

Utility companies typically use state building energy codes (hereafter referred to as ‘‘energy code’’ or ‘‘code’’) as the ‘‘baseline’’ for providing incentives to builders participating in utility-sponsored residential new construction (RNC) programs. However, as shown below, two facts call into question this assumption, affecting the economics of utility RNC programs: (1) builders may fall below energy codes, so that the actual baseline may be different than the state building energy code, and (2) builders participating in utility RNC programs may have higher frequency and levels of building compliance compared to nonparticipating builders, resulting in additional resource savings. As a result, the measured savings from RNC programs may underestimate actual savings, unless one has taken into account program participants' compliance with energy codes. A recent analysis of RNC programs has shown that many RNC programs are not cost-effective (Vine 1995). We believe many of these programs could be more cost-effective if utility regulators recognize the role of RNC programs in increasing compliance by participants with existing state energy codes.

The following discussion is subject to a few, important caveats, as noted below. Most importantly, the results are based on a small sample, in locations where many years and substantial resources have been targeted to energy code development, enforcement, training, and education. Thus, we expect more significant differences between the energy code and actual construction in those states where there have been few expenditures and minimal effort in energy code enforcement, training, and education.

In this paper, we examine six studies of building compliance in two regions of the U.S. (the Pacific Northwest and California) and describe some of the types of measures that are in noncompliance. We then compare building code compliance for utility RNC program participants and nonparticipants. In concluding, we point out some of the methodological limitations related to the study of code compliance which make it difficult to generalize from the studies examined in this paper to other regions in the country.

COMPLIANCE STUDIES

We examined statewide analyses of code compliance in three states which indicated the amount of noncompliance with state building energy codes (California: Berkeley Solar Group 1995 and Valley Energy Consultants 1994; Oregon: Frankel and Baylon 1994; and Washington: Warwick et al.

1993). Two additional California studies were limited to one utility service area (Pacific Gas and Electric Company: Eley Associates 1994; and Quantum Consulting and RCG/Hagler, Bailly 1993).

All of the studies examined single-family houses that were built during a similar time period (1992-94), and most of the studies used similar methodologies for evaluating compliance (reviews of plans and compliance documentation, site inspections, and energy simulations) (Table 1). Sample sizes varied from 89 to 1,230 houses, as did geographic location (from the cool, moist climates of the Pacific Northwest to the hot, arid valleys of Central California). All but one study (Berkeley Solar Group 1995) included some homes that participated in a utility RNC program. As discussed later, many of these studies had methodological limitations, making it difficult to transfer their findings to other parts of the country.

COMPLIANCE METHODOLOGY

Code compliance is difficult to measure and is rarely the subject of evaluation. Typically, codes include a variety of compliance options, or paths, in order to allow flexibility to home builders in meeting the code requirements.[1] In addition, there are typically a number of specific additional requirements that must be met for all projects (e.g., minimum furnace efficiency, air conditioner SEER, hot water pipe insulation, and duct insulation). Compliance can be measured on a prescriptive basis (e.g., identifying whether specific prescriptive components of the code (e.g., ceiling insulation) were installed or built), or on a performance basis

Table 1. *Building Code Compliance Studies*

State	Study	Year Homes Built	Sample Size	Type of Review	Site Inspections	Includes Utility Program Participants?
California	Berkeley Solar Group	1993–94	1,230 houses in hot valley climates	Energy/compliance documentation, site inspections, and monitoring	96	No
California	Eley Associates	1992	96 utility program participants and 42 nonparticipants (all air-conditioned residences in hot valley climiates)	Energy/compliance documentation, site inspections	All	Yes
California	Quantum Consulting	1992	40 nonparticipant houses built by production builders	Plans and site inspections	38	Yes
California	Valley Energy Consultants	1993–94	89 houses in 30 jurisdictions	Energy/compliance documentation, plans, and site inspections	All	Yes
Washington	Warwick et al	1992–93	128 houses participating in WSEC Program from 30 jurisdictions	Site inspections	All	Yes
Oregon	Frankel and Baylon	1993–94	283 houses from 65 jurisdictions	Energy/compliance documentation, site inspections	All	Yes

(e.g., comparing the energy use of an ''as-built'' home with the energy budget required in the building code). When evaluating code compliance using a prescriptive approach, one can examine code violations in energy calculations, plans, and in the field. Calculation violations are recorded when energy calculations are incorrect (e.g., energy claims or credits without supporting documentation). Plan violations are recorded when plans do not show energy features either indicated by the calculations or required by the energy codes. And field violations are recorded when measure installation is not in accordance with the plans.

