Commercial Building Energy Code Compliance in Washington and Oregon

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The States of Washington and Oregon have used energy codes to regulate the construction of non-residential buildings for more than ten years. These codes were modeled after the ASHRAE/IES 90-75 design standard. This study was designed to evaluate the degree to which new commercial buildings complied with these energy codes.

Buildings were recruited from a sampling pool containing all new commercial buildings permitted for construction in Washington and Oregon in 1990. A total of 141 buildings were recruited, 70 in Washington and 71 in Oregon. The sample was stratified by size to reflect the importance of large buildings. The recruitment process introduced some biases into the sample as schools, especially in Washington, had high participation rates and warehouses low ones.

Compliance was assessed by reviewing plans and visiting each building. Results were categorized by the building system involved--envelope, mechanical and lighting--and reasons for non-compliance. Architects, engineers and building officials were interviewed on energy code compliance issues.

About half of the buildings complied with all aspects of the energy code. Compliance on individual sections of the code exceeded 70%. Where code provisions were simple and straightforward (e.g., HVAC efficiency standards), compliance exceeded 95%. Certain problems were identified. Warehouses that were permitted as "unheated" buildings but later heated failed to meet envelope requirements. Lighting systems failed to comply most often because of changes made during construction. These findings indicate a need for more enforcement resources or a simpler code which can be administered with the available resources.

Introduction

In the mid-1970s, government agencies and utilities became interested in using building codes as tools for insuring energy efficiency in buildings. The design standards developed by ASHRAE in 1975 were considered a good model for a non-residential energy code. It was believed that engineers designing to these standards could deliver significant energy savings which would ultimately be passed on to the consumer in the form of reduced operating costs. This strategy--basing an energy code on an engineering design standard--assumes that engineers will be the vehicle for delivering energy conservation. As such, the need for a readily understandable and enforceable code is not of immediate concern.

In the Pacific Northwest, building codes have been used as a method for insuring energy efficiency in building design since 1980. The commercial codes are based on the ASHRAE design standards (ASHRAE/IES 1980). As the energy code evolved, various compromises and enhancements modified the original design standards. Most of these were designed to prevent the code from becoming unnecessarily burdensome for particular building types. A cost/benefit analysis was used to determine how provisions would be changed. New provisions had to provide operating cost savings that exceeded the added cost of meeting the energy code. Sometimes this process created more loopholes. For example, distribution warehouses which do not require space conditioning cannot benefit from insulation since there is no energy to be saved. As a result, the code was modified to allow "unheated" buildings to meet the code without insulation. Later the term was extended to cover buildings heated only to 50°F. Thus, many industrial warehouses, processing facilities and even offices avoid the insulation requirements simply because the initial permit identifies the building as unheated.

In 1991, Ecotope reviewed a random sample of 141 new commercial buildings, permitted during 1990 and built in Washington and Oregon. Both states have similar energy codes, both based on the ASHRAE 90A building standard for commercial buildings. The purpose of this study was:

1) to establish a baseline for new construction practices, 2) to review the degree to which these buildings complied with the local energy codes, 3) to assess the attitudes of building professionals and officials towards the energy code and 4) to suggest changes that would enhance code compliance.

Characterizing New Commercial Construction

We used the 1990 historical data files from a national construction industry information service which compiles data on commercial building projects throughout the country for potential contractors and subcontractors. We isolated buildings permitted in 1990 and eliminated remodels, renovations and projects which cost less than $200,000 to construct. Through this process, we identified 468 buildings (a total of 17.3 million square feet) in Washington and 213 buildings (8.3 million square feet) in Oregon. Figure 1 illustrates the geographic distribution of new commercial construction activity in Washington and Oregon in 1990.

Most commercial construction occurs in the urbanized areas of Seattle and Portland. These areas contain 77% of the square footage and 58% of the buildings. Figure 2 illustrates the distribution of building types. Four building types--office, retail, warehouse and school--make up 75% of all new construction.

