Residential Energy Code Compliance in the State of Oregon

FINAL REPORT

Mark E. Frankel
David A. Baylon

ECOTOPE
2812 E. Madison, Seattle, Wa. 98112 (206) 322-3753

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Executive Summary

This report has three major goals: 1) to establish the impact of the Oregon Residential Energy Code by assessing the levels of enforcement and compliance associated with the code; 2) to provide information on the thermal performance of the components of single-family residential construction; and 3) to assess the perceptions of individual code officials and builders regarding the code's acceptance and its influence on building practice.

Code compliance rates were evaluated in two different ways:

- *Prescriptive compliance.* The code includes specific construction requirements for building envelope components (ceilings, walls, windows, etc.) and other elements of residential construction. Compliance with prescriptive requirements for envelope components was evaluated separately from non-envelope measures. Since these are prescriptive requirements, homes must comply with all of the individual requirements, or be deemed as out of compliance with code requirements.

- *Envelope component performance-based compliance.* This evaluation compared the overall envelope heat loss rate of the house with the heat loss rate anticipated if the house were built exactly as described by the compliance path under which it was submitted (typically Path One). In this case, a house may have one or more components which do not perform as well as the code mandates, but other components may out-perform code requirements enough to make up the difference. A house with a heat loss rate the same as or lower than anticipated by code would be deemed to comply with code requirements, regardless of individual component make-up.

In addition to these compliance evaluations, Ecotope evaluated the impact of the OREC on energy use in the residential sector to predict energy savings impacts associated with non-compliance with the energy code. This evaluation was not used to define compliance rates.

To accomplish these goals, Ecotope, Inc., Delta-T and Clark's Energy Services reviewed a sample of 283 residences permitted in Oregon in 1993 and early 1994. Residents were selected at random from 65 code compliance jurisdictions, which together accounted for 94% of all single-family residential construction in the state of Oregon in 1993. Plan and field reviews were conducted between February and May of 1994. The field reviews were typically conducted on the same day as insulation, cover or final inspections of the homes. About 50% of the sample was surveyed at the time of the final inspection.

Overall, the sample size exceeded the targeted projections by approximately 16%, and also exceeded the study's statistical requirements (a 95% confidence interval and a 5% margin of error). The sample's size, and the fact that it was random with respect to the jurisdictions surveyed, indicates that this is a very representative sample of site-built residential buildings in Oregon.

The first review involved studying the actual submittals to establish the general nature of compliance for individual buildings. This review indicated that approximately 93% of all homes in Oregon were submitted under the Path 1 reference path (either directly, or as enforced by the building department). Four percent were submitted under Path 8, and 3% used the performance path. No other submittal paths were used. In general, builders provided limited compliance information on the plans, with 25% of the submittals having no path or energy code designation information on them at all. An additional 34% had minimal information on insulation levels relative to the prescriptive path noted. This suggested that the bulk of energy code enforcement occurred in the field.

When these homes were reviewed in the field, the lack of information in the plan submittals did not appear to be relevant. For the most part, builders met the minimum specifications of Path 1. The principal problem associated with the field review was the widespread absence of labeling on windows and doors. Overall, the level of compliance on individual components was quite high, but the number of houses which met all of the specific prescriptive requirements was much lower. In evaluating buildings as a whole, compliance with the prescriptive requirements for building components and heating systems was approximately 56%, and for non-component requirements it was approximately 55%.

When compliance was evaluated based on the overall envelope heat loss rate, it was found to be much higher (80%). If we allow a 5% margin of error for heat loss requirements, total compliance rises to over 98%.

