Commercial Building Energy Code Compliance in Washington

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1 Introduction

Beginning in April 1991, Ecotope, Inc. and Clark's Energy Services began an evaluation of the non-residential energy code in the states of Washington and Oregon. These codes are meant to increase energy efficiency in commercial buildings by regulating components which affect energy use. This volume reports on the findings from the review of 70 buildings in the State of Washington.

The purpose of this study was four-fold:

1. To characterize building activity and current construction practices by developing and selecting a random sample of new commercial buildings.
2. To assess code compliance in this sample by reviewing building documents, conducting site visits and comparing the results with code requirements.
3. To interview design professionals and building code officials to determine attitudes toward the energy code and perceived training needs.
4. To review the energy code and suggest changes which might enhance compliance.

We did not review code enforcement procedures directly. The impact of enforcement on code compliance was addressed peripherally in the interviews, but this study focused on building professionals and current building practices. Thus, the building as planned and built was deemed the arbiter of code compliance.

The evaluation was conducted from July 1991 through November 1991. The final sample contained 70 Washington buildings, chosen at random from new commercial buildings permitted in 1990.

1.1 Energy Code

While other building codes are designed to provide public health and safety by setting a minimum standard and limits of liability, the energy code is different. It is essentially a design standard seeking to codify energy efficient design practices. That was the intent of the original ASHRAE 90 standard, which was adopted by various jurisdictions across the country as a model energy code. It gave mechanical engineers and designers some guidelines for designing an energy-efficient building. Revisions of the ASHRAE 90 standard have become increasingly sophisticated and more like code. Nonetheless, they are still design standards, not health or safety standards.

In Washington, these design standards have become incorporated into a statewide guideline, the Washington State Energy Code (WSEC), which is currently enforced by almost 300 jurisdictions. Each jurisdiction is responsible for enforcing the code under local ordinance. As might be expected, the quality and success of enforcement varies dramatically even though the codes are identical. A few jurisdictions (parts of Pierce and Spokane Counties) enforce the 1987 Northwest Energy Code (NWEC) which is similar to the WSEC. Our review takes into account the differences between these codes for buildings in these jurisdictions.

Compliance is only one index of the impact of energy codes. Another index is the degree to which building practice has responded to these codified design standards. Section Three discusses compliance levels while Section Four describes the impact of the code on building practices.

1.2 Code Compliance

We evaluated code compliance for three major building systems:

Envelope

- Envelope compliance is based on the allowable component heatloss rate (Uo), given in Table 4-3, based on two geographic regions of the state.
- Component values are based on target values for wall, ceiling and floor assemblies. Overall compliance is based on the sum of these values, so component tradeoffs are allowed.
- Envelope compliance can also be demonstrated as part of an overall building 'energy budget' submittal, allowing tradeoffs in energy use between envelope, lighting and mechanical systems (Chapter 5).

HVAC

- Equipment efficiencies for both heating and cooling equipment are regulated. For cooling equipment, efficiency is expressed as EER or SEER. Heating equipment efficiency ratings depend on the fuel source and may be rated as AFUE, COP or HSPF. Required efficiences are shown in Tables 4-12 through 4-15.
- Economizers, or outside air cooling capacity, are required on systems delivering more than 90 MBH or using more than 3,500 cfm. Some types of systems are exempted from this requirement (Section 414).
- The maximum capacity of heating and cooling equipment is limited to 150% of the calculated load of the equipment at peak design conditions (Section 407).
- The amount of fan/pump energy used by distribution systems or air transport factor (ATF) is regulated. The ratio between cooling capacity and total energy required by the distribution system (ATF) must exceed 5.5 (Section 412).

Lighting

- Lighting is regulated by watts per square foot (lighting power density or LPD). The allowable LPDs for various building occupancy types are listed in Table 4-18.
- Exterior lighting (parking lots and building perimeter lighting) is also regulated but can be combined with interior lighting power for a total lighting budget. This allows tradoffs between interior and exterior lighting systems (Section 426).
- Specific switching strategies are required. Separate switching is required for all spaces under 400ft^2. Spaces larger than this must have dual-level switching. Luminaires near windows must have separate switches. Exterior lights must be controlled by automatic switching devices, such as timers or photocells (Section 425).

1.3 Methodology

The evaluation took place in three stages.

Using data from the F.W. Dodge database service, we developed a sampling frame of all new commercial buildings permitted in Washington during 1990. From this group, we recruited buildings to participate in this study. Buildings were selected for the final sample if we could obtain copies of the building documents, permission for a site visit and an interview with at least one member of the design team.

During the second phase of the evaluation, we reviewed the plans, did detailed take-offs of the building envelope, mechanical and lighting systems and compared the results with the code requirements for these major building systems. We also conducted an audit of each building, verifying aspects of construction and mechanical and electrical equipment, where possible. Since the buildings were in various stages of construction not all aspects of energy code compliance could be verified. When we could not verify installation, we assumed the equipment and fixtures shown on the building plans would be installed and based compliance on these specifications.

Finally, we used a structured telephone interview format to ask architects and engineers involved in the design of these buildings about the specific building's design process and the code in general. We also interviewed building officials from jurisdictions which were significant in terms of construction activity and asked them for general comments about the energy code and the code compliance process.

1.4 Report Organization

Section Two describes the sample selection and construction practices observed. Section Three summarizes compliance levels for all buildings, including data weighted for area and sample biases. Section Four describes the impact of the code on current building practices. Section Five summarizes the interview responses of building professionals and code enforcement officials. Section Six contains the project team's conclusions and recommendations.

2 Sample Development

The sample of Washington buildings was drawn from the F.W. Dodge Dataline service. This is a private database which tracks commercial construction throughout the country. We reviewed data for all of 1990. We eliminated buildings that cost less than $200,000 to construct, tenant improvements, remodels, renovations, industrial process buildings, parking lots, parking garages and other non-building projects. A total of 468 buildings, representing 17.3 million square feet, met our criteria. This was considered reasonably representative of all the new commercial buildings built in the state of Washington in 1990.

2.1 Geographic Distribution

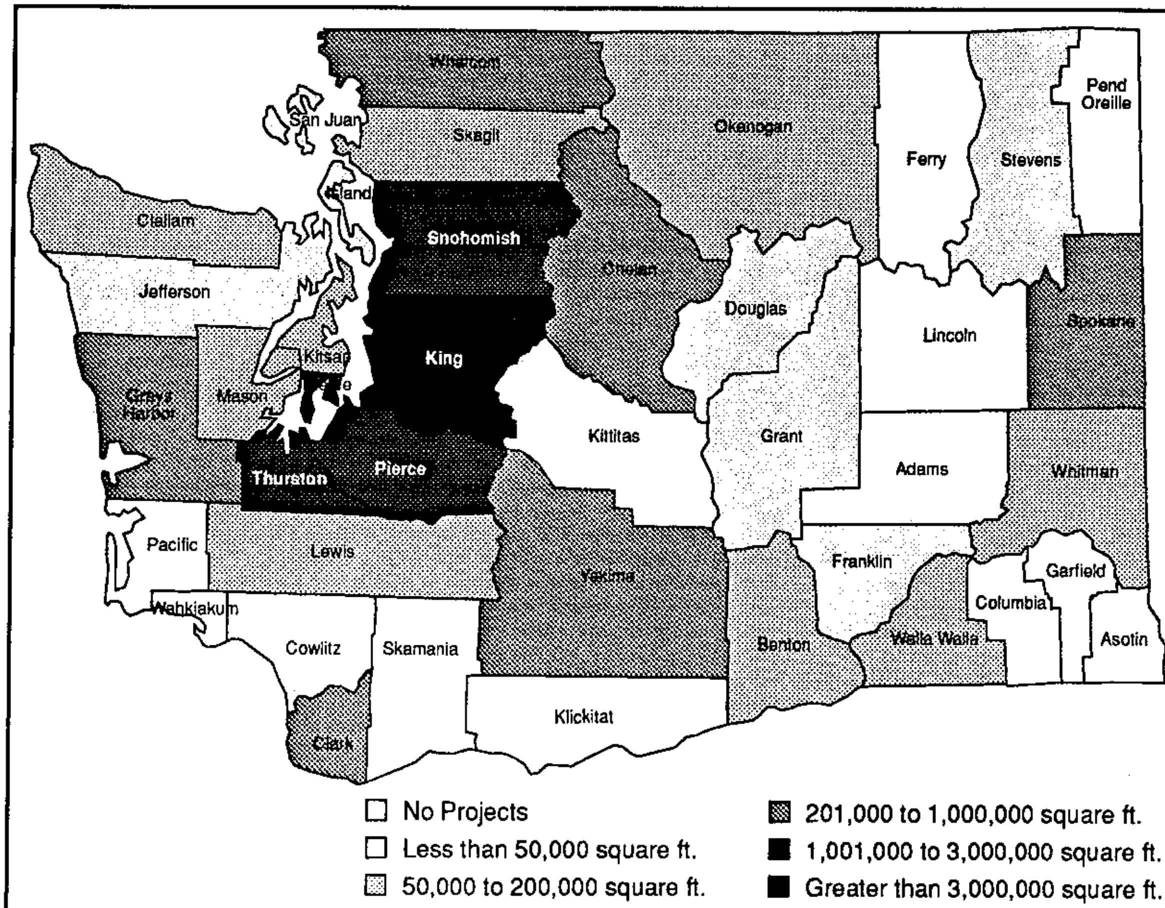

Figure 2.1
This map shows the distribution of square footage throughout Washington counties.

Most new commercial construction occurs in the four counties along the I-5 corridor around Seattle (King, Pierce, Snohomish, Thurston). These counties contain 64% of all new commercial buildings built and 79% of all the square footage built in the state during this year. In a random sample of buildings, these counties could be expected to dominate the compliance review.

2.2 Building Types and Size

The distribution of commercial building end uses was divided into eleven categories.

Office buildings dominate the sample, representing 30% of total construction. Over one third of the total square footage is represented by a wide variety of end uses, including health care facilities, grocery stores, assemblies, public institutions (such as jails, fire stations and maintenance facilities), restaurants and other uses not easily categorized.