In the prescriptive path, prescriptive components must be met, and lower-performing components cannot be traded off (or substituted) against a better one. In the energy performance path, the overall envelope heat loss rate of the built house is compared with the heat loss rate anticipated if the house had been built according to code. In this case, a house may have one or more components that do not perform as well as the code mandates, but other components may outperform code requirements enough to make up the difference. A house with the heat loss rate the same as or lower than anticipated by the code would be deemed to comply with code requirements, regardless of individual component makeup.

Several of the studies examined in this paper used the prescriptive approach for analyzing compliance, although most of these studies also examined the energy use implications of noncompliance. However, the prescriptive paths and requirements of state codes give relatively little margin for interpretation. Either a house complies exactly as required or it does not. This results in a low overall compliance rate. In general, this compliance rate does not reflect the anticipated energy performance impact of these homes, since often noncompliance is the result of a relatively minor variation between the code and the as-built condition, or an aspect of the code which does not significantly affect energy performance (e.g., low-flow water fixtures) (see below).

In this context, errors can be positive or negative (i.e., saving or costing energy). Thus, when evaluating compliance using a prescriptive path, it is important to know whether or not the cumulative effect of the errors alters compliance with the performance aspects of the energy code. In one of the evaluations of the California building energy codes, the following key questions were asked when evaluating discrepancies (errors) in compliance: (1) Will the error help or hurt compliance? (2) Is the error off by a factor of 3% or 30%? (3) Does the error involve something substantial like glass areas or something relatively unimportant like conditioned volume? (4) Were there an equal number of errors that substantially helped compliance or were the only errors made hurting overall compliance? and (5) Is the building substantially over compliance or barely meeting compliance with respect to energy consumption? (Valley Energy Consultants 1994).

As noted above, a few studies developed methods that translated building compliance into energy use, applying a heat transfer model that could be used in a standard engineering model of building energy use. For example, in the evaluation of building compliance in Washington, data were translated into indices that reflected the fraction of savings achieved for each construction element in terms of whole house heat loss (Warwick et al. 1993).

While most of the studies in our sample examined building compliance from a ''whole building perspective,'' one study evaluated compliance from a ''building component perspective'' (Warwick et al. 1993). In Washington, data were collected for major construction activities and graded compliance on a four-point scale, giving a relative measure of the completeness of compliance (rather than ''yes'' or ''no''). Site inspection procedures were geared toward specific stages of construction rather than specific sites. This approach prevented the development of site-specific indices (e.g. this site is within 90% of code compliance). Instead, compliance was summarized across sites and compliance topics (e.g., insulation, windows and doors, etc.). For example, house ''A'' might have an average component compliance rating of 2.50 for slab, 2.03 for floor, 2.21 for wall, 1.83 for ceiling, 1.33 for windows, 1.33 for doors, and 1.71 for duct (based on a scale ranging from ''1'' (the component fully complied with the code) to ''4'' (''worst compliance'')). Component check list results were averaged for compliance with building energy codes across all sites, providing an indicator of overall component compliance level and revealing categorical compliance problems.

Finally, it is important to note that the *quality* of construction was not normally evaluated in these studies. Unless clearly indicated by the building code, building officials prefer not to enforce workmanship (e.g., improperly supported floor insulation), deeming it too subjective and sometimes politically delicate to enforce. In the study conducted in Washington, the quality of the installation of some energy measures was found to be ''poor'' in some site inspections (e.g., compacted insulation around ductwork, loose insulation in floors, lack of insulation support in underflooring, and insulation gaps at ducting boots and elbows) (Warwick et al. 1993). In many cases, however, the authors found through site inspections that the quality of an installation did not appear to be at variance with the code and, therefore, was not identified as an item needing repair.

BUILDING CODE COMPLIANCE FINDINGS

In general, the analyses of code compliance in California showed that most buildings met the intent of the building energy codes and, on average, the houses complied with the codes. In both the statewide and utility studies, a high number of violations (in plans, in the field, and in energy impacts) was found, especially for builders not participating in utility new construction programs (see below). However, in two of the three studies where energy consumption was calculated (following the standard state rules for compliance calculations), the houses complied with the state building energy codes on average (i.e., the energy savings from the houses that complied compensated for the excessive energy use of those that did not comply); as discussed below, the third study (Quantum Consulting and RCG/Hagler, Bailly 1993) found some homes to be building below (i.e., did not meet) the state building energy code.