The principal difficulties associated with prescriptive compliance included: window performance issues, complicated by labeling anomalies in 1993; the use of uninsulated entry doors in excess of the 24 ft^2 allowance in the code; the use of R-30 insulation in vaulted ceilings where vaulted ceilings exceeded 50% of the floor area; and conditions in which blown-in insulation in vaults and attics did not meet the overall code requirements (due to underinsulation). Several compliance issues were complicated by omissions or contradictions in the text of the code. These difficulties generally had a very small impact on the total heat loss rate; except in homes with multiple problems, these were typically balanced by marginal performance improvements in other parts of the house. This was especially the case when improved window or door performance became part of the builder's package. Because of this feature of Oregon homebuilding, the overall impact of non-compliance on energy performance of Oregon homes could be expected to be very low.

The study indicated that the performance impact of the energy code was very close to the assumptions used in developing the energy code's cost-effectiveness. This is because the heat loss rates of nearly all of the studied buildings were very close to the heat loss rates anticipated by the code.

To determine the overall performance, Ecotope used the SUNDAY™ 3.0 program, modified to include the effects of heating system and duct locations. This calculation was similar to the calculation used during the development of the code. Based on previous studies, we determined that the average duct efficiency for homes with ducts was approximately 72% (that is, 72% of the space heat delivered into the ducts is actually delivered into the home). About 4% of the homes reviewed had duct systems in which a high level of duct efficiency would be expected - these are typically homes with full basements in which all ductwork is located within the heated space. Furnace efficiency tended to be above the level required by the code. The average furnace efficiency (A.F.U.E.) for gas furnaces was 80.7%. The average heat pump efficiency was 209%, or an HSPF of 7.1. Overall efficiencies for gas furnaces, when the duct systems were combined with the furnace, was approximately 58%. For heat pumps, this efficiency was approximately 152%. Electric furnaces had an overall delivery efficiency of 72%, which accounted for the impact of the duct system only. When energy impacts of the building stock and of non-compliance were calculated, these system effects were used to assess the actual total impact on Oregon residential buildings.

The overall impact of non-compliance was not very significant. In the case of gas-heated homes, non-compliance in building envelope components (which resulted in some increase in heat loss rate) was counterbalanced by the increased efficiency in the gas furnaces themselves. There was virtually no net increase in gas usage. In electrically-heated homes, a total of 1/2 of 1% increase in electrical energy usage could be anticipated in non-complying homes. The entire impact, when projected statewide, amounts to .03 megawatt average in extra electrical usage by this sector. The implications of this finding are that in spite of the nearly 50% prescriptive non-compliance rate, any deficiency has largely been balanced by a combination of improved efficiency in other building components and improved efficiency in mechanical equipment.

At the same time as the field review, Oregon builders and code officials were interviewed regarding the impacts of the code. The level of acceptance of the Oregon Energy Code was quite high among building officials and the building trades. A total of 104 interviews were conducted, 62 with code officials and 42 with building tradespeople. In general, building officials felt that significant areas needed to be addressed to ease the burden of code enforcement. These included more consistent window and door labeling requirements, and greater clarity in below-grade and slab insulation requirements, in order to allow more consistent enforcement of these components and more direct review of builders' plans.

For builders and architects, the principal code issues were: ongoing changes in the code requirements that create confusion in the building community as to the precise requirements; and the cost of code compliance to builders. Both of these issues were mentioned by about 50% of the interviewees. Other issues included lack of clarity in either code enforcement or code language, and the lack of training and technical backup that would allow them to interpret the code in complicated situations.

Overall building characteristics were reviewed as part of the code compliance review. These characteristics did not directly relate to code compliance, but were an effort to characterize the single-family building sector in Oregon. This "base case" of construction practices could be used to describe conservation programs, and to provide a basis for cost-benefit analysis of future improvements in building and code practices.

In general, 90% to 95% of any particular envelope component complied with the code, and in general the actual performance levels of the individual components was well-described by the code. On average, at least, component U-values were within a few percentage points of the values specified in the Oregon code. In addition to the building components, the ducts and heating systems were also reviewed. All of the observed furnaces and heat pumps complied with the code. Approximately 73% of all homes were heated with gas furnaces with ducts. In addition, 17% of the homes had electric furnaces or heat pumps with ducting configurations similar to the gas furnaces. Only 10% of all homes had zone electric or other heating that did not include a ducting system. Ninety percent of all homes in Oregon use forced-air heating. Of these, almost 90% had more than half of their ducts located in unheated crawlspaces, attics or garages.

