Compliance With The 1994 Nonresidential Washington State Energy Code

Kevin Madison, Utility Code Group, Seattle, WA
David Baylon, Ecotope, Inc., Seattle, WA

ABSTRACT

This evaluation was conducted to assess compliance with the 1994 Washington State Non-Residential Energy Code (NREC), and the effectiveness of the Code Implementation Plan, code simplification activities, and other utility-supported training and implementation efforts. A field review was conducted on a random sample of 88 commercial buildings in Washington permitted and built in 1995 and 1996. Compliance was assessed on all major components of the NREC. The baseline was taken from a similar review conducted in 1991. A full energy audit of each building was conducted, and approximately 200 interviews with architects, engineers and building officials.

Overall compliance was marginally better than the baseline, but significantly better for those groups directly impacted by the Implementation Plan or training programs. Attitudes toward code compliance improved significantly among the professional communities (especially building officials) as available support increased. Acceptance by architects and engineers improved dramatically from the baseline study, with most respondents indicating that the energy code was a major consideration when designing structures. Marketing and training components of the Implementation Plan also had an impact on these groups, especially in buildings reviewed by Special Plans Examiners/Inspectors.

The evidence suggests that the simplification and direct implementation support included in the 1994 energy code revisions had substantial impacts on both compliance and acceptance, as well as on overall building practices throughout Washington. This paper will include suggested revisions to the NREC to simplify energy code compliance and enforcement in a climate of reduced utility funding for energy conservation programs.

Introduction and Chronology

Code Revision Process (1992)

In 1992, the State of Washington made draft revisions to the existing nonresidential energy code (NREC). The process involved the review of ASHRAE/IES 90.1-1989 by several committees and resulted in a translation of those design guidelines into code language. The only variations from ASHRAE 90.1 were more stringent envelope requirements for electric resistance heating, a lower exemption threshold for economizers, and lower unit lighting power allowances.

During the public review process of the draft revisions, Ecotope completed a compliance study of nonresidential buildings built in 1990, which showed that almost 50% of the buildings did not meet at least one fundamental portion of the existing energy code (Baylon et al. 1992). More importantly, the study found a relatively high level of animosity toward the energy code among design, construction and enforcement sectors, and a wide-spread belief that non-compliance would not result in negative consequences. The Ecotope study concluded that, given the complexity of the existing code and the low level of support underlying it, code compliance and industry attitudes would not improve, and most likely would get worse, if the draft being considered at that time was approved.

As a result of this study, the State of Washington simplified the draft code; developed an Implementation Plan addressing needs of various industry sectors; and negotiated funding from Washington's electric and natural gas utilities for training, technical assistance, enforcement support and evaluation (Madison et al. 1994).

Quality Assurance Review (1995)

In 1995, Ecotope conducted an awareness survey of 400 design, construction and enforcement professionals, and a quality assurance review of 40 buildings in selected jurisdictions (Baylon et al. 1996). This survey showed that awareness of energy code requirements had dramatically increased since the 1992 study, with the majority of designers, contractors and code officials indicating a legal and even professional obligation to comply with the NREC. The Special Plans Examiner/Inspector (SPE/I) plan review and inspection process was responsible for nearly perfect compliance levels in some jurisdictions. The high level of promotion, training and technical assistance resulting from utility funding was responsible for the general shift in attitude and practice.

In spite of this seeming success, all industry sectors regarded the envelope requirements as needlessly complex, and code officials still believed that many HVAC requirements were confusing and difficult to verify. In contrast, all sectors were generally supportive of the separate requirements for single zone HVAC systems.

The 1994 NREC and associated Implementation Plan did not necessarily achieve the goal of increased simplicity. For example, more than 30 prescriptive envelope tables were added. Each of the tables was fairly simple, but the task of identifying the best table to use for compliance from among so many choices actually became more difficult. However, the utility-funded Implementation Plan provided much more support to code officials, designers and installers in the form of third party review, technical support, and technical training. This support helped Building Departments enforce a more complicated code than would otherwise be feasible.