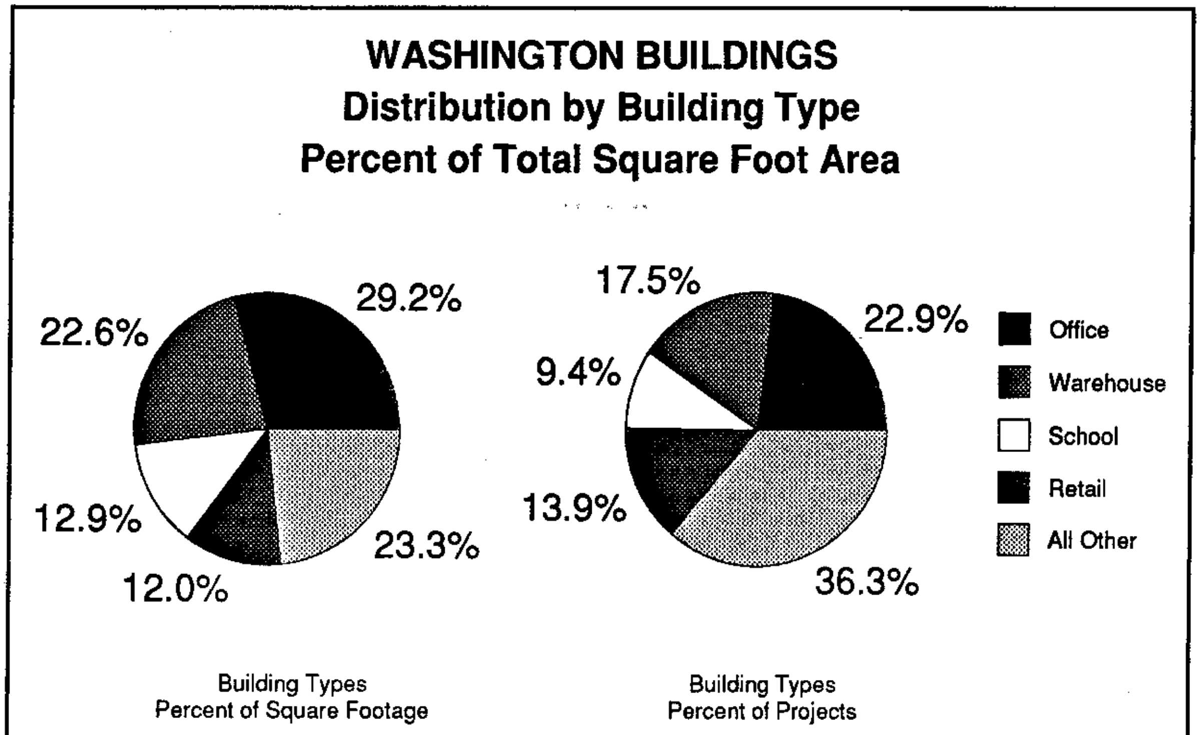

Figure 2.2
This figure illustrates the distribution of buildings and square footage by dominant building type in Washington. The other category includes the following building types: grocery, restaurant, assembly, public instititution, lodging, health and miscellaneous.

The average building size for the state of Washington is 37,000 ft^2. However, 50% of all the square footage was in buildings over 83,000 ft^2 or 11% of all the buildings built in Washington. Because of this skewed distribution, we stratified the sample to insure that large buildings were adequately represented. Biases associated with stratification were removed by assigning case weights proportional to the increased probability of a building being selected due to its size.

Buildings were recruited for participation through phone calls to the persons, generally architects, listed as the principal contacts in the Dodge database. We asked them to supply us with copies of the building plans and specifications and grant permission for a field visit. In some cases, where we could not obtain documents directly from the building professional, we were able to use the SCAN films of the bid documents submitted to Dodge by the architects.

Table 2.1 illustrates the distribution of buildings by area. Table 2.2 shows the distribution of the Washington final sample. It shows that the final sample was reasonably representative of the building population as a whole, with the exception of schools which were over-represented because of their high participation rate, and warehouses which were under-represented due to low levels of cooperation from building designers and owners.

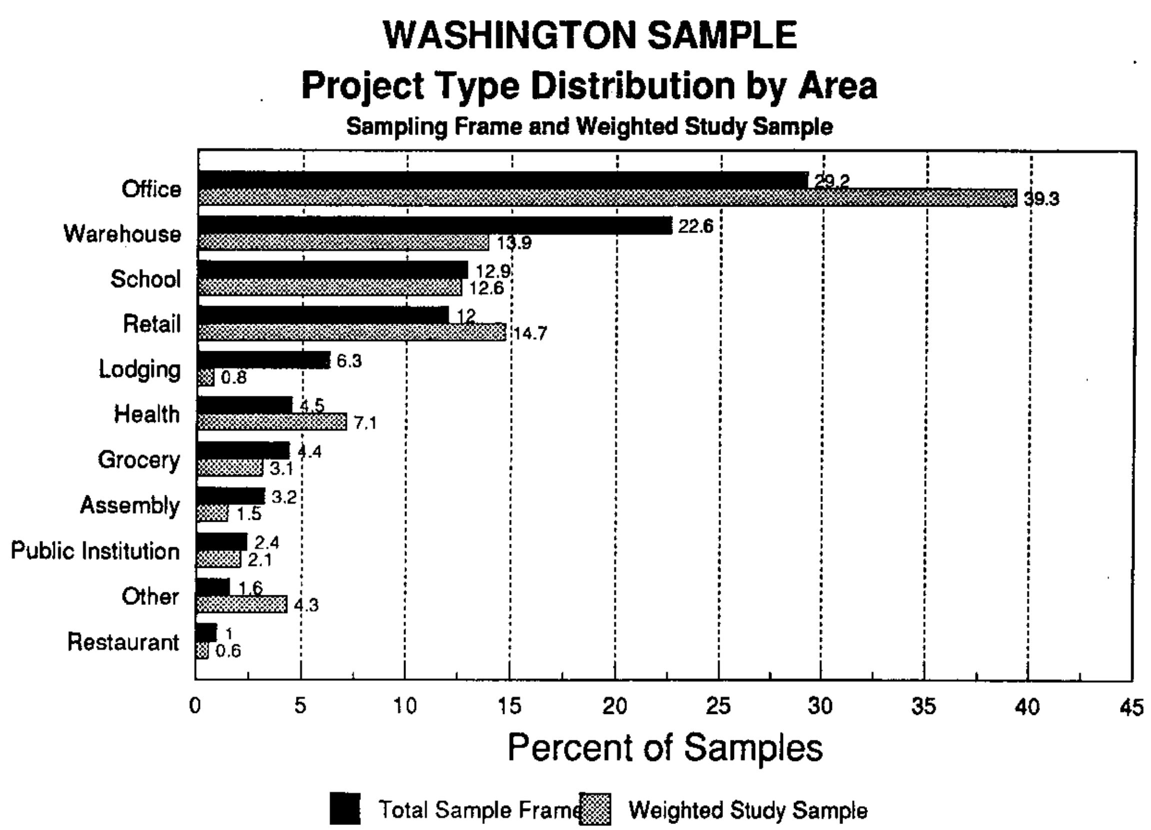

Figure 2.3 This figure illustrates distribution of square footage by end use category for the total population and the final sample. The over-sampling of large buildings resulted in an increased percentage of square footage being assigned to schools and offices. But again the sample is reasonably consistent with the distribution of the square footage for the total population.

Table 2.1 Washington Building Size Distribution						
Size Bin (SF/bldg) (000)	#	%	Cum %	Area (000,000)	%	Cum %
> 320	6	1.3	1.3	2.70	15.6	15.6
160 - 320	11	2.4	3.7	2.62	15.1	30.7
80 - 160	33	7.1	10.8	3.47	20.0	50.7
40 - 80	71	15.2	26.0	4.08	23.5	74.2
20 - 40	78	16.7	42.7	2.16	12.4	86.6
10 - 20	89	19.0	61.5	1.32	7.6	94.2
< 10	100	38.5	100.0	1.01	5.8	100.0
Median: 16,000 ft^2 Midpoint:83,000 ft^2 Mean:37,000 ft^2						

Table 2.2 Washington Sample Development						
	Total population		Recruitment pool		Final sample	
Building Type	#	%	#	%	#	%
Office	107	29.15	37	31.94	20	31.88
Retail	65	11.99	16	8.49	9	10.58
Grocery	17	4.38	7	4.52	4	3.84
Restaurant	41	0.99	10	0.43	3	0.26
Warehouse	82	22.61	22	21.46	3	10.56
School	44	12.94	24	18.67	20	29.53
Assembly	34	3.15	4	0.85	2	0.74
Public Institution	25	2.35	4	0.58	3	0.86
Lodging	21	6.30	7	6.29	1	0.33
Health	17	4.51	2	4.73	2	8.00
Other	15	1.63	3	2.02	3	3.42
Total	468	100.00	136	100.00	70	100.00

3 Energy Code Compliance

Of the 70 Washington buildings sampled, 36 buildings (51%) met the code. Large buildings were more likely to comply than small buildings: 60% of the large buildings and 43% of the small buildings met the code. This occurs because several very large office buildings demonstrated compliance using the energy budget submittals. This issue is discussed in Section 3.6 below. Since large buildings represent a much higher percentage of overall square footage, both in the sample and in overall building activity, when the sample is weighted for area and sampling bias, the level of compliance rises to 59%.

3.1 Compliance By Building Type

Table 3.1 shows the results of the evaluation of the 70 Washington commercial buildings.