To help characterize Oregon homes, approximately 25% of the sample was reviewed using a blower door to test overall air infiltration levels. The median measurement for air tightness in Oregon homes was approximately 7.8 air changes at 50 Pa. This result translated into an overall natural air change rate of approximately 0.38 air changes of natural infiltration. This result was somewhat surprising, as it represented a greater amount of leakage than had been discovered in some other large samples of the single-family residences in the Pacific Northwest. However, this level of tightness does suggest some improvements over the construction practices observed in 1980 - 1986.

The conclusions drawn from this extensive study of Oregon residential buildings can be summarized as follows:

1. Overall building energy performance in Oregon is consistent with levels anticipated in the Oregon State Energy Code and its development, and consistent with the performance implied by the codes. Although detailed prescriptive compliance is low, the overall impact of this non-compliance on heat loss and energy use is balanced by other factors in the buildings.

2. Overall energy code compliance and performance is quite uniform throughout the State of Oregon. There seem to be few or no jurisdictional impacts explained either by size of jurisdiction or by geographic area. Some jurisdictions noted that certain areas of the code were either burdensome or confusing in their localities. On the whole, these problems did not appear to have impacted overall compliance or performance. Interviews with code officials and building professionals revealed several areas of confusion which could be clarified in future code development. There is a clear need for consistent interpretation of the labeling and testing of building components (especially windows, doors and various below-grade insulation components.)

3. The Oregon energy code has been integrated into building practice in the State of Oregon. Most, if not all of the central provisions, such as requirements pertaining to window performance and high-density insulation batts have been integrated as standard features into buildings, and there is evidence that almost all builders in Oregon comply with these provisions. Levels of enforcement and inspection appear to be effective in ensuring this compliance. The only significant area in which energy performance could be noticeably improved is the development of more stringent standards relating to heating systems and duct distribution systems.

4. Finally, utility programs, both for gas and electrical energy usage in the state of Oregon, seem to have a significant impact on compliance, as all of the buildings reviewed that had been involved in utility programs did in fact comply with the energy code. On average, these homes' performance was 6% better that anticipated by the code.

It appears that the Oregon energy code, as written, enforced and practiced delivers the level of performance in Oregon residences consistent with the energy code's goals.

1. Introduction

In the Fall of 1992 ECOTOPE, Inc., Delta-T, and Clark's Energy Services began a review of the Residential Energy Code for the state of Oregon (OREC). This code was designed to increase energy efficiency in Oregon homes through the use of insulation and window and door performance standards.

The goals of this study were:

1. Estimate the difference in annual energy use in Oregon between what is anticipated by the residential energy code and what is characteristic of current construction practices.

2. Identify major reasons for variation between energy code requirements and current construction practice.

In order to accomplish these goals, Ecotope identified the following objectives to guide this study:

1. Determine the levels of compliance to OREC particularly in relation to the code compliance options offered within the code.

2. Assess the energy impact of any non-compliance with the Oregon Residential Energy Code.

3. Characterize construction practices used in home building in the state of Oregon.

4. Determine perceptions of the code among building officials and residential home builders.

1.1 Code Compliance

The primary issue here is to establish compliance levels with the OREC. The code includes a variety of compliance options, or paths, in order to allow flexibility to home builders in meeting the code requirements. There are a number of specific additional requirements which must be met for all projects (e.g. minimum furnace efficiency, hot water pipe insulation, duct insulation, etc.). The compliance options allowed under the code have been developed based on a cost effective reference path, which uses a set of prescriptive requirements for insulation and thermal performance for various house components. This "path" is modified to accommodate such variations as smaller, low income housing, log homes, solar or sun-tempered homes, etc. Each of these variations describe a set of components which combine to form a compliance "path". Path One is the reference path, and eight other prescriptive paths are included in the energy code. A performance path option, where component trade-offs are allowed based on the Path One baseline, is also allowed under the code.