Impact Evaluation

In 1996, Ecotope conducted an impact evaluation to examine compliance with the 1994 NREC and the effects of various aspects of the utilities' implementation activities (Baylon et al. 1997). The study involved site visits to 88 new nonresidential buildings and 20 tenant improvements. Interviews were conducted with more than 200 engineers, architects, contractors and code officials. Though the study revealed total compliance had increased only marginally, more in-depth analysis indicates that this conclusion does not accurately capture the true improvement. In almost all cases, non-compliance was due to only one code requirement not being met, and the margin by which the code efficiency targets were exceeded was considerably smaller than seen in the 1990 sample.

Other improvements were more apparent. Certain implementation activities, such as support for third-party plan review and inspection, had a substantial positive effect on compliance (although this effect varied considerably by jurisdiction). Acceptance by the design and construction sectors had improved dramatically from the 1992 study in all jurisdictions. One constant theme emerged from interviews conducted with design professionals, building officials, and builders -- the demand for a more simplified code that would ease comprehension, compliance, and enforcement.

Industry Attitudes Toward The NREC

Improved compliance over that observed in the 1992 study is primarily attributed to the significant financial support of the region's utilities. As utility funding decreases, the State of Washington is seeking to reduce costs of energy code compliance through code simplification that maintains minimum efficiency levels. To that end, interviews with engineers, architects, contractors and code officials provide important guidance on the next evolution of energy codes in Washington.

General support and acceptance of the energy code was expressed by 63% of design and construction professionals, while 25% expressed hostility. Table 1 depicts these attitudes based on responses to key questions made during the interview, as classified qualitatively by the interviewers. Other than complexity, the most urgent complaint by design professionals was that enforcement is uneven across jurisdictions.

Code officials were generally supportive of the energy code; however, hostility was much higher among field inspectors than plan reviewers. Resistance was highest in jurisdictions requiring third-party plan review and inspection for all nonresidential projects, regardless of size. The most frequent suggestions for improvement were a more prescriptive code and simplified compliance procedures.

Table 1. NREC Support Levels by Profession

	Architect	Engineer	Contractor	Other	Plans Examiner	Field Inspector
Supporter: (Promotes NREC)	0%	1%	5%	4%	52%	21%
Complier: (Likely to comply)	57%	75%	38%	59%	24%	38%
Indifferent: (Not inclined to comply; will when required)	16%	4%	29%	7%	10%	29%
Resistor: (Antagonistic toward NREC)	27%	19%	29%	30%	14%	12%

Compliance Findings and Recommendations

All of the sample buildings were subjected to document reviews and on-site inspections. Compliance was determined by a review of three key areas which had the greatest impact on overall energy use (and in which compliance could be verified): envelope, HVAC systems, and lighting. In some cases, the expected building use was changed during the leasing process. Failure to comply with the NREC due to equipment added after occupancy did not affect the compliance determination, but was noted by the reviewers.

The sample design was based on a Neyman allocation and a Dalenius-Hodges stratification methodology (Cochran 1977). This procedure uses an optimized sample to ensure representativeness that correctly characterizes the entire range of building types across the population. Sample buildings were recruited via the F.W. Dodge *Dataline* database, which provides the most comprehensive statewide survey of new commercial construction available. Sample buildings were separated by square footage into three strata, and allocated to one of 11 use types. Sample weights were applied to each stratum to reflect the sampling probability afforded each building. Table 2 compares the compliance findings for the 1992 and the 1997 reviews. In both studies, compliance with prescriptive aspects of the energy code was much greater than the overall compliance rate.

Table 2. Comparison of Compliance Rates by Sample.

	% of Sample		% of Weighted Sample		% of Area Weighted Sample	
	1995	**1990**	**1995**	**1990**	**1995**	**1990**
Envelope	84	80	84	78	86	78
HVAC	86	76	87	74	80	74
Lighting	81	76	67	72	83	72
Total	61	51	50	47	59	47

Building Envelope Compliance

According to interviews with building officials, two-thirds of the projects used prescriptive paths to demonstrate building envelope compliance. Conversely, architects asserted in interviews that 60% of the envelope compliance was demonstrated with the component performance path in order to avoid the need for slab edge insulation. The observed envelope compliance rate in the field sample was 84%. About 60% of these buildings also complied with prescriptive envelope requirements; compliance was unaffected by the slab edge insulation requirements.