Fifty percent of the square footage is found in buildings over 90,000 ft^2 but only 8% of the buildings are this large. Obviously the impact of the energy code on these large buildings is significant. However, a simple random sample would not necessarily include these large buildings. Therefore, we stratified the sample into large and small buildings. We chose 40,000 ft^2 as the cutoff point, anticipating that, with a 40% attrition rate, we could recruit 35 large and 35 small buildings per state from the sampling pool.

Developing the Sample

The construction industry database contained telephone numbers for project architects and building owners. We used these contact numbers to recruit participants for the study. To secure a total of 141 participating projects, we contacted 260 buildings. This was a success rate of 50%, somewhat poorer than we expected. Based on the comments we heard during the recruitment process, some of the lack of participation was due to the uncertainty and disaffection the professional community feels towards the energy code. The recruitment process introduced biases into the sample, particularly in Washington where schools were over-represented. Each school funded by the state goes through an energy life-cycle review process. Without exception, the building professionals who worked on these schools agreed to participate. Conversely, only 20% of the warehouses recruited agreed to participate. We expect that both responses were related to professional confidence about code compliance. We developed weighting factors to use in reporting the results to adjust for these recruiting biases and the stratification of the sample.

Reviewing for Compliance

Compliance was assessed through plan reviews and field audits. We reviewed the final set of building drawings used for bidding and construction. These were obtained directly from the design professionals or on microfilm from the construction industry information service. After the plan review, we visited the buildings which were in various states of construction. Most were nearing completion and we were able to review compliance for three major building systems: envelope, HVAC and lighting. We did not review other items (such as duct and pipe insulation and building service water) regulated by energy codes. In some buildings, particularly large office buildings, the lighting systems were not yet installed. In these cases, compliance was based on the building documents. If the documents did not describe a particular system, code compliance was assumed.

Compliance of the building envelope was based on two values: overall heat loss rate (UA) and overall thermal transmissivity value (OTTV), which describes the envelope induced cooling load. Both Washington and Oregon establish a performance standard for UA, but only Oregon requires that buildings meet an OTTV standard. Thus, OTTV was not used to assess compliance for Washington buildings.

Compliance of the mechanical system was based on several factors: the efficiency of both heating and cooling equipment, sizing (which is limited to 150% of the calculated heating and/or cooling load in Washington only), the presence of economizer cycles in cooling equipment above a certain size, and the air transport factor (ATF) (regulated only in Washington).

Compliance of the lighting system was based on a review of interior lighting power density (LPD), exterior lighting budgets and the existence of certain minimal controls (including bi-level switching on interior lights and the use of a timer or photoelectric control for exterior lights). In Washington, exterior and interior lighting budgets are combined into a total lighting budget. In Oregon, they