The "prescriptive" paths have several features that define compliance with their provisions. First, the provisions are not designed to be altered by trading off a lower-performing component against a better one. This is supposed to be limited to the "performance" path alone. Second, all paths except Path Eight have no limit on the amount of window area, although they have very specific performance requirements for the windows. Third, the prescriptive paths allow some flexibility in accommodating "architectural" features which cannot be easily adapted to the individual provisions of the code. These include dormers and other ceiling features, solid wood panel doors for use in entry areas, and small amounts of glazing which do not meet the code requirements.

This variety of compliance paths and options complicates the definition of code compliance somewhat, since any given house must be evaluated in a variety of ways before its energy code compliance can be characterized or ruled out. In particular, the performance path option means that a house may incorporate components which do not meet the prescriptive code requirements for individual components, while still meeting the building performance requirements. This makes the evaluation of energy code impacts on individual building components problematic. Another complicating factor is that a particular building may seem to meet the code from a performance standpoint, but still fail to comply with more specific requirements of the code. It should be noted that the development of the code focused on performance goals which were based on the components in the reference path. For purposes of estimating the performance of individual homes, the reference path was used to determine the magnitude of deviation or improvements in the home as built.

With these issues in mind, we have developed two levels of compliance evaluation for use in characterizing residential energy code compliance in the State of Oregon.

1.1.1 Prescriptive Compliance

There are nine compliance paths in the Oregon Residential Energy Code. These paths have different combinations of insulation, window area and other related requirements. In principle, to comply with any one of these prescriptive paths, the builder would ensure that each separate component defined in the prescriptive path met the requirement contained in the code. Thus, if the prescriptive path calls for R-21 walls and R-38 ceilings, the builder would be obligated to deliver at least that level of performance for those two components. In effect, the prescriptive compliance would review each of these components *individually* and assess whether they meet the code as written. If they did not, the home would not be in compliance with the letter of the energy code, and neither would the component(s) in question. This result can be summarized as a percentage of non-compliance by home, and as a percentage of non-compliance by component.

It is important to note that a home complying with all the provisions of the prescriptive path is likely to exceed the performance expectation of the OREC itself. This is because any variation in building characteristics would result in a reduced heat loss which would not influence the characteristics of any other component. As part of this evaluation, certain code requirements did not necessarily influence the performance evaluation, such as the presence or absence of pipe insulation, low-flow fixtures, etc., which are nevertheless requirements of the code.

1.1.2 Component Performance Based Compliance

A second level of compliance consists of trade-offs between individual components to achieve the overall level of performance defined by the code. By determining the overall building heat loss rate, and comparing it to the energy code's standards, the whole house can be evaluated vis-à-vis the requirements of the performance path provided for in the Oregon code. Although this path is seldom used, this method provides an analysis tool for purposes of evaluating code performance.

It should be noted that although a house might not meet prescriptive requirements of the code, performance improvements to other components may lead to compliance with performance path requirements. The definition of performance compliance under this method is that the building complies *overall* with the energy code, on the basis of total heat loss rate, even though a particular component may not comply with the individual requirements of a prescriptive path. At the outset, our analysis of this process will use a comparison between the overall UA of the building and the overall UA required by the performance trade-off method.

1.2 Performance Analysis and Code Impact

Another aspect of our evaluation was determining whether a building actually met the goals of the Oregon Residential Energy Code, given its overall energy performance, and to assess the impact and performance which might be expected for the homes permitted in Oregon in 1993 as compared to the expectations from the same home built to meet the OREC exactly. This prediction will be based upon a comparison between the code building as defined by the performance path, and on the actual building as proposed and built. To do this the heating energy is predicted using a computer simulation based on the home as sited, heated and built versus the same home, configured in the same way with only those aspects controlled by the code altered to correspond exactly to the code requirements.