Table 3.1
Washington Compliance by Building Type

		# of Buildings		
Size	**Building Type**	**Studied**	**Complied**	**Percent**
Large ($>40,000ft^2$)	Office	7	5	71%
	Retail	4	0	0%
	Grocery	2	2	100%
	School	17	10	59%%
	Warehouse	1	0	0%
	Health	2	2	100%
	Other	2	2	100%
	Total	35	21	60%
Small ($<40,000ft^2$)	Office	13	6	46%
	Retail	5	1	20%
	Grocery	2	1	50%
	School	3	3	100%
	Restaurant	3	1	33%
	Institution	3	1	33%
	Assembly	2	1	50%
	Warehouse	2	1	50%
	Lodging	1	0	0%
	Other	1	0	0%
	Total	35	15	43%
Total		70	36	51%

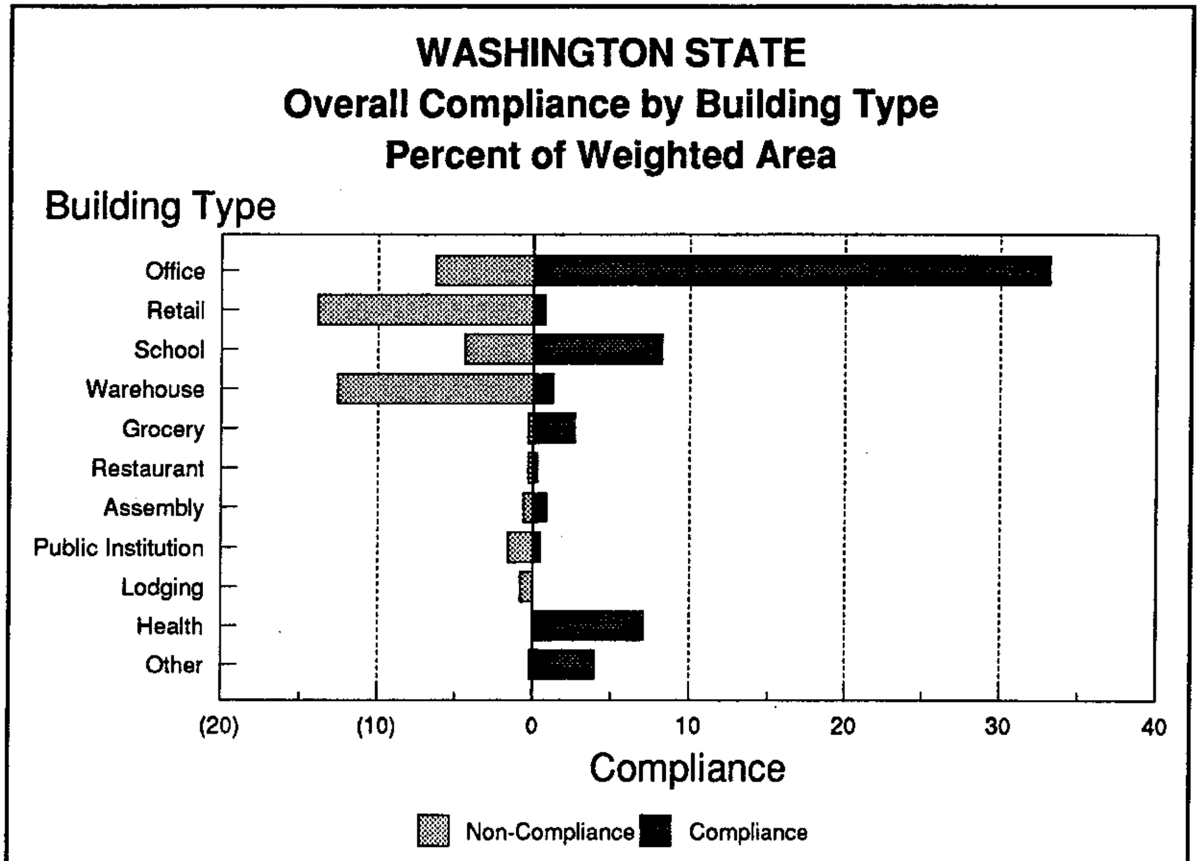

Figure 3.1
This figure illustrates compliance in commercial buildings by building type. Each bar represents the percent of total floor area of the sample, weighted for sample bias. Several building types show significant compliance problems, most notably retail stores and warehouses. The apparently high level of compliance of office buildings is partly attributed to energy budget submittals (see Section 3.6).

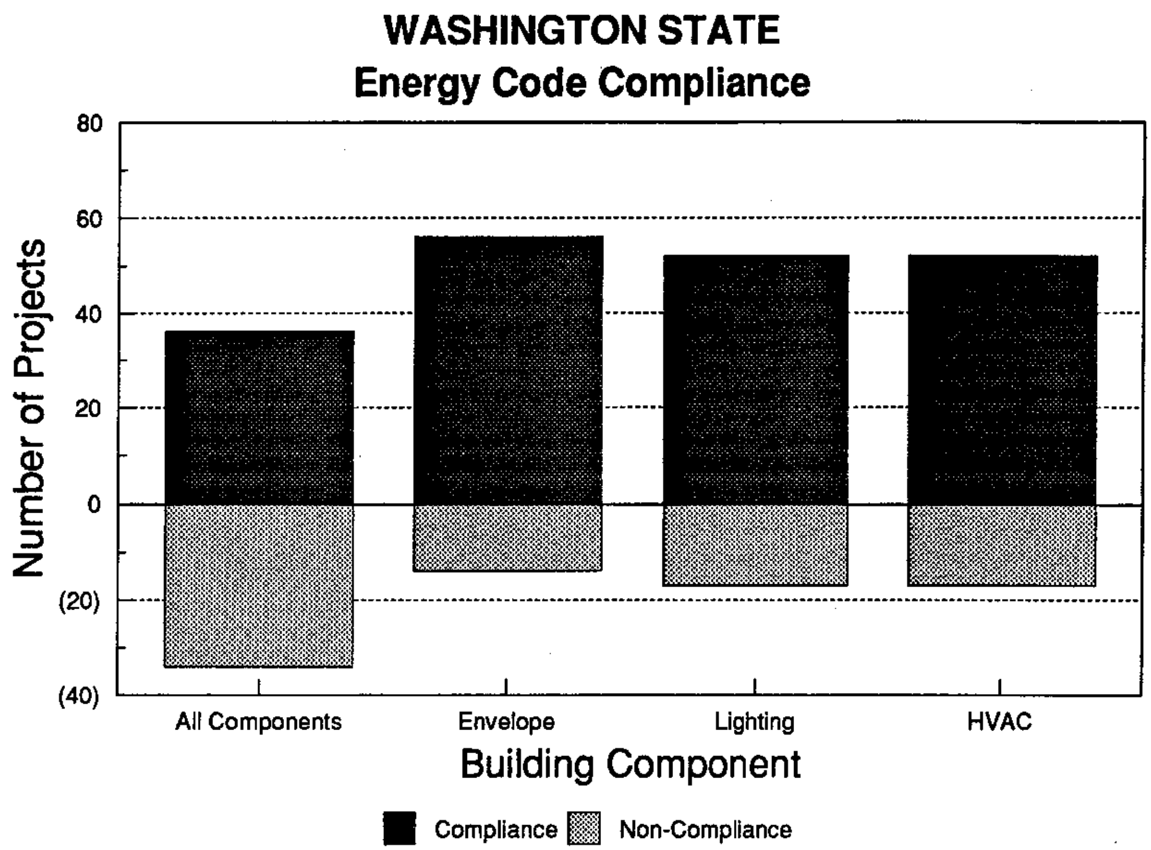

Figure 3.2
This figure shows levels of compliance for each major building system.

3.2 Compliance By Building System

Compliance levels averaged about 75% for lighting and HVAC systems, while envelope compliance was close to 85%. While a high percentage of buildings were likely to comply with any given aspect of the code, only about half the buildings were able to comply with all aspects of the code.

Envelope

Table 3.2 Washington Envelope Non-Compliance			
	Building Size		
Component	**Large**	**Small**	**Total**
Heating Criteria (UA)			
Wall (U_o)	3	1	**4**
Ceiling (U_o)	3	1	**4**
Wall & ceiling (U_o)	4	2	**6**
"Unheated"	0	3	**3**
Field Changes	1	1	**2**
Energy Budget Submittal	4	0	**4**
Total	**8**	**6**	**14**

Table 3.2 summarizes the reasons for non-compliance of the building envelope in the sample.

Fourteen (20%) of the buildings surveyed failed to comply with envelope provisions. Small buildings general failed when the designer used excessive amounts of glazing. Three-fourths of the non-complying small buildings had glazing areas in excess of 25% of the wall area. For large projects, about half the buildings had 25% or more glazing as a percent of wall area.

Four of the buildings failed to comply due to ceiling insulation strategy alone. The Washington energy code requires R-30 insulation levels for low-rise commercial buildings, a fairly stringent requirement. Three non-complying buildings were permitted as unheated buildings but were considered heated buildings during the review since heating was installed during construction.

Not counting "unheated" buildings, two buildings which were out of compliance with envelope provisions failed due to changes in the field, after the project was permitted. An additional 15% of the buildings were also changed in the field, resulting in reduced thermal performance but not causing non-compliance. Most field changes involved reducing the amount of insulation. However, 7% of the projects were upgraded in the field, with two buildings brought into compliance as a result.

Four of the projects which did not comply with envelope requirements were submitted using energy budget submittals. Although the envelope did not meet the code's thermal performance requirements, we classified the building as complying due to the energy budget calculations. This issue is discussed further in Section 3.6.

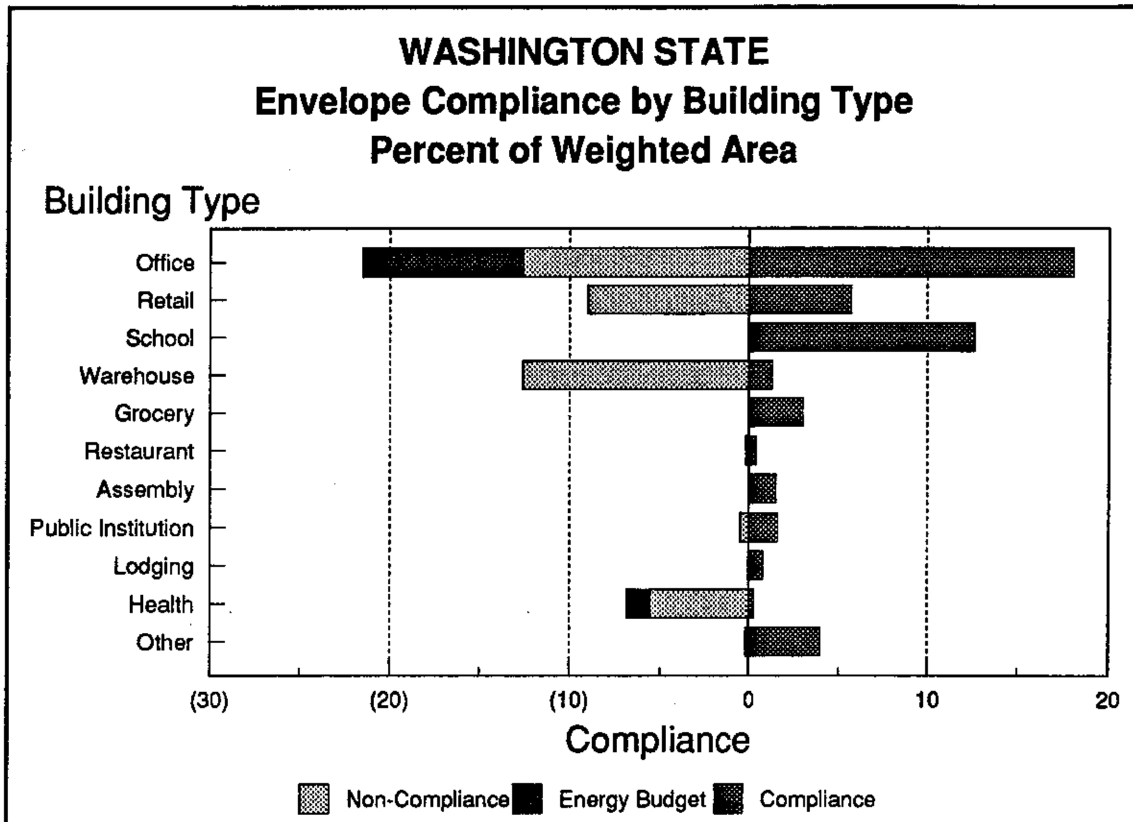

Figure 3.3
This figure illustrates the level of compliance with envelope requirements. Most buildings complied although significant levels of non-compliance were noted in four building types--warehouses, office, retail and health. The office and health buildings submitted using the energy budget approach did not comply based on envelope requirements but were considered in compliance overall.