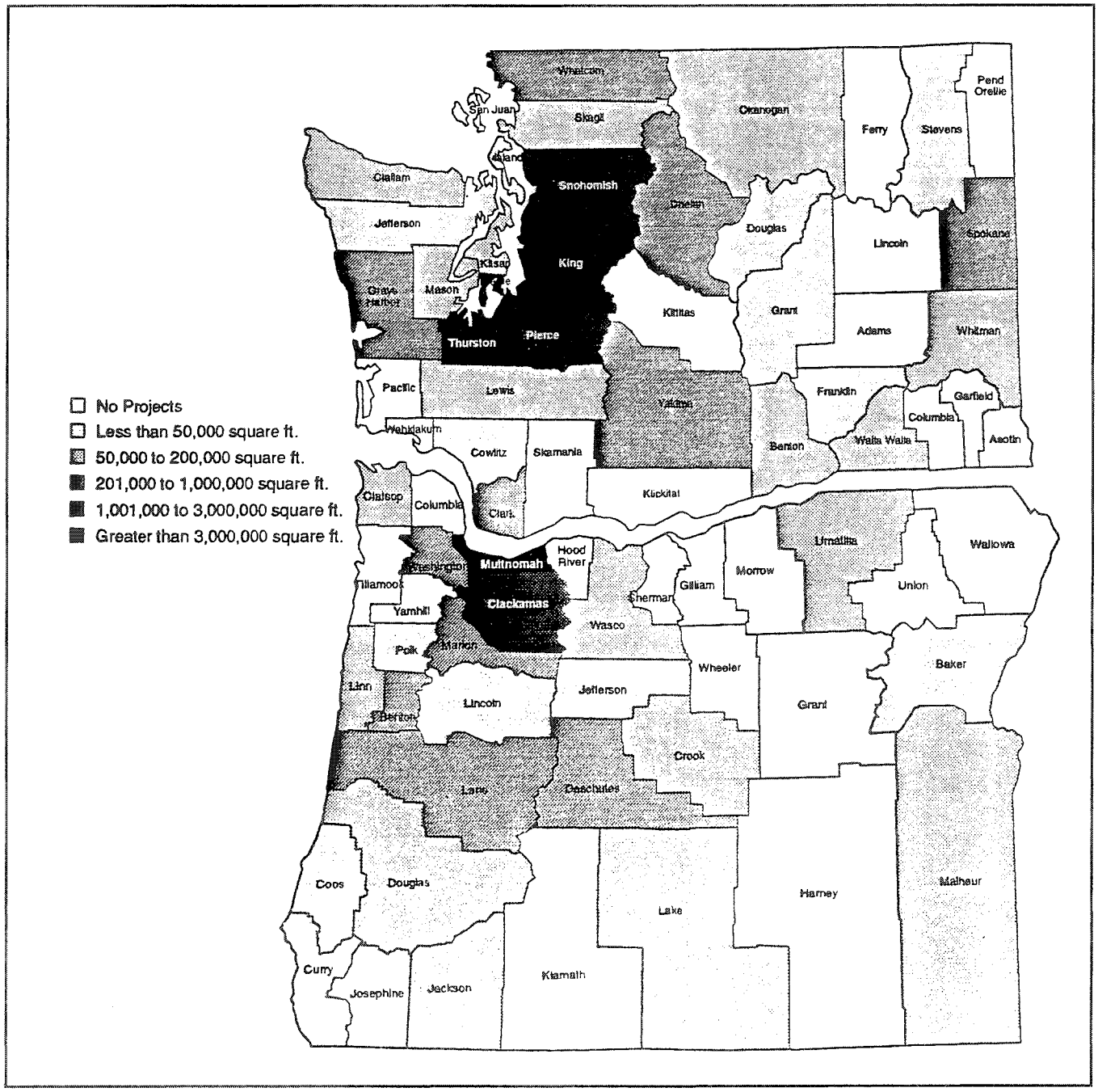

Figure 1. Square Footage of Commercial Construction Activity by County

are regulated separately. In addition, both states give credits (thus increasing the lighting budget) for the use of daylighting, occupancy controls and, in Oregon, programmable controls.

Table 1 shows the distribution of compliance by building type for these three major building systems.

While substantial variations exist between building types, 52% of the buildings (and 51% of the area sampled) complied with the relevant energy code. When this sample was re-weighted to account for the stratification of the sampling, the overall percentage of compliance slipped to 47%. Figure 3 shows the distribution of compliance by major building systems.