Compliance with glazing requirements is extremely complicated due to two factors: 1) there are over 30 prescriptive paths and 2) the 1994 NREC assumed that all or most window manufacturers would have their products certified in accordance with National Fenestration Research Council (NFRC) standards. While ASHRAE procedures or manufacturers specifications were allowed for shading coefficient, only a conservative default table was included as an alternative for determining window U-factors. Although NFRC certification is common practice for residential windows and skylights, no NFRC ratings on commercial glazing products and systems were observed.

Only one designer indicated that the NREC caused the use of less glass than they desired; however, many indicated that they specified different U-factors as a result of the NREC. Table 3 shows the statewide average glazing percentage. NREC requirements for U-factor and shading coefficient are not significantly different between climate zones if the glazing percentage is below 30%. Ten percent of the buildings did not comply with shading coefficient requirements. In this sample, however, better shading coefficients did not correlate with increased glazing area.

Insulation requirements for opaque assemblies were sometimes a source of confusion. Prescriptive insulation requirements and system performance criteria vary depending on climate zone, the use of electric resistance heat and assembly type. It is possible to use some metal framing and insulation configurations in both climate zones, while not other assembly types. Metal and wood studs may be used interchangeably even though one is much less energy efficient than the other.

Table 3. Glazing Levels By Building Type

Building Type	Population (N)	% Window Area	U-Factor Actual	U-Factor Code
Office	10	25.6	.58	.59
Retail	13	11.5	.78	.77
Grocery	6	6.2	.72	.74
Restaurant	6	16.2	.60	.69
Warehouse	14	9.1	.73	.77
School	7	17.0	.59	.70
Assembly	6	8.8	.57	.75
Institution	4	11.3	.58	.65
Lodging	2	11.0	.54	.90
Health	2	13.5	.50	.40
Other	17	6.9	.69	.79

Envelope Improvements and Simplifications

The 1997 evaluation results suggest some fundamental envelope requirement simplifications are possible without affecting overall efficiency levels. With the exception of wall insulation levels, there appears to be no need for different criteria based on climate zones. This study, as well as the previous two studies, support a greatly reduced set of prescriptive requirements and performance criteria. These would improve compliance, enforcement and industry acceptance. Table 4 shows the recommended building envelope requirements.

Table 4. Recommended Requirements: Building Envelope

		Climate Zone 1		Climate Zone 2	
Opaque Component		**R-Value**	**U-Factor**	**R-Value**	**U-Factor**
Roof		25	0.04	25	0.04
Opaque Walls*		11	0.10	19	0.07
Opaque Doors		n/a	0.60	n/a	0.60
Floors		19	0.05	19	0.05
Slab on Grade		no requirement		no requirement	
Glazing Component		**U-Factor**	**SC**	**U-Factor**	**SC**
Vertical**	<10%	0.60	no req	0.60	no req
	10-30%	0.50	0.65	0.50	0.65
	>30%	0.40	0.45	0.40	0.45

* Other variations for wall construction types would be included.

** Overhead glazing requirement would be included.

HVAC Compliance

NREC requirements for HVAC systems are almost entirely prescriptive. The NREC also allows single zone systems to utilize a "simple systems" path. These were the most common systems observed in most size categories. In buildings smaller than 10,000 ft^2, these were typically package rooftop systems (constant volume). Requirements for simple systems consist of: 1) ensuring all new equipment meets federal standards; 2) use of air economizers; and 3) use of 7-day programmable thermostats. Non-compliance for this group of systems was primarily related to economizer or control issues. Requirements for complex systems closely follow ASHRAE/IES 90.1-1989, although most requirements have been translated into prescriptive provisions. The added simple systems path provided a concise compliance path for the majority of buildings in this sample. Ironically, this "addition" resulted in increased acceptance and compliance for the entire HVAC code.