HVAC Systems

Table 3.3 indicates which measures of the HVAC requirements were not met by the Washington buildings. Overall, 17 buildings (24%) failed to comply with the energy code due to the characteristics of the HVAC system installed.

Table 3.3
Washington HVAC Non-Compliance

	Building Size		
Measure	**Large**	**Small**	**Total**
Efficiency	2	2	4
Sizing	5	8	13
Economizer	2	0	2
ATF	1	0	1
Field changes	1	1	2
Total	8	9	17

Oversizing of the mechanical system was the most common cause of non-compliance. Thirteen buildings (18%) failed for this reason. In eleven cases, this was the only aspect of the mechanical system out of compliance and, in 5 cases, this was the only aspect of the entire building out of compliance.

Four projects failed to meet code requirements for minimum equipment efficiency. In two buildings, the contractor substituted low efficiency equipment during construction for the more efficient equipment specified at the time of the permit.

Only two buildings failed to provide economizers where required. However, it is likely that many more projects had economizers which were not set to provide a full 100% outside air capacity as required by the code. This aspect of the equipment was extremely difficult to verify from the plans or in the field

One building failed to meet the required Air Transport Factor (ATF). This building was submitted under an energy budget submittal, so it was considered in compliance overall.

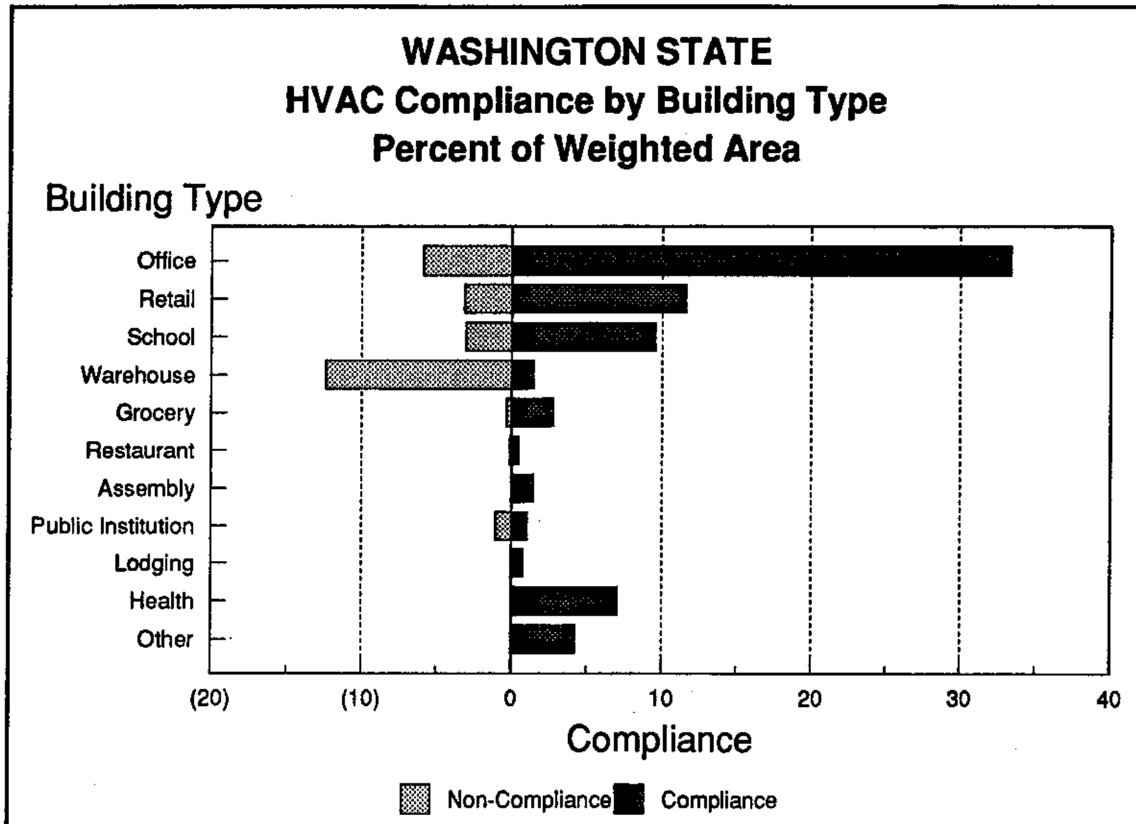

Figure 3.4
This figure illustrates compliance with energy code HVAC requirements by building type.

Lighting

Lighting system compliance was based on three criteria: interior lighting budget established by occupancy type, exterior perimeter and parking lot lighting, and control systems (both interior and exterior). The interior and exterior lighting allowances can be combined into an overall lighting budget, so exceeding one budget does not necessarily lead to non-compliance with code lighting requirements.

Table 3.4
Washington Lighting Non-Compliance

Lighting Provision	Large	Small	Total
Interior LP	1	4	**5**
Exterior LP	0	2	**2**
Both	5	4	**9**
Switching	1	0	**1**
Field Changes	2	5	**7**
Total	**6**	**11**	**17**

Table 3.4 indicates which provisions of the lighting code were not met by the buildings studied.

Our review checked compliance with the interior and exterior lighting requirements. We compromised on the switching requirements. We ignored the requirement for switches for luminaires next to windows--most designers ignore this requirement. We only failed a building for the dual level switching requirements if the lights for a whole floor was operated by a single switch.

Seventeen buildings failed to comply with the lighting code. Restaurants and small offices most often failed to meet the interior lighting power budget. Retail stores and restaurants most often failed to meet the exterior lighting power budget.

Because Washington code combines the exterior and interior lighting budgets into one overall budget, a building can fail to meet the exterior or the interior budget but pass overall. Twelve buildings (17%) exceeded the interior lighting budget but passed when exterior lighting was taken into account. 12% failed the exterior lighting budget but passed overall.

Changes in the field after permitting were the single largest cause of non-compliance. Over 40% of the buildings which did not meet the code failed because subcontractors substituted less efficient ballasts, fixtures and lamps for those specified, or added fixtures beyond those specified on the plans. Typically, cheaper fixtures were installed or 40 W lamps were installed where 34 W lamps had been specified. Subcontractors usually blamed order time or budget constraints for these substitutions. Energy code issues were seldom considered. Although changes of this nature are fairly easy to spot in the field, code officials seldom required any changes to bring buildings back into compliance with lighting code requirements.

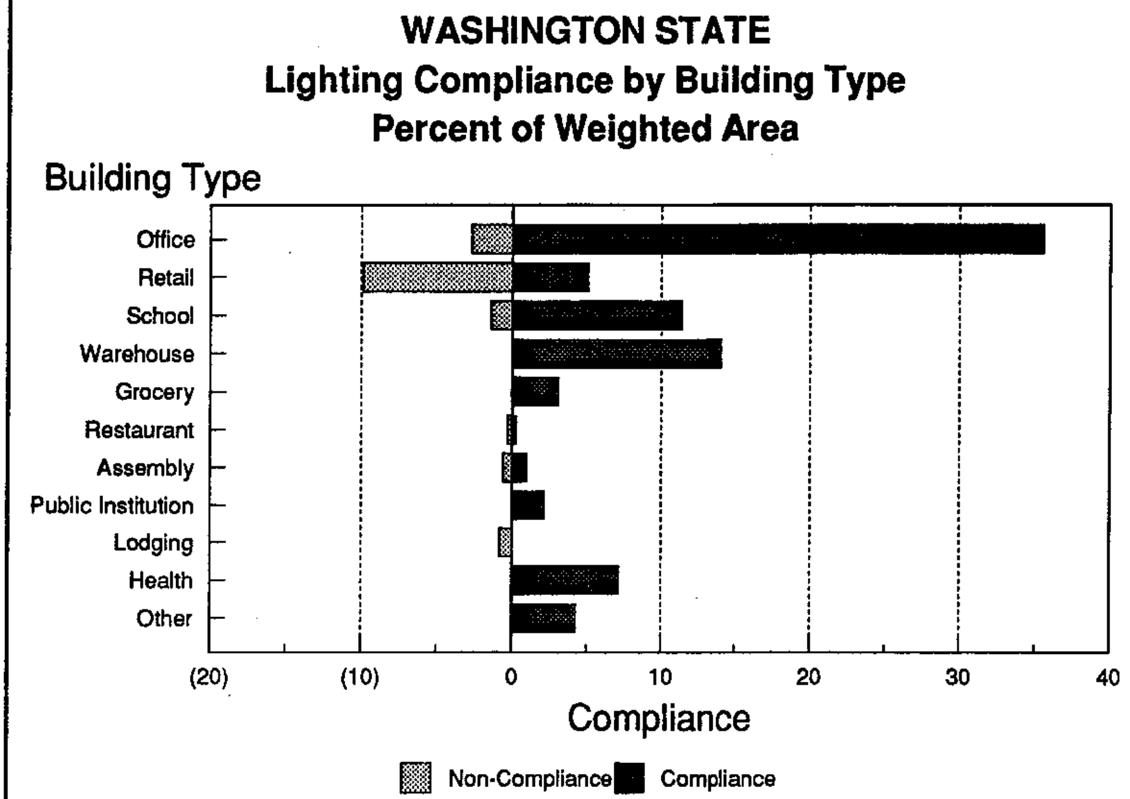

Figure 3.5
This figure summarizes compliance with the lighting requirements of the energy code. In Washington, 24% of the buildings studied failed to meet lighting requirements. Small buildings seemed to have more trouble meeting lighting code requirements, particularly in the retail sector. When the sample is weighted with area the overall result shows much higher compliance than a project by project review.