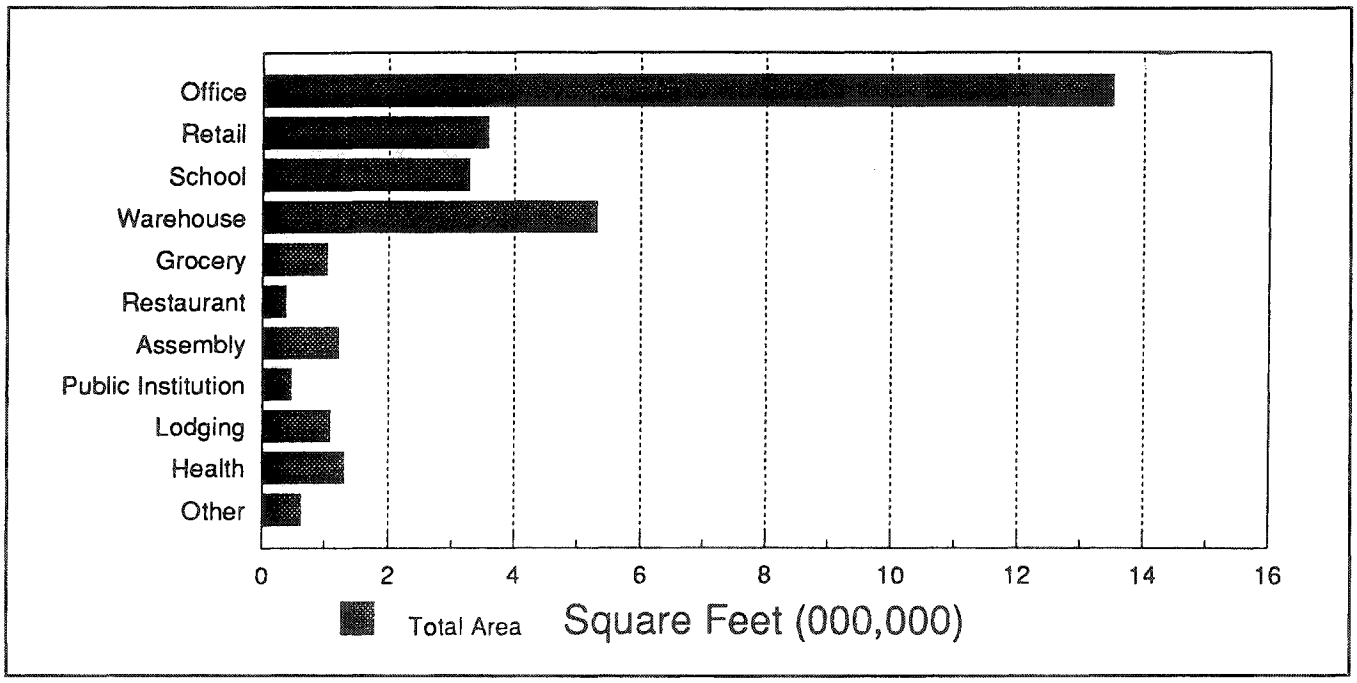

Figure 2. Permits and Construction Starts, Area by Building Type

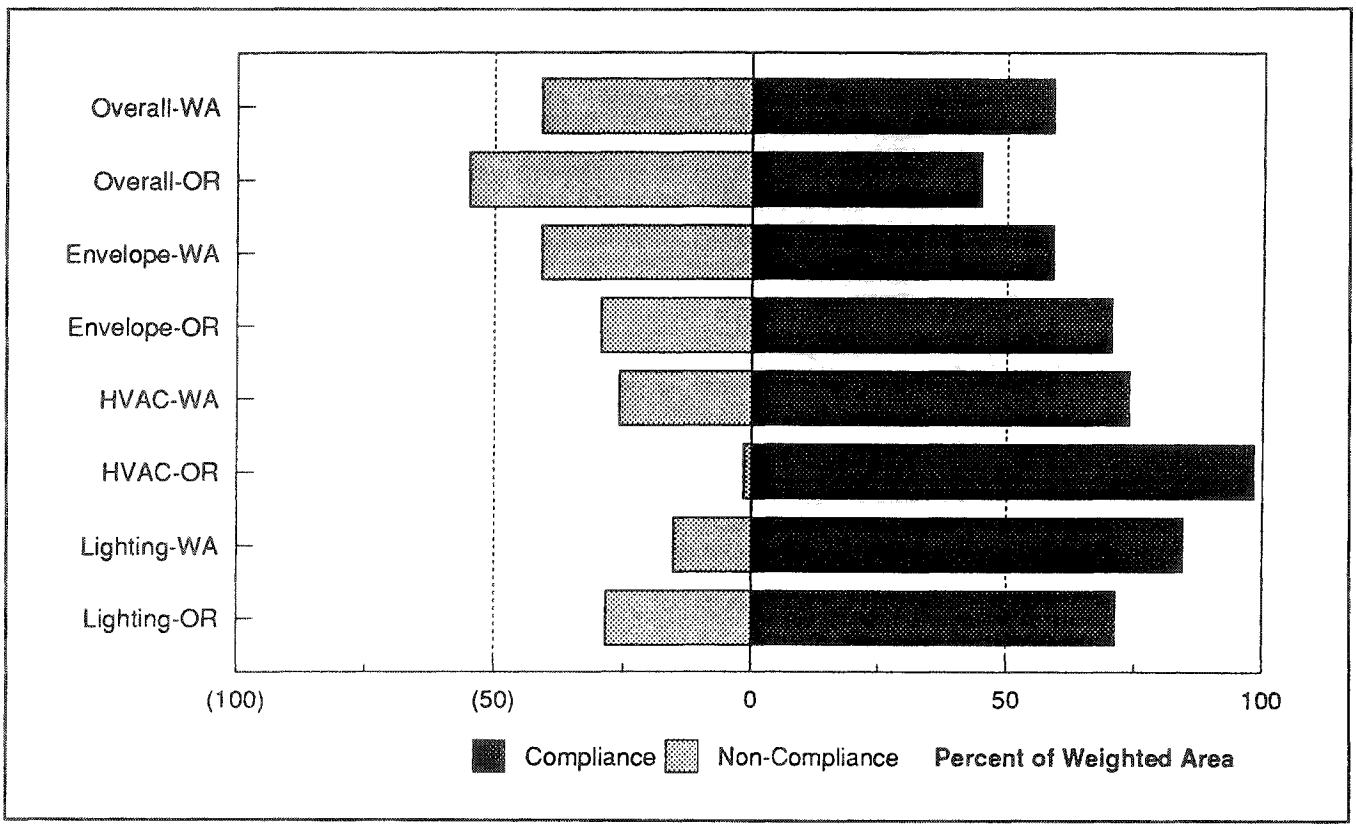

Figure 3. Energy Code Compliance by State and Building System

Table 1. Code Compliance Summary by Building Type

Size	Type	Number of Buildings Studied	Complied	Percent
Large	Office	12	6	50%
>40,000 sf	Retail	8	2	25%
	Grocery	6	3	50%
	School	23	15	65%
	Warehouse	6	1	17%
	Health	3	2	67%
	Assembly	1	1	100%
	Other	3	2	67%
	Total Large	62	32	52%
Small	Office	24	13	54%
<=40,000 sf	Retail	16	6	38%
	Grocery	3	2	67%
	School	8	7	88%
	Warehouse	2	0	0%
	Restaurant	8	2	25%
	Institutional	7	3	43%
	Lodging*	1	1	100%
	Assembly	6	5	83%
	Health	2	1	50%
	Other	2	1	50%
	Total Small	79	41	52%
Total		141	73	52%

*Lodging not regulated under Oregon non-residential code.

Compliance by system is substantially better than overall compliance, averaging 75%. In Oregon, the relatively simple efficiency standards set for mechanical systems resulted in 96% compliance. Conversely, in Washington which regulates ATF and overall equipment sizing and thus requires complex calculations, mechanical system compliance levels dropped to 72%. In both Washington and Oregon, large buildings had poor levels of envelope compliance because of high levels of glazing. In both states, unheated buildings are exempt from envelope requirements and most warehouses are permitted as unheated buildings. However, when we observed heating systems during a field audit of a warehouse, we considered it a heated building. This caused most warehouses to fail to comply with envelope requirements. Although LPDs are regulated and reviewed in most jurisdictions, inspections are rare. Thus, field changes which increased lighting levels were the largest single cause of lighting non-compliance. This was true for approximately 30% of all buildings that failed to comply based on lighting.