The NREC also includes additional mandatory requirements for duct sealing and insulation, pipe insulation, and zone level controls for multi-zone systems. Information on these system elements was collected during document reviews, field visits and interviews.

The evaluation revealed important insights into the enforcement of requirements for sealing, insulation and controls. Code officials sometimes look for the existence of insulation, as well as the R-value for ducts. However, pipe insulation thickness is usually not reviewed since it is rarely included on the submitted plans. Likewise, control specifications, which would demonstrate code compliance, are not included on the plans or on the compliance forms. Only a detailed review of specifications and design diagrams would allow a code official to discern if the system meets the NREC. Not surprisingly, there was no evidence of plan review or field enforcement of control requirements for complex systems. With the exception of thermostat controls in single-zone systems, HVAC control systems were not included in the determination of compliance.

HVAC Simplifications

Even though the fewest specific recommendations for improvements were received for the HVAC section of the NREC, there were a large number of general requests for a more simplified HVAC code. For simple systems, allowing weekday/weekend thermostats would add greater flexibility to the code and make enforcement easier, while only causing a negligible increase in energy use.

Equipment efficiency requirements should continue to mirror federal manufacturing requirements. These standards need to appear in code documents as relevant. The net effect in almost all cases would be to require newly purchased equipment.

For complex systems, code officials found control requirements particularly difficult to enforce. Aside from zone level thermostatic controls and reset requirements, we recommend the removal of control design and operations requirements within the code. The growing use of energy management systems and long-term warranties and commissioning practices, combined with increasing complexity, certainly reduce the practical application of any code requirement.

Duct and pipe insulation requirements are drawn directly from ASHRAE/IES 90.1-1989, and involve a complex combination of code language, tables of insulation requirements, and calculation procedures for alternative systems. These are difficult to understand and enforce. These requirements should be simplified to require a minimum R-value for all duct insulation (perhaps R-5 or R-7) and minimum pipe insulation thickness, as specified in Table 5.

Table 5. Recommended Pipe Insulation Thickness

Fluid Description	Minimum Pipe Insulation Thickness (inches)*	
	Feeders & Runouts to Terminal Devices	All Other Piping
Steam	1.5	3.0
Hot Water	0.5	1.5
Chilled Liquids	0.5	1.0

* Maximum thermal conductivity may also be appropriate.

Lighting Compliance

Lighting compliance was primarily achieved using lighting power density (LPD) calculations to determine a lighting power allowance (LPA) for various areas within the building. The NREC also contains a prescriptive path which allows unlimited use of unlensed fixtures with two T8 lamps and electronic ballasts or pin-mounted compact fluorescent fixtures with electronic ballasts. A review of compliance forms for the sample identified only four buildings that used the prescriptive path. Three of these would have complied with the LPA approach. Overall lighting compliance was 83%.

The application of different LPAs to various sub-components of the building allows considerable abuse to occur in LPD calculations. In one case, a lighting designer labeled a room ultimately used for storage as a conference room in order to take advantage of the much higher allowed LPA. This same engineer also "overestimated" the floor area in some spaces. Presumably, if the building as a whole had a single lighting power allowance, the abuse associated with this kind of practice would be much easier to control. In spite of requirements for space-by-space calculations, use of the LPA approach did not result in significant differences in installed lighting power across different building types. Retail spaces had the highest LPDs of all building types, while storage spaces had the lowest.

Table 6. Lighting Loads by Building Type

Building Type	Population #	Actual LPD	Code (Allowed) LPD	Ratio
Office	10	1.11	1.18	.94
Retail	13	1.76	1.41	1.33*
Grocery	6	1.56	1.43	1.09*
Restaurant	6	1.26	1.35	.95
Warehouse	15	.56	.81	.72
School	7	1.16	1.37	.85
Assembly	4	1.17	1.58	.76
Institution	4	1.17	1.58	.76
Lodging	2	.53	.83	.64
Health	2	1.00	1.50	.67
Other	17	1.09	1.57	.69

* Exceeds allowed LPD.