3.3 Compliance By Jurisdiction

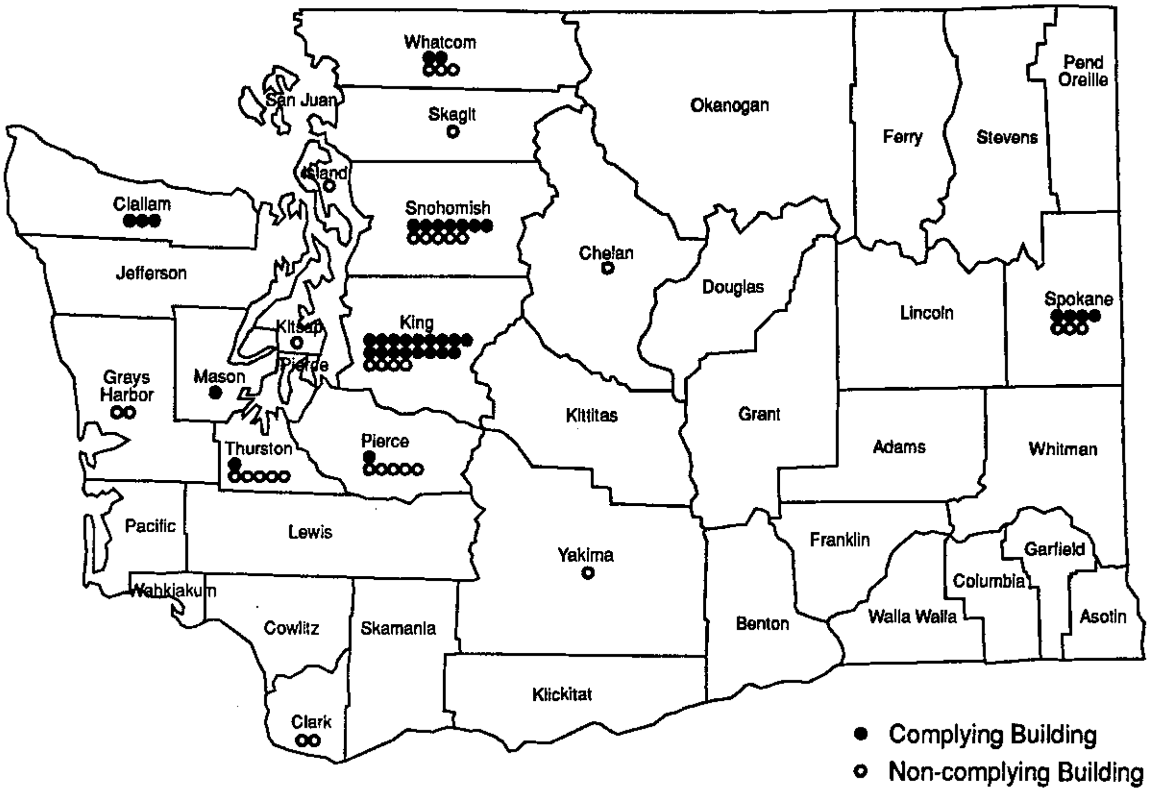

Figure 3.6
This map illustrates the distribution of our sample and the level of compliance by county.

The level of compliance is uneven and not easily explained by size of county or location. Nevertheless, several points should be noted. King County contained more than twice as many buildings as any other Washington county and achieved a high compliance rate of 81%. The counties with the next two largest sample groups, Snohomish and Spokane, achieved compliance levels near 58%. Pierce and Thurston Counties, which each contained about 9% of the study sample, achieved poor compliance levels of 17%. Clallam County contained only a small percentage of the study sample, but achieved an impressive 100% compliance in the projects reviewed. In Clallam County, the building code jurisdiction cooperates with an energy specialist in the local utility to review building energy code compliance. This practice is similar to the pattern in Seattle and parts of Snohomish and Pierce counties. In most cases, this arrangement noticeably improved code compliance.

3.4 Code Compliance in Utility Support Programs

Based on interview information, ten buildings in the Washington sample received incentives or design assistance from utilities through the Energy Smart Design (ESD) program. Table 3.5 shows utility program participation and compliance.

Table 3.5
Washington Utility Program Participation & Compliance

	Number	Complying	Percent
Envelope	10	6	60%
HVAC	10	8	80%
Lighting	10	10	100%
Total	10	*9	90%*

* Three buildings were submitted using energy budget submittals.

Although a high percentage of these buildings complied with code requirements, the program was designed to encourage buildings to exceed the code requirements by 30%. This level of efficiency was typically not attained. Furthermore, in at least a third of the cases, installed lighting was less efficient than was specified. In half of the buildings, the envelope insulation was below code minimums; four of these buildings claimed compliance using energy budget submittals. Several buildings included HVAC equipment which barely met code.

Designers were typically unaware of how utility incentive-supported measures had fared during the construction process. These findings suggest a need for improved monitoring and inspection to assure the integrity of utility incentive programs.

3.5 Compliance Under State Programs

In Washington, 17 of the 20 school buildings submitted Energy Conservation Reports (ECRs) early in the design process, as required by the state. The ECR requirements encourages the consideration of various energy conservation measures during design. It is not directly related to the compliance process, and meeting ECR guidelines in no way guarantees energy code compliance. Unfortunately, about 25% of the local jurisdictions apparently consider completion of an ECR sufficient to demonstrate energy code compliance. Several engineers and architects also expressed this view.

Many measures identified by the ECR process were subsequently deleted from the buildings due to construction delays or substitutions, or in order to reduce construction costs. It is noteworthy, however, that although the ECR does not guarantee compliance with energy code requirements, it does lead to higher compliance levels than in the sample as a whole.

3.6 Compliance Using Energy Budget Submittals

The Washington energy code allows building designers to demonstrate compliance using an energy budget submittal. This permits designers to trade energy savings in one aspect of a building for inefficiencies in another. For example, a highly efficient lighting system can make up for a building envelope which would otherwise not meet the code. Five buildings in the Washington sample claimed energy code compliance using this approach.

Of these five buildings, only one met all code requirements as applied to other buildings in the sample. The other four projects failed to meet at least one aspect of the code and would have been classified as non-complying except for the special exemption for energy budget submittals. One of these buildings failed to meet both envelope and HVAC requirements.

Although Ecotope did not have access to the energy budget submittals, it became clear during our analysis that this can be a large loophole in the code.

4 Energy Code Impacts

Compliance is only one dimension of the impact of the energy code on building practices. In our evaluation, buildings which failed to meet any one of the nine criteria evaluated for the Washington energy code were considered non-complying. Theoretically, a well-constructed and relatively efficient building could fail to meet the energy code because it failed to meet one criterion.

If the code is viewed as a design standard, on the other hand, then the important criteria is the overall energy efficiency of the building stock and the degree to which building practices have been changed by the code during the twelve years it has been used in Washington.

Comparing the Washington results with the results from the companion sample of 71 Oregon buildings gives us some insight into the impact of the energy code on overall building practice since the two states have similar codes which differ in enough specifics to make comparison instructive.

This section contains several graphics comparing the Oregon and Washington samples using box plots. The median (the mid point of the data) is the line in the center of the box and the box represents the amount of scatter in each building type. The width of the box is proportional to the square root of the number of buildings in each category.

4.1 Building Practice

Building Envelope

The Washington energy code regulates only the heating conditions of the building envelope. Table 4.1 summarizes and compares the performance of Washington buildings on two main indexes of compliance: overall heat loss rate (UA/ft^2) and wall U_o. This table shows that, in general, building envelopes performed better than the code. This is true even though Washington requires large amounts of insulation in low-rise commercial buildings, which comprised about 89% of the sample. The amount of variation within the sample is small and reflects the impact of the code. Most of the variation in small buildings is due to the two small uninsulated buildings permitted as "unheated" which became heated after occupancy. These buildings have heat loss rates three times higher than the code allows.

Table 4.1
Washington Envelope Performance

	Heat Loss Rate (UA/ft^2)				Cooling Budget (OTTV)			
	Sample		Code		Sample		Code	
Size	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Small (< 40,000ft²)	.240	.196	.255	.062	.170	.118	.250	-
Large (> 40,000ft²)	.125	.040	.145	.045	.165	.086	.250	-
Total (weighted)	.132	.076	.145	.057	.194	.096	.250	-
Utility	.161	.064	.176	.072	.250	.089	.250	-

While both states have similar levels of compliance with the envelope provisions of the code, the Washington code has more stringent insulation requirements for low-rise buildings and about a 10% lower U_o requirement for wall and window systems. The overall result is that the Oregon code allows a 40% higher heat loss rate (in this sample) than the Washington code.

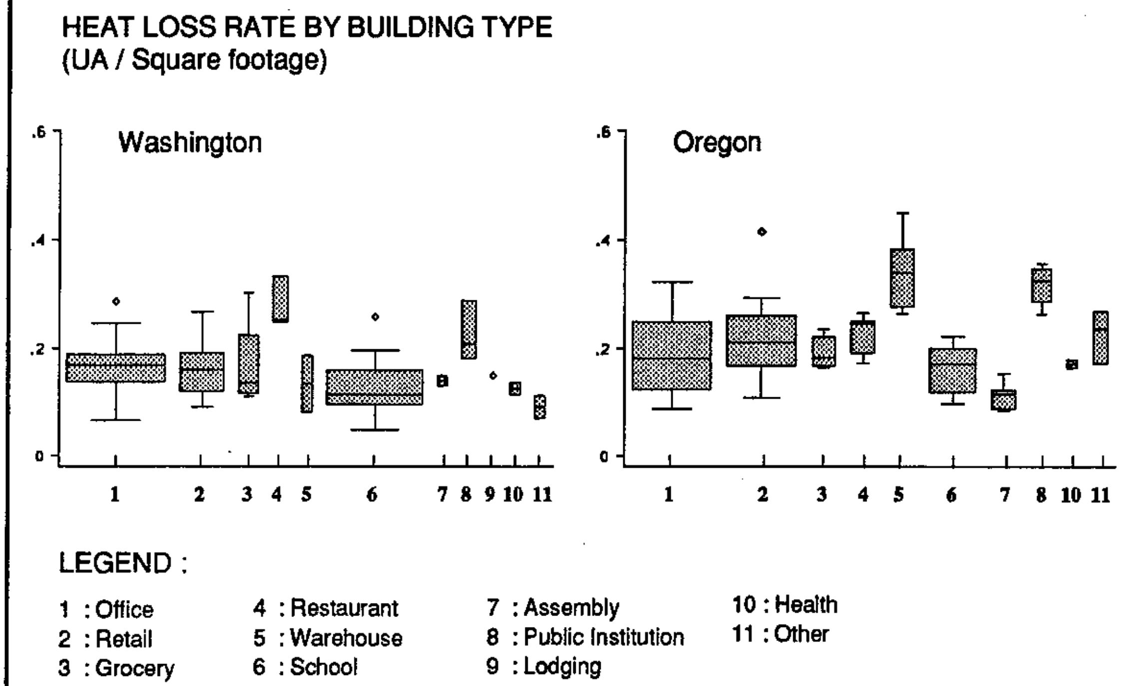

Figure 4.1
This figure shows that the Washington sample has a 30% lower normalized heat loss rate. At the higher end of performance, the Washington and Oregon buildings are similar but the less stringent Oregon code has resulted in buildings which tend to spread towards higher heat loss rates. This is best explained by a tightening in building practice fostered by the more stringent Washington code.