Figure 4 shows the level of compliance by county. There is little relationship between compliance and level of construction activity. In fact, several urbanized counties have poor compliance rates (e.g., Multnomah County in Oregon (Portland) and Pierce County in Washington (Tacoma)).

Conducting Interviews

We interviewed both design professionals and building officials.

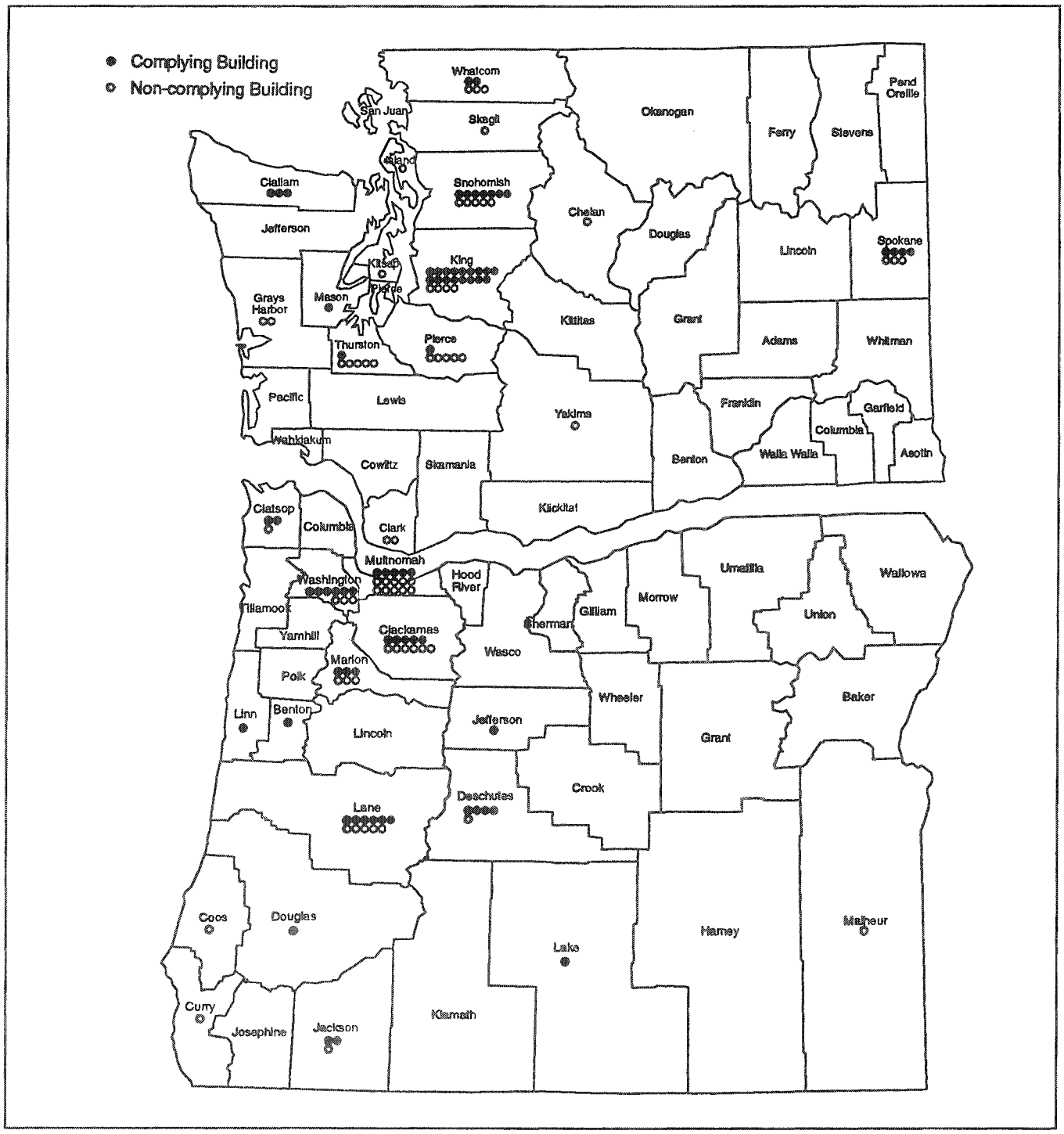

Figure 4. Energy Code Compliance by County

Following the plan reviews and site visits, we attempted to interview the architect, principal mechanical engineer and principal lighting engineer for each building. We conducted 285 interviews, talking with 122 architects, 80 mechanical engineers, 53 lighting engineers and assorted general contractors, owners representatives, and lighting and mechanical equipment installers.

During these interviews, we focused on code compliance responsibility and specific problems with the code

enforcement process during the building's design and construction. One-half of the architects interviewed said that they were not involved with establishing energy code compliance, not even for the building envelope, nor did they take the code into consideration during the design process. Code compliance was generally left to mechanical engineers who provided architects with insulation specifications which would meet the code. Only 10% of the architects interviewed were involved with the code compliance of either the lighting or mechanical system.

Lighting designers generally favored the code. Most of those interviewed felt the code was easily met. Lighting designers who were not particularly well-informed about advanced lighting technologies seemed more reticent to accept the code-regulated LPDs than those who were familiar with the newer technologies. Most lighting compliance problems, however, were not due to the design but to changes in the field. Usually these occurred during the bidding process when installers substituted less efficient (and less expensive) fixtures for those specified. In some cases, particularly in retail uses, the owner or occupant increased the number of fixtures and thus the total lighting wattage. Once the building was permitted, little attention was given to meeting the lighting code.

Almost none of the design professionals said that code compliance issues were a major factor in determining the design of the mechanical or lighting system. Likewise, feedback from building officials had little effect on design or construction. In fact, only 6% of all those interviewed said they received *any* feedback from code officials on energy code requirements.