Table 6 provides the observed installed connected lighting loads for different building types. Examination of 20 tenant improvements as part of this study, as well as 40 new buildings built in 1995 (Baylon et al 1996), yielded similar findings.

The energy code mandated dual level switching prior to the 1994 revisions. In 1994, daylight switching was mandated in its place. None of the designers were pleased with this change. When switching was observed in the field, very few buildings used daylight switching in normal operating conditions even when special attention was paid to the energy code requirements. In fact, very few building operators understood daylight switching use as an energy conservation measure. It seems, however, that dual level switching has become standard building practice in Washington and was commonly used even in the absence of a code requirement.

Lighting Simplifications

Based on the reviews in this study, a single table of recommended building-wide LPA values was developed. Table 7 would enable nearly all buildings observed in this study to comply with the NREC. Only fixture count, fixture wattage, and total floor area are required to verify compliance with this approach. No space designations are necessary. These requirements would apply to all permanently installed lighting, including track lighting. The connected load for track lighting should be calculated as the maximum of the installed wattage of heads or a designated wattage per lineal foot of track. Under this approach, all non-permanent lighting would be ignored since it is usually not installed at the time of inspection. Tenant improvements would apply under the appropriate category without regard to other building activities.

Table 7. Recommended Lighting Power Allowances

Building Use	LPA* (W/ft^2)
Specialty Task Buildings Painting, welding, carpentry, machine shop, gymnasium, barber shop, laboratories, or where required for safety reasons.	2.0
Retail, Workshop, Factory & Non-Office or Non-Assembly Buildings Open to the Public Aircraft or auto repair shop, cafeteria, fast food business, library, casino, all retail.	1.5
Office, Assembly, Education & Institutional Institution, nursing home, school, laundry, museum, bank, church, police & fire station, meeting room, conference or banquet facility, exhibition hall, theater, restaurant, bar.	1.2
Warehouse	0.7
Covered Parking Facilities	0.2

* Whole building calculation.

Enforcement

The Special Plans Examiner/Special Inspector (SPE/I) Program was instituted by the utilities, the Washington Association of Building Officials (WABO) and the Seattle Regional Office of the International Conference of Building Officials (collectively referred to as "utility and code officials" in this study). The principal element of this program was a test and certification program developed and administered by the code officials. For three years after the effective date of the code, utilities reimbursed project owners directly for energy plan reviews and inspections performed by SPE/Is.

Building departments participating in this program usually required projects to be reviewed and inspected by private, third-party SPE/Is (paid for by the project owners). Of the jurisdictions interviewed, 23% relied on SPE/Is at least some of the time, and 20% required them for all plan reviews. Nearly all participating jurisdictions felt the program was working well for them, noting that the service relieved them of additional work. Others noted its usefulness with larger, more complex projects or when they were overloaded with projects.

An unanticipated benefit of the SPE/I program was the large number of code officials, engineers and architects who earned certification but did not act as third-party providers. Many code officials became certified, but their jurisdictions did not charge additional fees for energy plan reviews or inspections. Many certified engineers and architects also served as in-house specialists on energy code issues.

The highest observed compliance rates were in buildings where either a third-party plans examiner or inspector (or both) were involved with the project: 89% for envelope, 89% for HVAC and 78% for lighting. Projects for which at least one architect or engineer was a registered SPE/I had overall compliance rates of 67%, compared to 55% for the remainder of the sample. Table 8 shows compliance rates by the type of reviewer involved in energy code compliance. These determinations were usually made as a result of interview questions and could rarely be determined from document or field reviews.

Table 8. Compliance Rates by Reviewer Type

		Energy Code Compliance %			
Reviewer	**Population #**	**Envelope**	**HVAC**	**Lighting**	**Overall**
SPE/I	12	100	92	92	83
In-house Specialist	18	89	89	78	67
Other	58	79	84	79	55
Total	88	84	86	81	61

Aside from third party review and certification, the study results indicate that achieving the goal of increased enforcement was extremely inconsistent. While much of the confusion among code officials observed in the 1990 sample has been abated by training efforts, compliance has not appreciably improved. Failures of enforcement appeared equally frequently at both the plan review and inspection stages. A troubling trend is that compliance was lowest in some of the largest growth areas. Compliance levels in King, Pierce, Snohomish and Spokane counties were all less than 50%. In one case, this was apparently the result of a public disclosure by a building official that the energy code would be ignored. Most of the larger and more complex buildings were constructed in these four regions, but only one large jurisdiction required the use of SPE/Is on a consistent basis (the others conducted enforcement in-house).