In the analyses of code compliance in Oregon and Washington, most buildings met the intent of the building energy codes and, on average, the houses complied with the codes. The Oregon evaluation found many problems with compliance from both a whole house and component perspective: while only 55% of the houses met *all* of the specific prescriptive requirements (prescriptive compliance is the basis of the Oregon Energy Code), the level of compliance on individual components was high (85%) (Frankel and Baylon 1994). When compliance was evaluated based on the overall envelope heat loss rate, compliance was 80%, or 98% if the heat loss rate was allowed to vary within 5% of the code target to comply. On average, these homes' energy performance was 6% better than anticipated by the code (Frankel and Baylon 1994).

While there was some noncompliance (3%) with the Washington code, the impact on thermal performance of typical homes was estimated to be minor (Warwick et al. 1993). Nevertheless, as noted above, compliance with the code still left plenty of room for improvements in the quality of measure installation which affects energy use.

In summary, the type of approach used in measuring compliance will have a significant impact on the evaluation of utility RNC programs. If compliance is measured using only a prescriptive path (as is sometimes done in the evaluations of utility RNC programs), then the actual baseline of energy performance is lower (i.e., less stringent) than the state code due to noncompliance. However, if the energy impacts of noncompliance are calculated, then homes, on average, comply with the state codes (at least in the states examined in this paper—see below for more discussion).

Specific violations

All of the studies found noncompliance for selected measures. We mention some of the more common examples, so that the building community (as well as program evaluators) can learn from the experience of others for improving the energy efficiency of homes. In one of the California statewide studies (Valley Energy Consultants 1994), the most common residential violations (excluding lack of insulation certificates and installation certificates for manufactured devices) found at the building level were the following:

(1) **Glazing area.** The ratio of glass to floor area has a significant effect on building energy compliance. This component was a common error in both plan check and field inspection. The largest number of errors were from plan to calculations, where the amount of glass shown on the plans was not accurately reflected in the energy calculations.

(2) **Water heater tank insulation.** Tanks requiring insulation frequently were not reported in plans and often did not have insulation installed, even after final inspection (many builders thought that the water heater tank had sufficient insulation, requiring no additional insulation).

(3) **Glazing type.** Typically, the glazing type called for on the energy calculations was not shown on the plans.

(4) **Thermal mass.** Thermal mass credit was taken where inappropriate (e.g., a common frame wall), and often incorrect values were used; in addition, features receiving thermal mass credit were not shown on the plans, although used in energy calculations.

In the second statewide study in California (Berkeley Solar Group 1995), almost 70% of the 96 audited houses overstated (compared to compliance form data) the efficiency of one or more 5 key measures (Table 2), and all audited houses overstated the efficiency of at least one efficiency measure. As seen in Table 2, there were as many cases of understated efficiency as overstated efficiency. And for mandatory measures, those which the energy codes require in all new houses and which cannot be traded off in calculations, two measures were found in noncompliance: (1) hot water pipe insulation was missing in 21% of the houses, and (2) high efficacy fluorescent lights in kitchens and bathrooms were missing in about 50% of the houses.[2]

In the evaluation of Pacific Gas and Electric's (PG&E) residential new construction program (Eley Associates 1994), key discrepancies were found for the following measures among a sample of 96 RNC participants and 42 nonparticipants:

(1) **Wall insulation**. Over half of those homes in which wall inspection could be inspected (i.e., 5 out of 9) had different levels of wall insulation than was indicated on the compliance documentation (1 had lower R-value, and 4 had higher R-values);

Table 2. ***Building Code Compliance in California***

Measure	Accuracy of Stated Efficiency (Complaince Form Compared to Field Audit Aata)		
	Percent of Forms that Overstate (%)	Percent of Forms that are Correct (%)	Percent of Forms that Understate (%)
Furnace efficiency (rated AFUE)	8	38	54
Air-Conditioner Efficiency (rated SEER)	17	32	51
Attic insulation (R-value)	45	41	14
Glazing (number of panes)	35	61	4
Glazing area	30	38	32

Source: Berkeley Solar Group 1995.
Note: See Table 1 for a description of housing sample.

(2) **Attic insulation**. 23 discrepancies (14 had less insulation than indicated and 9 had more insulation than indicated);

(3) **Air-conditioning SEER ratings**. 59 discrepancies (20 had lower than listed, 39 had higher than listed);

(4) **Furnace seasonal efficiency (SE) ratings**. 100 discrepancies (28 had lower SE ratings than listed, 81 had higher than listed); and

(5) **Duct insulation**. 6 discrepancies (all had less insulation than indicated).