During the interviews, we asked if the building design had been influenced by any of the utility rebate or state-sponsored programs available. Twelve percent of the sample participated in utility programs which provided either design assistance or rebates. Of this group, 76% complied fully with the energy code, a substantial improvement on the sample as a whole.

We also interviewed building officials from selected jurisdictions. Despite the poor findings for compliance, most building officials believed the compliance in their jurisdiction was "good." Building officials often mentioned factors which made plan review and inspection difficult. They said the energy code language was complex and ambiguous, particularly for HVAC systems. They often did not have enough time or personnel to adequately review and enforce the energy code. It was hard to coordinate inspection schedules, particularly for lighting, so that inspectors could be present at the appropriate time. They also mentioned the lack of a standardized, well-defined process for review and enforcement.

In Washington, some building designers submitted energy budget simulations to demonstrate code compliance. This allowed trade offs, so that a building could reduce insulation levels or increase glazing levels, provided the mechanical system or lighting system was more efficient. Approximately 50% of the buildings using the Energy Smart Design rebate program submitted energy budget simulations. In Oregon, where no similar path was available, large buildings participating in utility programs often failed to comply with envelope requirements even though the building was fairly efficient. Although supposedly more efficient, the lighting systems of buildings participating in utility programs were not substantially better. As with the sample as a whole, this was largely due to field changes. The efficient lighting systems sponsored by the rebate program were not installed because the contractor or owner substituted less efficient fixtures or ballasts or increased the number of fixture during construction.

Approximately 15% of the buildings in the sample participated in a state-sponsored life cycle cost review and 62% of these buildings were in compliance with the overall code.

Building Practice and Energy Code Impacts

Measuring the level of compliance is only one way to analyze the effect of the energy code. After all, a building was considered non-complying if it failed to meet one provision of many in the energy code. We also examined the impact of the energy code on building practices.

Envelope

The average building heat loss rate for the entire sample was about 12% below the code maximum, with about 80% of the buildings meeting the envelope code. This is true in both states even though the Oregon code is somewhat less restrictive than the Washington code.