The Oregon code regulates the cooling impact of the envelope by setting a target OTTV. A comparison of Washington and Oregon OTTVs shows a similar pattern to that noticed for heatloss rate. The Washington buildings have OTTVs that average 14% lower than the Oregon buildings even though OTTV is not regulated in Washington. This shows that regulating overall heatloss rate can improve performance on cooling criteria.

HVAC

The Washington code regulates HVAC system sizing as well as equipment efficiency, air transport factor (ATF) and economizers. Only sizing presented a problem for compliance. Table 4.2 shows the relationship between overall equipment sizing and the code limit of 1.5 times the calculated load. Most buildings meet the cooling sizing limitation but the average small building does not meet the heating sizing criteria. This is by far the largest single reason that a quarter of the Washington HVAC systems were out of compliance. Since equipment size is regulated in Washington but not in Oregon, a comparison of the data shows the impact of the code itself.

Table 4.2
Washington HVAC System Sizing

	Heating (capacity/load)			Cooling (capacity/load)		
	Sample		Code	Sample		Code
Size	Mean	SD	Mean	Mean	SD	Mean
Small (< 40,000ft^2)	1.71	.64	1.5	.99	.42	1.5
Large (> 40,000ft^2)	1.28	.49	1.5	1.06	.42	1.5
Total (weighted)	1.26	.45	1.5	1.21	.49	1.5
Utility	1.09	.32	1.5	1.2	.3	1.5

Figure 4.2 compares heating system sizing in Washington and Oregon buildings.

Both states regulate equipment efficiency by setting a lower limit or floor on efficiency. Figure 4.3 shows how this affects code compliance. This is an ideal situation, showing how all code provisions should work; providing an effective minimum which equipment does not violate.

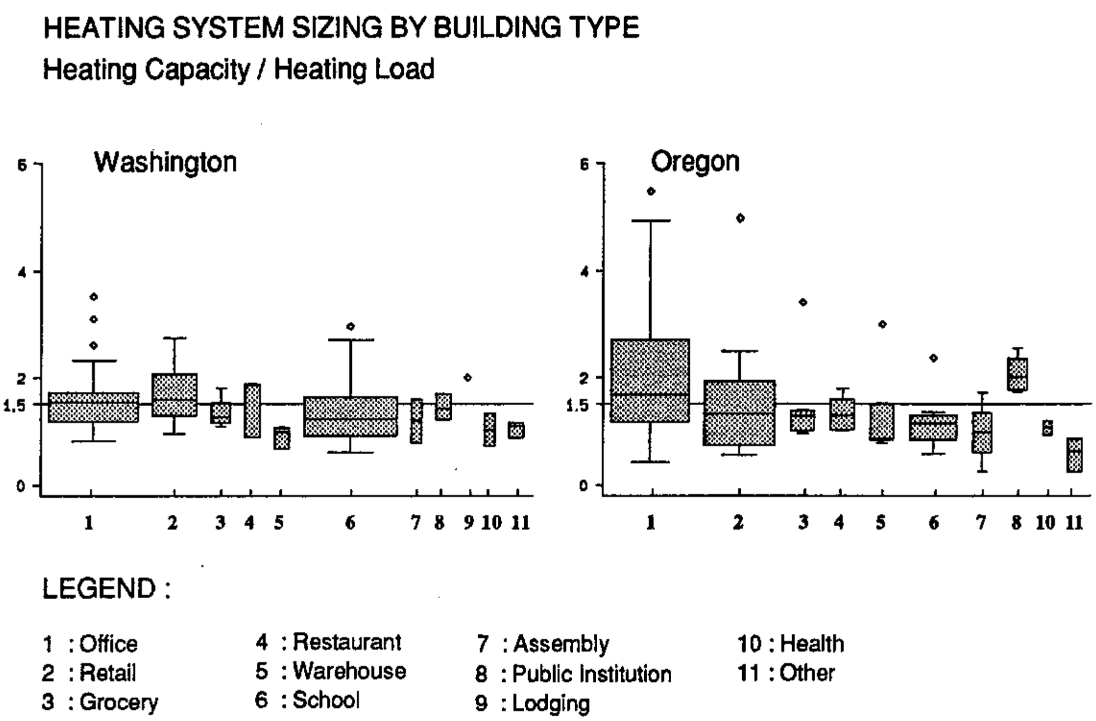

Figure 4.2
This figure compares equipment sizing in Oregon and Washington buildings. There is no requirement for sizing in Oregon while in Washington heating or cooling equipment cannot exceed 1.5 times the calculated load. Even though much of the Washington sample does not comply with the requirements, there is much less spread in the Washington data. This illustrates a major effect of code requirements: even where compliance is a problem, the requirement reduces the variation in design practice substantially.

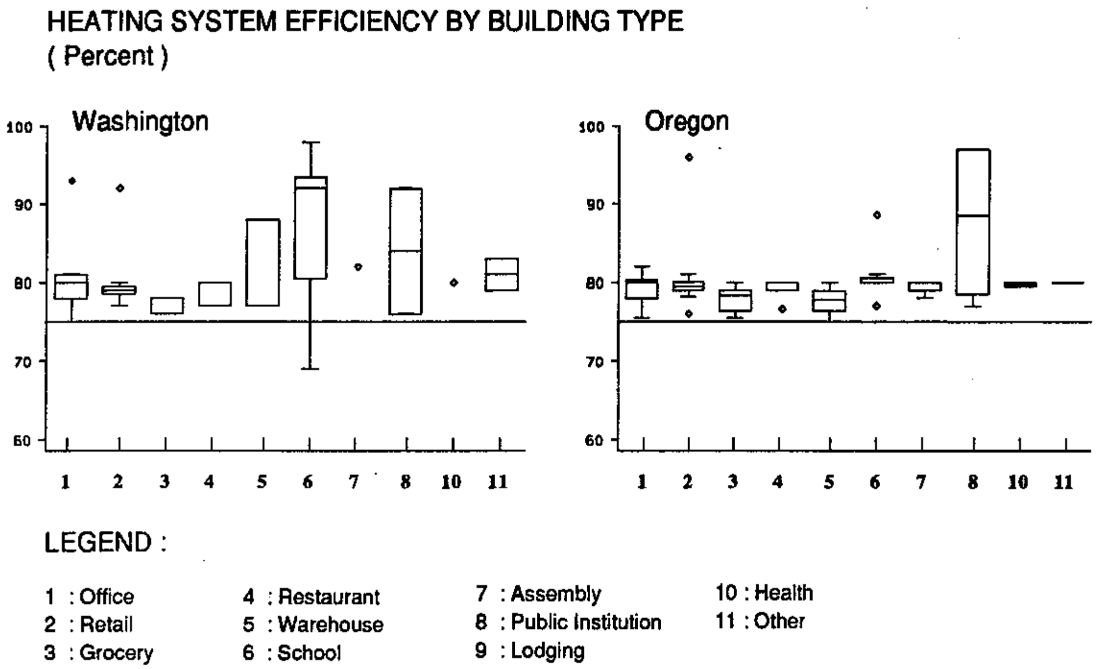

Figure 4.3
This figure compares the two states on heating system efficiency for fossil fueled devices. The Oregon sample has much less scatter than Washington but both are well above the average code requirements. We believe this is due to manufacturers developing more efficient equipment. Most of the more efficient equipment in Washington buildings is in schools where the state-mandated lifecycle cost purchasing process seems to result in more efficient equipment.

Lighting

As with the heat loss rate, the average building shows a 10% improvement over the code standard, although 40% of the buildings exceed the code required lighting power budget. This is because a low amount of exterior light offsets the interior budget sufficiently to result in compliance in about half of those cases. This compares to the Oregon sample in a way that illustrates the value of straightforward code provisions.

Table 4.3 summarizes interior LPD in Washington buildings.

Table 4.3
Washington Interior LPD

	LPD		Code LPD	
Size	**Mean**	**SD**	**Mean**	**SD**
Small (< 40,000ft^2)	1.82	.71	1.91	.82
Large (> 40,000ft^2)	1.59	.41	1.74	.12
Total (weighted)	1.58	.53	1.74	.31
Utility	1.56	.53	1.93	.72

4.2 Utility Programs

According to the architects and engineers interviewed, only ten Washington buildings received utility incentives for participating in the Energy Smart Design (ESD) program. It was not clear whether these incentives were meant to subsidize specific energy improvements or were paid to the designers to develop recommended measures. The performance of these buildings was disappointing. When compared to the weighted average of all buildings, these buildings were about equal to the sample as a whole for lighting efficiency and about 20% less efficient on envelope requirements. For the most part, these buildings do not appear to be particularly more efficient than other similar buildings in the sample.

There are several possible explanations for this. First, the building was reviewed for possible measures but none were incorporated into the design. Second, though ESD measures were incorporated into the design, they were not installed due to decisions made during the bidding or construction process. Third, the ESD measures did not directly impact the code levels. For example, a building may have received an energy efficient lighting package, identified in the ESD program, but failed to comply with the code in building envelope. Fourth, ESD measures, though identified and given incentives, were not verified by utilities and thus specifications deteriorated during the installation process. Finally, the energy budget submittals developed for the utility program allowed trade-offs which reduced the performance of some aspects of the building (mainly the envelope).