The contribution of the differences between submitted and inspected energy efficiency features to the overall source energy use of each home was typically less than 1 kBtu/ft^2/yr. The most significant energy use impact came from changes in mechanical system efficiencies (e.g., air conditioner SEER ratings and furnace SEs), rather than changes in the building shell.

In the evaluation of building code compliance in Oregon, the principal difficulties associated with prescriptive compliance were: (1) window performance issues, complicated by labeling anomalies in 1993; (2) the use of uninsulated entry doors in excess of the 24 ft^2 allowance in the code; (3) the use of R-30 insulation in vaulted ceilings where vaulted ceilings exceeded 50% of the floor area; and (4) conditions in which blown-in insulation in vaults and attics did not meet the overall code requirements (due to under insulation) (Frankel and Baylon 1994). The principal problem associated with field reviews in Oregon was the widespread absence of labeling on windows and doors. Compliance with other requirements (e.g., vapor barriers, low-flow fixtures, outside combustion air) was 55%. Finally, in the evaluation of building code compliance in Washington, the lowest compliance level was for slab-on-grade insulation; the highest compliance level was for windows and doors (Warwick et al. 1993).

UTILITY PROGRAM PARTICIPANTS

Three studies demonstrated that compliance with state building codes is higher for participants in utility RNC programs than for nonparticipants. The energy comparisons were based on simulation runs (using onsite data where available) and, therefore, did not account for differences in construction quality. In the evaluation of PG&E's 1992 RNC program, nonparticipating homes in PG&E's service territory were, on average, built 5.8% kBtu/ft^2/yr below (i.e., did not meet) Title-24 building energy codes (based on calculated energy usage) across all measures and equipment (Quantum Consulting and RCG/Hagler, Bailly 1993). In contrast, PG&E's program required participating builders to participate in the program's ''Plan Check'' process to comply with the codes when they might not have otherwise done so (i.e., 100% compliance). Accordingly, PG&E claimed additional energy savings from its program through its role in enforcing compliance with the energy codes. The 5.8% enhanced enforcement savings for homes built under the 1992 Title-24 energy codes was filed in PG&E's March 1994 Advice Filing with the California Public Utilities Commission (CPUC). The

CPUC approved PG&E's request, and the savings were incorporated in PG&E's 1994 earnings claim.

In a follow-up study, Eley Associates (1994) found that PG&E's program increased both the frequency and level of compliance (determined by calculating the home's overall reduction in calculated annual source energy use compared to a similar standard compliance home) with the 1988 Title 24 building energy codes in PG&E's service territory (Table 3). Although both participating homes and nonparticipants were found, on average, to comply with Title 24, the compliance margin of participating homes was nearly twice as great as that for nonparticipants. Furthermore, nonparticipant homes were more than ten times as likely to fail to comply with Title 24 than participants homes. The savings were primarily in source cooling energy use (26% cooling energy reduction for participants, compared to a 7% reduction for nonparticipants), the focus of PG&E's RNC program.

Utility programs in Oregon seemed to have had a similar, significant impact on compliance: all of the homes participating in utility RNC programs complied with the code and their performance was 6% (based on annual kWh) better than anticipated by the code (Frankel and Baylon 1994).

In conclusion, while the data are very limited, it appears that utility programs can be successful in making sure that homes built in their program exceed the state energy code.

METHODOLOGICAL LIMITATIONS

Each of the studies examined in this report has one or more methodological limitations, making it very difficult to transfer the lessons learned from these studies to other parts of the country. Some of these limitations are explicit, while others are implicit. The purpose of this section of the paper is to make people aware of the different kinds of limitations (self-selection bias, comparison sample bias, market bias, and geographical bias) affecting code compliance studies.

Self-selection bias

All of the studies depended on the cooperation of building departments, developers, and builders that voluntarily agreed to participate in the study (some in each group refused to cooperate and were not included). In some cases, the houses studied were selected by building department officials who chose projects convenient to them (e.g., projects that were already scheduled for field inspection). Generally, the researchers sought to minimize the possibility of bias by telling building department officials that specific findings would remain confidential and that no punitive actions would be taken based on findings recorded in their jurisdiction. However, it was likely that building departments positively inclined toward state energy commissions and building energy codes would also be more willing to participate in the study than those with a more negative view.