To more accurately assess these impacts the effect of heating systems and distribution systems are included. Since the code does not regulate distribution systems for location and leakage the derived distribution efficiency was used for both the as-built and the code reference home. For furnaces and heat pumps the manufacturers' AFUE or HSPF rating was used to get the as-built conditions while the code minimum used the values from section 5305 (c) of the OREC.

This methodology was applied to assess energy impacts of non-compliance with the OREC. Since code enforcement and compliance only impact those homes which fail to comply, the amount of extra energy use by those homes comprises the energy impact of non-compliance. There were two groups of non-complying homes reviewed. Those which had total heat loss rates in excess of the code reference path and those which had heat loss rated more that 5% greater than the code reference path. This method will illustrate the relative size of the non-compliance in individual houses. The impact for both groups will be projected to the entire sample frame, the 1993 permitted homes.

In all cases, the impacts on space heating are divided into electrically heated, gas heated and other homes. When calculating energy impacts on the utilities the effects of heating and distribution systems are taken into account. The impacts of other systems such as domestic hot water, cooling, lighting, etc. were not included in this analysis.

1.3 Characterizing the Sector

The next goal of this study is to characterize the nature of residential construction with regard to implications for energy consumption. This includes the evaluation of home size, construction characteristics, and energy performance. An understanding of these practices can inform Oregon residential construction and future building code formulation, and the impact of the Oregon energy code on these practices can also be assessed. We gathered this information, both from submitted plans and on-site characteristics, to determine the building materials and components used by Oregon builders. We also examined the selected heating system types and their efficiencies and construction practices. In addition, we studied the distribution of new single-family residential construction throughout the state, and the local variations in building practices.

The second aspect of construction practice will be code enforcement and documentation practices. This review will include detailed interviews with builders and building officials, and will assess the building community's decisions regarding compliance with the Oregon energy code.

1.4 Interviews, Builders and Building Officials

As a final step the principle players in Oregon residential building were interviewed. The goal here was to gain insight into perceptions of the code and the degree to which the OREC has been integrated into building practice.

The structured interview administered to building officials was aimed at discerning the enforcement and compliance techniques applied to the energy code in the jurisdiction. In addition, information about size and staffing were collected.

The interview with builders was more free form and focused almost exclusively on attitudes toward the specific requirements of the OREC. Efforts were made to focus on the degree to which the energy code has become current practice in the building community. These interviews were further supplemented by informal conversations with sub-contractors and suppliers. These were focused on their particular specialties as they related to the particular provisions of the OREC, and the degree to which the code influences their practices.

2 Study Methodology

The goals of this study were attained using four main sources of information:

1. *The selection of a representative random sample of new Oregon homes.*
This sample was drawn from homes built and inspected during the period when field work was conducted, and was constructed to represent the distribution of new single-family homes permitted in Oregon in 1993.

2. *A review of each home selected, through the building departments.*
Code documentation provided by the builders and evaluated by the building departments was reviewed. This review included any field notes made by plan reviewers for the permit application regarding whether the building met the energy code, or what modifications were required.