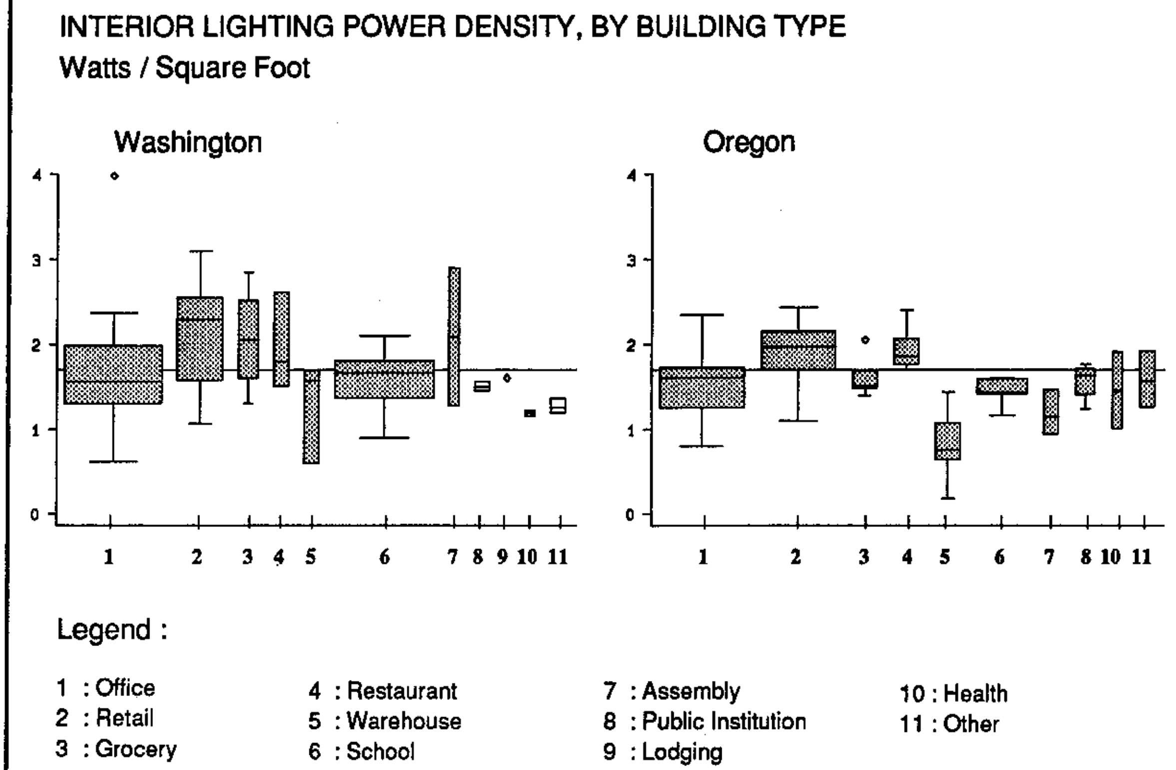

Figure 4.4
This figure compares Washington and Oregon LPDs. Even though Washington code requires a lower LPD in the retail sector, the average Washington building has a somewhat higher interior LPD than the average Oregon building and there is more scatter. Washington code permits designers to combine interior and exterior lighting budgets into an overall lighting budget. In many Washington buildings, particularly schools and offices, where exterior lighting of parking lots and building perimeters is not required, this allows designers to increase the interior LPD. Thus, even though the code-required interior LPD for Washington is lower and the levels of compliance higher, this loophole reduces the code's effectiveness compared to the Oregon code's more straightforward interior LPD budget. (The 1.7 W/sf line is provided for clarity. It does not represent the code mandated LPD in all cases.)

4.3 Summary

Most buildings comply with the energy code on most measures. On average, construction practices in the Washington sample are as good or better than the code demands. One can conclude that the code has improved building practices or, at a minimum, that building practices are well represented by the current code.

5 Interviews

5.1 Design Professionals

We attempted to interview at least one design professional or owner's representative for each building evaluated. Table 5.1 illustrates the distribution of interviews for the Washington sample.

Table 5.1
Washington Building Professionals Interviewed

Architect	61
Mechanical Engineer	37
Lighting Engineer	23
Owner's Representative	3
Contractor	0
Mechanical Installer	6
Lighting Installer	4
Other	2
Total	**136**

We used a structured interview format which focused on the specific building being evaluated and design decisions made to meet the energy code. Many of those interviewed responded with general answers based on their experience with the code overall. Although we collected a great deal of information, it tended to be anecdotal or impressionistic. It was impossible to systematically categorize most of these responses.

Overall Enforcement

Many designers cited inconsistent enforcement as the most time consuming and frustrating aspect of the energy code. Because they did not believe the code was enforced, many designers submitted drawings which did show energy code compliance. Very few designers could remember an instance where feedback was received from code enforcement officials on any energy code issue. Only 9 of the Washington respondents indicated that they had received such feedback on the particular building reviewed. In the absence of feedback, the designers assumed their projects complied. Lack of feedback almost certainly leads to neglect of energy code requirements. Feedback provided by building officials often led to increased incorporation of energy saving measures, although these buildings still might not comply with other code requirements. Some designers noted that feedback from code officials gave them a better understanding of energy code requirements.

Table 5.2
Frequency of Code Enforcement in Washington
Cited by Building Designers

Enforcement Response	Yes	No
Comments or Feedback from Code Officials	9	122
Enforcement Affected Design	13	117
Revisions to Project Required	10	120

Enforcement Problems

Building professionals repeatedly mentioned certain problems. Usually these were due to confusion about the code requirements or inconsistent interpretations. These are summarized below by building system.

Envelope

- When asked about problems with envelope code requirements, designers most frequently cited problems with slab insulation and thermal breaks. They are required but are not enforced and, even when noted on drawings, are not usually included in the building. Furthermore, the code is unclear about evaluating slab insulation tradeoffs for component analysis.
- Thermal values for building components are not standardized. Some jurisdictions require ASTM tests (window and doors). Some require ASHRAE references. Some don't require any documentation at all.
- Some mechanical engineers questioned the levels of insulation required by the code given the extensive internal heat gains in their buildings.

HVAC Systems

- The prescriptive requirements in the code tables are often difficult to interpret and cause confusion in equipment selection (although most buildings easily complied with these provisions). Equipment efficiences are difficult to determine.
- Contractors installed used or refurbished equipment without documenting the efficiency of this equipment. This was rare, occurring twice in this sample. Substitutions occur during bidding without considering equipment efficiency tradeoffs.
- Designers could demonstrate compliance with the sizing provision by overestimating building loads. These calculations are not regulated by the code and thus are easily abused.

Lighting

- Designers thought that most jurisdictions did not review lighting compliance and saw no reason to include LPD calculations on their drawings.
- In several instances, lighting installers substituted less efficient fixtures for those specified. In seven cases, this resulted in non-compliance. The designers were typically unaware that field changes had affected energy code compliance, if they were aware of the changes at all.
- Several designers for retail spaces said their clients needed and wanted more lighting than the code allowed. They felt obligated to meet these requests.
- Lights are often added in the final stages of construction, as part of tenant improvements, for display lighting or at the behest of the owner. These additions are not reviewed for code compliance.
- Task lighting is not regulated by the code. Several designers noted instances where task lighting exceeded connected lighting.

Code Responsibilities

While it is generally acknowledged throughout the building professions that the architects serve as owner's representative and project manager on most building projects, a surprisingly small number of architects take responsibility for any part of the energy code. Table 5.3 shows who was responsible for code compliance according to the design professionals we interviewed.

Table 5.3
Washington Code Responsibility
By Profession and Building System

Building System	Architect	Consulting Engineer	Contractor/ Installer	Other
Envelope	28	29	3	1
HVAC	4	29	8	1
Lighting	11	22	3	1

In only 40% of the cases did the architect or primary building designer take responsibility for any aspect of the energy code. When the architect did take responsibility for code compliance, this usually involved only the building envelope. This may be due to the perception that the code is a difficult, confusing technical document. It is clear that most architects approached energy code compliance reluctantly.

In actuality, consulting engineers dominate the design and energy code compliance of all building systems. In most cases, they work for the architect or owner's representative; sometimes they work for the mechanical or electrical subcontractor.

The overall picture is one of minimal effort toward code compliance throughout the building professions.

- Architects routinely expected engineers to be responsible for energy code compliance. Even those who took responsibility for code compliance typically used calculations submitted by the mechanical engineer to decide the levels of insulation and window areas in the final building design.
- Relatively few architects understood much about the calculations and evaluation procedures used to establish envelope performance in the energy code.
- Most architects and some engineers appeared to believe that the jurisdictions are responsible for their understanding of the code. The architects consistently noted difficulties with consistent interpretation from one jurisdiction or official to another.
- Most architects (75%) interviewed said they wanted more training but only 34% of the engineers requested more training.
- Lack of consistent enforcement was cited as a having a corrosive effect since buildings which evade code provisions are less expensive to build.
- The code itself was noted as a source of substantial problems because of inconsistent wording which seems to allow a variety of interpretations and causes confusion.

While many architects commented on code problems, few of them have any grasp of the code provisions. Many of their comments about envelope provisions did not reflect the actual code language and seemed to be based on hearsay from other building professionals. The engineers interviewed were somewhat critical of specific provisions. But most agreed that the code was not difficult to understand or incorporate into their designs. This was particularly true for lighting designers.

5.2 Interviews with Code Officials

The purpose of this study was to review code compliance and current building practices. Since up to two years had passed between the permitting of individual buildings and our interviews, we assumed that direct information about individual building enforcement would be difficult to access. As a result, the interview with the code officials focused on the general patterns of code review and enforcement and the nature and extent of training and understanding of the energy code.

Eleven building departments were interviewed in Washington. These departments were for the most part selected to insure that the major jurisdictions with large amounts of commercial construction were reviewed and that some sampling of smaller jurisdictions with minimal activity were also surveyed.

In larger jurisdictions these interviews usually included at least two and sometimes three individuals involved in various aspects of building inspection and plan checking in the commercial sector and often included the person primarily responsible for energy code review.

Because of the general nature of these interviews, most of the information was anecdotal, although a structured interview was conducted and certain information was collected from all people interviewed. Responses have been summarized under three headings:

Training and Resources

- Code officials frequently mentioned the inadequate amount of time allowed for reviewing energy code provisions and the need for more funding or manpower.
- Larger jurisdictions tended to have personnel with specific building energy code responsibilities and were more likely to have participated in formal training programs. This training, and the large volume of projects generally led to a more thorough understanding of specific code provisions, although it didn't necessarily lead to increased compliance (e.g., Pierce and Thurston counties).
- The amount of training or experience in energy code issues seemed closely related to a code official's sense of the value and enforceability of the energy code. Many code officials in smaller jurisdictions did not understand the importance of energy efficient construction further illustrating the need for more training.
- Three fourths of the code officials interviewed requested additional training.
- Several officials commented that recent experience with utility incentive programs had increased their understanding of the energy code.