Similarly, it may be reasonable to assume that developers willing to have their homes inspected were more likely to comply with state building energy codes than those who were unwilling. Also, builders participating in utility RNC programs may be viewed as ''free riders:'' they would have built the same houses even if they had not participated in the utility program. However, in our interviews, we found that most DSM program managers believe that the builders participating in their utility RNC programs would *not* have built energy-efficient homes that met program standards if there had not been a program (i.e., zero free ridership) (see Vine 1995). Therefore, we do not feel there is a self-selection bias regarding the samples of utility program participants in these studies.

Table 3. *Level and Frequency of Compliance With Building Code*

Groups	% Non-Compliance Homes	Submitted (Planned) Compliance Margin[a]	Inspected (As-Built) Compliance Margin[a]	Lower 90% Confidence Limit	Upper 90% Confidence Limit
Utility Program Participants	1%	13%	14%	13%	15%
Non-Participants	12%	8%	8%	6%	9%

Source: Eley Associates 1994.
[a] Margin is based on calculated annual source energy consumption, compared to that of similar standard compliance house.

Nevertheless, in many cases, the samples in these studies were ''biased'' but to a degree unknown and, therefore, may not be representative of the rest of the building community.[3]

Comparison sample bias

In some areas, it is difficult to find a sample of homes to act as a ''control group'' to compare to homes built in a utility program. For example, in the evaluation of PG&E's new construction program, 61% of the home builders in the nonparticipant sample also built homes in the utility program (Eley Associates 1994). Similarly, in the evaluation of the Washington code, code officials in jurisdictions not participating in the Washington State Energy Code Program typically took part in training and technical assistance offered through the program, reducing their potential as a ''control'' group for comparison purposes. Therefore, the differences between homes built under a utility RNC program versus nonparticipating homes are affected by the degree of program spillover or market transformation that has occurred in the area (Vine 1995). Unlike the findings from the previous section, this point reinforces the need for looking at market transformation impacts of RNC programs, i.e., to look at energy savings via code compliance for both participants and nonparticipants in utility RNC programs.

Market bias

The goal of these studies is to encourage and enhance the enforcement of building standards. Typically, building departments are chosen randomly, and building departments provide a list of buildings near completion for review. However, due to nonresponse bias (e.g., some building departments refuse to participate) and differences in construction activity levels (e.g., some building departments are located in areas where there is little new construction), the samples evaluated in some studies may be limited, reflecting specific climates (e.g., hot valley climates), areas with lots of new construction, and specific builders (e.g., production builders versus custom home builders). Combining this result with the secondary objectives of some studies to help building departments with ''trouble buildings'' (leading building officials to select projects that reflect particularly troublesome code applications) or small- to medium-sized jurisdictions that have never received monitoring and training, the samples in some of these studies may be unrepresentative. In sum, the more focused the targeted population, the more difficult to generalize the results to other buildings and builders (assuming the target group is unrepresentative).

Geographical bias

Compliance with state building codes reflects the institutional environment for both code adoption and compliance established prior to code adoption. For example, California, Oregon and Washington have spent a considerable amount of resources on improving the expertise of builders and building code officials through training and educational programs. In addition, many jurisdictions have had over 15 years of experience with energy efficiency codes, code support (by utility, local government, and code officials), and code enforcement. Accordingly, other areas in the country with less experience and expertise in building codes and building code compliance will undoubtedly experience different results than those reported in this paper (e.g., higher rates of noncompliance with state building codes).

In summary, most of these biases do not negatively affect the primary conclusion of this paper (increased code compliance by utility program participants). In fact, estimates of savings from these programs are probably conservative, compared to other regions of the country.

CONCLUSIONS

In this paper, we have shown that many homes do not meet energy codes based on a prescriptive path and also that (based on a small sample) homes participating in utility RNC programs have higher frequency and levels of building compliance compared to nonparticipating homes. We expect these differences (as well as the energy implications of noncompliance) to be greater in those states with less experience and expertise in building codes and building code compliance. Accordingly, we believe utility RNC programs in other states could be more cost-effective if utility regulators recognize the role of RNC programs in increasing compliance by participants with existing state building codes; or, conversely, if they recognize the general degree of noncompliance among nonparticipating builders. Furthermore, although not a significant problem in the studies examined in this paper, utility regulators should also consider recognizing the role of RNC programs in improving the quality of workmanship, particularly if the persistence of energy savings is deemed to be important.

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END NOTES

1. For example, there are nine prescriptive and one performance compliance paths in the Oregon Residential Energy Code.

2. Monitoring data also showed that the state building energy code assumptions of a large nighttime setback of the heating thermostat setpoint and 100% continuous air conditioning could not be supported.

3. Typically, utility program participants are required to participate in these studies, as a condition of their participation in the program.

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