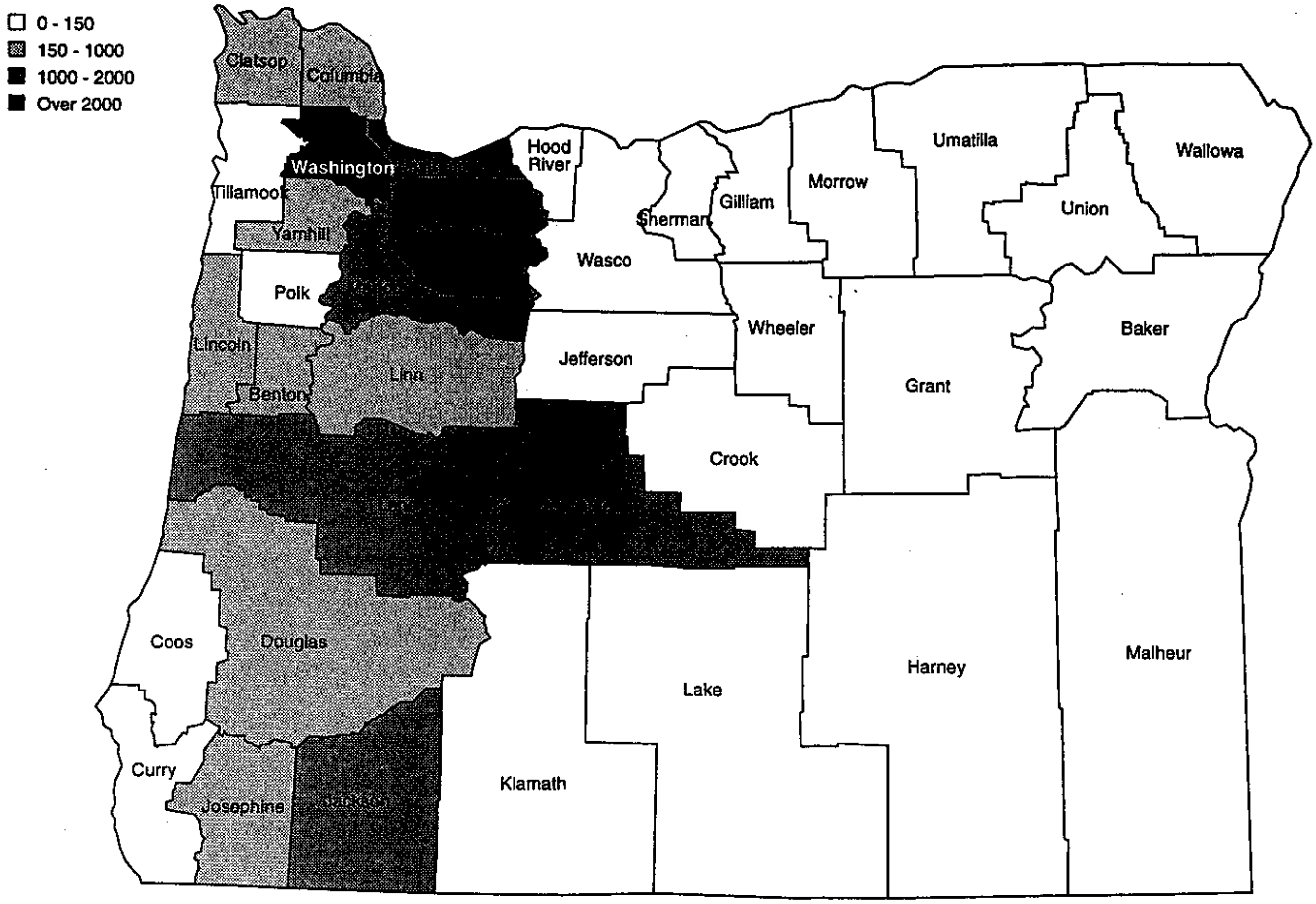
3. *A field review of buildings as found during the inspection process.*
This inspection will verified information gathered during the review of plans and permit documents, and obtained other data about construction types. Reviews were conducted at various stages of construction according to the availability at each jurisdiction.

4. *Interviews conducted with building officials and builders.*
This allowed us to assess responses and attitudes towards the Oregon energy code's adoption and enforcement, and to clarify enforcement and compliance procedures used by these groups.

2.1 Sample Development

In order to accomplish the study goals, a sufficient number of Oregon homes were sampled to obtain results representative for the entire state. Since no centralized permit records exist in the state of Oregon, the sampling methodology must take into account the individual jurisdictions' impact on the entire building stock, and a sampling method must ensure that homes reviewed in each of these jurisdictions are a collectively unbiased representation of building practices. Map 2.1 indicates the density by county of permits for residential construction in Oregon for 1993.