Compliance and Enforcement

- Almost unanimously, those interviewed described energy code compliance within their jurisdictions as 'good'. This applied to jurisdictions of any size, regardless of whether projects were reviewed for compliance with all aspects of the energy code.
- Building officials were consistently frustrated by a lack of information on submitted plans. This led to an increase in the time required to review submittals, making manpower limitations even more acute. In some cases, lack of information made it impossible to verify compliance.
- Many jurisdictions have no formal process for following energy code issues through from submittal to completion. In most cases, responsibility for the compliance review of a project is passed from plan reviewers to building inspectors over the course of the project. Energy code issues may or may not be passed along. The timing of site inspections often does not correspond with energy code inspection requirements. Changes which occur during construction are often not evaluated for their impact on code compliance.

Building Systems

Envelope

- Most of the jurisdictions surveyed indicated that slab insulation and thermal breaks were consistently a problem area for energy code enforcement. Designers tended to ignore or misinterpret slab insulation requirements.

- Several of the building officials interviewed felt that the definition of 'unheated' spaces was unclear and often manipulated by designers.

- Envelope compliance with energy code provisions was rated as good by all the jurisdictions surveyed.

HVAC

- Several jurisdictions indicated that mechanical system compliance was not reviewed, or that they relied on the engineer's stamp for energy code compliance. Most requested additional training in this area.

- Code officials cited problems with lack of economizers, difficulty determining equipment efficiency and problems evaluating control systems.

Lighting

- Most jurisdictions felt that compliance with the energy code was weakest in the area of lighting requirements. They mentioned consistent lack of documentation, despite requirements in many jurisdictions that lighting levels be indicated on plan submittals. LPD requirements were consistently misinterpreted or ignored. Changes in the lighting design during the project were particularly difficult to monitor.

- Several jurisdictions said they relied on the Department of Labor and Industries (L&I) for lighting inspections. L&I indicated that they do not inspect for compliance with the energy code at all.

- Tenant improvement projects consistently fail to meet LPD limits. Various reasons for this were given, including code ambiguities, inadvertent or intentional misinterpretation of the code by designers, and lack of a formal review process for lighting in these projects.

6 Conclusions

The low level of compliance in this sample and the cavalier attitude of building professionals towards the code suggest the need for substantial changes in enforcement. There are several ways to enhance enforcement.

6.1 Documentation

The current code requires minimal documentation. Only one jurisdiction required architects and engineers to note LPDs, equipment efficiency ratings, and equipment sizing on the drawings where they could be readily reviewed. We rarely saw these references in other jurisdictions.

Requiring documentation on plans would facilitate code reviews and inspections. Specifications are reviewed sparingly in building departments and virtually unused for on-site inspections. Information which must be reviewed in the field should be on the drawings.

We recommend requiring the following key information be noted on drawings and bid documents and checked during inspection.

Envelope
• Insulation values for walls, ceilings and floors on typical sections or in notes.
• Window U-values and shading coefficients on window schedules.
HVAC
• Equipment efficiency rating (EER) or other efficiency information on equipment schedules.
• Economizers specified on equipment schedules.
• Equipment capacity, fan size and horsepower on mechanical schedules.
Lighting
• Lighting watts and fixtures noted on lighting schedules.
• Control credits, when applied, noted on drawings.

6.2 Code Provisions -- Prescriptive Approach

Enforcement problems are compounded by the complexity of the code. The code as written demands a level of understanding of mechanical systems and, to a lesser extent, lighting systems and controls, that is usually associated with trained engineers, not building officials. Furthermore, building officials do not have sufficient time to check or inspect most provisions of the energy code due to lack of resources. Code enforcement would improve if the code was viewed, not as an engineering design standard, but as a set of straightforward provisions used to insure a minimum standard of efficiency in all buildings.

If the energy code were simplified, it would reduce the time required for review and enforcement. Simplifying and focusing the energy code will insure that certain measures are included in all buildings. However, this is at a price, and that price is that the potential energy conservation delivered by the code will be reduced. A new prescriptive code might include the following provisions:

Envelope

- Use a prescriptive approach to regulate the envelope: require that all walls be .07, all windows .60 and all ceilings and floors .05. Remove restrictions on glazing area.
- Drop the requirement for building floor slab insulation for large unheated slabs (over 3,000 ft^2).
- Require a shading coefficient of .75 for exposed glazing in a building with cooling.
- Eliminate the "unheated" designation, except in very limited situations (e.g., greenhouses), and require all buildings meet the minimum U-values for all components.

HVAC

- Retain the existing efficiency provisions with improved standards for large cooling equipment.
- Mandate economizers for air handlers over 2,000 cfm; this would include most single zone rooftop and related packaged units.
- Drop HVAC sizing and ATF criteria.

Lighting

- Retain the existing LPD format but require notations on fixture wattage on code submittal documents.
- Insure lighting inspections are conducted as part of the field inspection for code compliance.
- Eliminate exterior lighting budgets.
- Retain requirements for automatic switching on exterior lights.
- Eliminate control credits.

Energy Budget Submittals

- Drop any provisions allowing designers to use energy simulations to demonstrate code compliance.

6.3 Code Design Standard Approach

The alternative to the prescriptive approach described above is to continue with the current design standard approach and provide the additional resources and documentation necessary for enforcement.

In general, design professionals have not yet accepted the code as a mandatory set of provisions to be followed as part of the permit process nor have they accepted the necessity for detailed documentation of energy code provisions on drawings and specifications. This can only change if building departments demand this level of compliance and documentation before issuing a building permit. This would require additional resources in terms of time and trained personnel.

Most code provisions can be easily verified during a plan review. However, during our evaluation of 141 buildings in Washington and Oregon, we spent from four to six hours a building conducting detailed reviews of plans and specifications for a limited number of provisions. Each field inspection took at least four hours, and we only inspected each building once and often could not review all components regulated by the energy code. To insure energy code compliance, building officials should spend at least eight and perhaps twelve hours reviewing plans and specifications and inspecting to insure compliance. This is comparable to the total time than building officials are now able to devote to the entire code enforcement process, including enforcing structural, fire, life and safety codes. Continuing to view the energy code as a design standard and allocating the time necessary to enforce it would cost between $500 and $800 per new commercial building and somewhat less for tenant improvements and remodels.

In large jurisdictions, trained staff members are available to review details of mechanical and electrical submissions. In smaller jurisdictions, staff members may not be trained to deal with this level of complexity. It seems essential to develop a cadre of code officials who could be called upon to enforce the energy code throughout the state, in lieu of or in cooperation with local building officials. In this way, engineers and other specialists could be devoted directly to energy code compliance.

6.4 Utility Programs

Utility programs should be much more effective than they are. The utility is responsible for insuring that the rate-payer's money is actually producing energy savings. We noted two problems with utility programs.

1) There is no definition of current practice building to be used as a baseline to insure that the utility is financing improvements over current building practices. Quite often engineers commented that they would have added the conservation measures funded by the utility even in the absence of a utility program. In cases where the energy code requirements are actually below current design standards, the utility pays for the owner to build a current practice building. For example, the typical chillers used in large buildings have EERs of about 16, almost double the code minimum. In an energy budget submittal, this normal level of performance can look like energy conservation and can compensate for poor performance of the building envelope or a poorly designed distribution system.

2) Simply offering cash for the development of better designs is not enough. As with the code, enforcement is necessary to insure that energy efficiency is implemented. Utilities must inspect and verify the installation of items subsidized under the ESD program. There was evidence in this sample that some ESD measures identified in the specifications were not implemented during construction.

Addressing the problems encountered in ESD and utility incentive programs is beyond the scope of this project. But it is important to remember that the delivery of energy efficiency in the commercial sector is not strictly a responsibility of the code. For certain sorts of improvements, especially in mechanical systems, lighting and controls, utilities must take the lead. It is the utility benefits associated with conservation that gave us the commercial energy code in the first place.

6.5 Efficiency vs Compliance

It is taken as axiomatic that energy code compliance is equivalent to some level of energy efficiency. Conversely, buildings that do not comply with the code are inherently less efficient than buildings that do. In actuality, this may not be the case.

Some provisions of the code have little or no relationship to actual energy use (such as heating system sizing). Other provisions may under some conditions actually increase energy use (such as the use of lighting control credits). Our findings indicate that while more than half of the sample fails to comply with the code, the average building complies.

It is wise to consider the impact of complex codes which require some technical understanding and detailed calculations. Many design professionals argue that the code is unnecessary interference in their business. Our findings indicate that in some cases this interference has not been productive. It is appropriate to identify the limitations of energy codes and concentrate efforts on strengthening and simplifying those provisions which do indeed deliver improved energy efficiency and can be easily enforced.

The level of non-compliance found in this sample is unacceptable because it sends the message that the level of efficiency mandated by the code is optional. If we cannot enforce these standards, we should choose standards that can be enforced and let utilities and designers advance the state of the art through well-designed incentive programs.

7 Acknowledgements

Ian Brown, Bob Davis and Erin McMahon did most of the evaluations of the individual buildings. Their competence and dedication were essential in the completion of this report. Andy Eckman of the Bonneville Power Administration and Jeff Harris of the Northwest Power Planning Council provided review and support which made this project possible. Finally, Judith Darst and Pat Gibbon of the Washington State Energy Office provided review and project management for the State of Washington.

8 References and Related Reports

This report is one of a series. *Energy Code Compliance in Commercial Buildings, Washington and Oregon* is the full report on the study. It contains more detailed and comprehensive information on the methodology, sample development, building evaluations and interviews.

We also wrote a parallel summary on code compliance in Oregon.

In addition, there are seven appendices which provide back-up documentations. These include energy code tables, data collection forms, the Dodge database building list, and building summaries for each sample. This compendium of documentation is available for those seeking further details.

Baylon, David, Mark Frankel and Curtis Clark, *Energy Code Compliance in Commercial Buildings, Washington and Oregon*, 1992. For the Washington State Energy Office, Olympia, WA and the Oregon Department of Energy, Salem, OR.

Baylon, David, Mark Frankel and Curtis Clark, *Commercial Building Energy Code Compliance in Oregon*, 1992. For the Oregon Department of Energy, Salem OR.