Impacts of Code Simplification on Enforcement

As utilities in Washington continue to drop their funding levels for code enforcement and implementation, it becomes increasingly important that energy codes be fashioned to function within the traditional enforcement models. For the majority of buildings, this would require a set of minimum prescriptive provisions with alternatives for straightforward system performance calculations. Nearly 60% of all code officials interviewed believed that a more prescriptive code would be easier to enforce. More widespread, consistent enforcement could be a significant market force for the industry to learn and apply the code.

Larger, more complex buildings may not benefit from these same simplifications, however. The nature and size of the systems, not their corresponding code requirements, are what make these buildings difficult to inspect. Though utilities hoped the SPE/I program would be used for these buildings, it was mainly used by smaller jurisdictions seeing only simple buildings. A simplified code such as the one described here would be more easily implemented for simple buildings, thus freeing up remaining resources for enforcement support of more complex buildings.

This shift in resources would have the added benefit of greater energy savings as well. An analysis of construction starts shows that, in 1992 study, 26% of the buildings (121 total buildings) comprised 75% of the total floor area completed that year (Baylon et al. 1992). In the 1997 study, 28% (220 buildings) comprised 77% of the floor area (Baylon et al. 1997). Targeting the next evolution of the SPE/I program toward 30% of the buildings, which comprise approximately 80% of the built floor space, would likely achieve a much higher compliance rate (and resulting energy savings). In the 1995 sample, most buildings complying under the SPE/I approach were simple and relatively small buildings. This supports the conclusion that the program was successful with small jurisdictions where a more appropriate solution would be a simpler code. Future SPE/I funding should be targeted toward larger and more complex buildings for which enforcement is most difficult and the greatest energy savings can be achieved.

Energy Budget Path

None of the buildings surveyed in the 1995 sample used an energy budget path (also called performance path) to demonstrate compliance. In the 1990 sample, in excess of 15% of the buildings were permitted under this path. In 1990, utilities provide substantial subsidies for the use of simulation as part of their incentive programs. In the absence of these incentives for the 1995 stock, no engineers found the use of simulations to be cost-effective or helpful with code compliance.

Conclusions

The code compliance studies for the 1990 and 1995 samples showed compliance with prescriptive aspects of the energy code to be much higher than the overall compliance rate. The final recommendation in both studies was to provide a simplified code avenue <u>which is enforceable by building officials</u> using ordinary enforcement techniques. It is important to recognize that most building officials are not mechanical engineers or energy design professionals. These officials must be given the tools and time required to enforce code provisions. The required enforcement time is a primary consideration in the development of a prescriptive energy code.

Any new, simplified energy code in Washington should include the following:

- Greatly reduced number of prescriptive paths that reflect the general design practices observed during the study.
- Reduced numbers of categories and requirements for duct and pipe insulation.
- Possible reduction in the number of HVAC equipment efficiency and control requirements as industry practices progress.
- Fewer lighting power categories, with "whole building" regulations.

Enforcement and implementation revisions should include:

- Targeting simplified approaches at smaller, less complex, buildings (70% of the total permit activity).
- Changing focus of third-party enforcement and compliance support to larger buildings (80% of the built floor space).
- Utilizing simplified code requirements and high expectations of compliance as the primary marketing tools for training and technical assistance.

The development of the Implementation Plan and a Marketing Plan provided effective enforcement support. However, if the utilities are to be removed from the process, then conventional enforcement standards must be the basis for energy code development. If building professionals perceive the code as actively enforced, design and calculation accommodations will be made relatively quickly. As long as these calculations are not unnecessarily onerous or complex, the sustainability of the energy code will be the result.

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