MAP 2.1
Density of 1993 Residential Construction Permits by County



2.1.1 Designing the Sample

The final sampling goal was to draw 283 homes from 62 code jurisdictions, a sample representative of single-family residential construction in Oregon. The size of this sample was arrived at using a criteria based on a desired confidence interval of .95 and a total population of Oregon residential permits of approximately 14,000 per year. Since this sample was to represent the building activity in the state, without direct reference to the performance of any particular jurisdiction the criteria was originally based on a simple random sample which would not stratify on any criteria. The sample size was based a binomial distribution of the distinction between compliance to the OREC and non-compliance. The original sample size was based on the assumption that the level of compliance across the state would be 75%. This criteria was based on the compliance to individual section of the nonresidential energy code in 1991 (Baylon, et al, 1992). Using this criteria and applying standard statistical techniques an initial sample size of 256 homes was estimated. This sample size was increased slightly as resources became available to ensure good confidence intervals if the initial compliance assumptions proved optimistic. an additional 20 homes were added for a pilot study, this group was later included in the overall sample as the field protocol and results of the pilot study were very comparable to the larger sample. Final about 16 homes were added to the sample to focus on smaller jurisdiction. These jurisdiction were selected based on proximity to the main sample but focused on counties that might not otherwise been included in the sample. There were four counties targeted in for the group of houses: Clatsop, Crook, Polk, and Tillamook. In general we attempted to sample from these counties unless there were not home available for inspection during the field visit. With these modifications coupled with several homes which had to be dropped because of anomalies in the field notes the final sample was 283 homes which exceeded our original criteria. and represented about a 2% sample of the single family residential permits in 1993.

To achieve a representative sample, the buildings selected must be selected at random, since all buildings in the target population must have an equal chance of being selected. A random sample of single-family residences under construction in the State of Oregon was more problematic than it might appear to be.

The State of Oregon does not maintain a list of buildings currently under construction. Indeed, in the case of many jurisdictions, no list is available even for the jurisdiction itself. In Portland,, for example, once a building is under construction it is assigned by geographic area to a particular inspector or inspectors. After this, the building's progress is solely the responsibility of the inspector. The building is listed in City of Portland's records only after completion and final inspection. This process is typical of jurisdictions that do not have a computerized tracking system for buildings proceeding through the inspection process. While the City of Portland is the largest of these jurisdictions, it is by no means the only one. Several, (in fact, most) smaller and some large jurisdictions maintain no central tracking systems, either during the permitting or inspection processes. As a result, it is impossible to assemble the number of annual permits to sample, even if jurisdictions are individually surveyed. To solve this problem the field technicians were directed to select the homes to be sampled at random from the homes available for inspection on the day(s) when they were at the jurisdiction. The sample then is based on the process of calling for inspections being at least unbiased with respect to the timing of our field visits.

The field review process began in February 1994 and was completed in May 1994. It was conducted by nine field technicians working at various locations throughout the State of Oregon. Field technicians working in particular jurisdictions selected homes to be reviewed at random from the available homes. Larger jurisdictions were visited by up to three separate technicians at intervals separated by up to four weeks. Smaller jurisdictions were generally visited once by a single technician and one to three homes were reviewed during the visit.

Technicians identified homes currently at or near final inspection as potential candidates for review. This turned out to mean any home which had received a "cover" inspection. In some jurisdictions with small amounts of construction even this criteria had to be relaxed to review any building past the "framing" stage of construction. Thus the sampling frame was limited to only those homes available at the time of the visit. This is very different form the total number of homes permitted in Oregon in 1993. This was actually a sample of homes that were available to be surveyed in any one jurisdiction at some time in the first quarter of 1994. The majority of homes were permitted in the latter half of 1993. For any particular home, its chances of being drawn into the sample for review were strictly a function of its position in the inspection process at the time of the visit. Thus the sample was really limited to this group, although several homes were from early 1993 permits and before and a number of homes were permitted in 1994. Field technicians were not asked to screen for permit date for purposes of inferring the results of the survey to a state-wide impact. These 283 homes were assumed to be a random and unbiased estimate of the 14,884 homes permitted in Oregon in 1993.