HVAC

Most HVAC systems installed in this sample of buildings were single zone systems, usually rooftop packaged units. Except for re-conditioned equipment, all the equipment met the efficiency standards in both states. The single

largest cause for non-compliance in Washington was failure to meet the system sizing requirements. System sizing is not regulated in Oregon and Oregon buildings had a 22% increase in system size when compared to Washington buildings. Both states regulate HVAC control systems and "simultaneous heating and cooling" but we did not review these provisions.

Lighting

More buildings (26%) failed to meet lighting requirements than any other code requirement. The largest single reason for non-compliance was field changes which increased the number of lighting fixtures or reduced their efficiency. While there are many reasons for these changes, all the lighting designers and installers interviewed mentioned the absence of field reviews for lighting system compliance. However, average lighting power density was 5% below the code in Washington and 19% in Oregon. This difference is due to the way the two states regulate lighting. Oregon regulates interior and exterior lighting separately. Washington allows designers to combine interior and exterior lighting budgets into one overall budget, which means a designer can design an interior system which is over budget if the exterior lighting is under budget. If Washington regulated lighting the same way Oregon does, the level of non-compliance in the Washington sample would double.

Summary

Standard building practice seems to be consistent with the code. However, problems occurring during the design or enforcement process result in at least one significant code violation in about half of the buildings surveyed.

Conclusions

The most important conclusion of this study is that the complexity of the energy code seriously diminishes levels of compliance. This is due to the lack of understanding of these codes among the professional community and, more importantly, the lack of understanding and enforcement from building departments. Many code provisions require the use of complex calculations to determine if the building meets the code. These calculations require some understanding of the engineering principles involved in designing commercial buildings. Most building officials are unable to review these calculations, partly because of lack of time and partly because of lack of skills. The ASHRAE 90A design standard encourages this level of complexity since it is written for mechanical engineers and design professionals. It seems obvious that compliance levels would improve if the code were simplified.

We found only one jurisdiction (Seattle WA) where building officials were reasonably well informed about all aspects of the energy code. Not surprisingly, this jurisdiction had dramatically better compliance levels than did other jurisdictions. It should be pointed out that this jurisdiction enjoyed considerable support for the energy code and was able to devote time and resources to code compliance not available elsewhere.

During this study, we spent eight to twelve hours reviewing each building, including the plan review and field audit. Building officials told us that they have approximately eight to ten hours to review each building they are assigned. This review must cover compliance of the building with structural, fire, safety, zoning and other related codes. Clearly, they have, at best, an hour or an hour and a half to review and inspect for energy code issues. The current code and indeed all the proposed design standards are too complex to be checked in a commercial building in such a short amount of time.

Building designers, particularly architects, do not provide a significant level of code compliance. Despite their position as licensed professionals and even after ten years of codes, they do not believe they are responsible for ensuring energy code compliance either during design or construction.

Improved inspection and verification procedures are essential to the enforcement of the energy code. Inspection procedures should be developed which will identify changes made during the construction process that diminish efficiency. At least two installers explained to us that if they actually bid to meet the code, they would lose the bid to other installers who do not use the code as a basis for their bidding since meeting the code requires using more expensive equipment. Apparently this is a particular problem for lighting fixtures and economizer cycles but we suspect that, in one form or another, it also impacts other components of the building envelope and mechanical system.

Given the level of enforcement activity, particularly during building construction, it seems apparent that much of the code compliance observed is actually the result of the efforts of the design community. Many decisions to include more efficient equipment or envelope construction practices are based on client demands. While average building practice roughly corresponds to the code, a significant number of buildings fail to meet all code requirements. Code officials are not successful in reviewing and altering building practices in this fraction of commercial construction. Either code enforcement should be enhanced so that adequate resources are available for reviewing commercial buildings or the code should be

revised to make enforcement simpler and interpretation less difficult. In this way the code might be enforced with existing building department resources.

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