The solution to these sampling problems was to develop a target number of homes in each jurisdiction based on the fraction of permits issued in the entire state versus those issued in the jurisdiction. Thus if a particular jurisdiction issued less than 30 permits (about 0.2% of Oregon permits annually) there would be no homes selected or assigned. In addition to these considerations about 15 homes were not assigned. These were allocated to 6 small jurisdictions on the Oregon Coast and in the Willamette Valley to increase the representation of small jurisdictions in the sample. The intention was to weight these extra cases to account for over sampling if appreciable biases were introduced.

2.1.2 Number of Buildings Per Jurisdiction

The number of buildings to be drawn from each jurisdiction was the second part of sample selection. A ratio between the number of homes built in any particular jurisdiction and the number of homes built in the entire state of Oregon in the first nine months of 1993 was developed and multiplied by the target sample size (270 homes). This might be called an "expected values sample", since the expected value in any one jurisdiction would be the ratio of the total sample frame to the total permits in any jurisdiction.

We selected this method for two reasons:

1. For homes in larger jurisdictions (75% of the homes sampled and 1/3 of the jurisdictions), the number of homes sampled was the "expected" value set by the proportion of all homes in that jurisdiction. This insures that these jurisdictions are adequately represented in the field sample.

2. A true random sample would cause a number of homes to be drawn from jurisdictions that have little or no building activity. Because of limited resources, jurisdictions with minimum construction were eliminated. It is of greater importance to have an adequate sample of jurisdictions to characterize the state as a whole. These consist of: the four counties in the Portland-Salem area; and Deschutes, Jackson, Josephine and Lane Counties in western and central Oregon. Homes were drawn from smaller jurisdictions, but when these jurisdictions were not accessible, they were not included. In order to evaluate compliance characteristics in the smallest jurisdictions, we targeted several specific jurisdictions and allocated sample houses to them. Since this method allocated several houses to very small jurisdictions, these jurisdictions were in effect oversampled. There were 13 additional homes not allocated in the initial sample which were also used to enhance the sample in several

smaller jurisdictions. Specifically, these oversampled jurisdictions were located in Clatsop, Tillamook, Crook and Polk counties.

Appendix B shows the sample by jurisdictions sorted by number of permits in 1993 and the allocation of the 283 homes in our sample. As can be seen in Table 2.1, the top 11 jurisdictions represent over 50% of 1993 residential construction in Oregon, and therefore half the sample as well. These jurisdictions are all in one of seven Oregon counties; specifically, Clackamas, Deschutes, Jackson, Lane, Marion, Multnomah and Washington counties. The next ten jurisdictions are also in those counties; thus, in the seven counties represented here, the jurisdictions actually account for over 75% of the total sample. The remaining 25% of the sample is found in smaller jurisdictions, mostly on the Oregon coast. The distribution shown here reflects the distribution of single-family homes built in Oregon. These jurisdictions provide a large number of Oregon buildings, and characterize the Oregon home-building economy, almost to the exclusion of the rest of the state.

TABLE 2.1
Permit Distribution in the Eleven Largest Jurisdictions

Jurisdiction	Permits	Percentage (%)
State of Oregon	14,884	100.0
Washington County	1,735	11.6
Clackamas County	795	5.3
Portland (Multnomah County)	829	5.6
Deschutes County	558	3.8
Marion County	539	3.6
Salem (Marion County)	598	4.0
Tigard (Washington County)	451	3.0
Bend (Deschutes County)	464	3.3
Medford (Jackson County)	600	4.0
Eugene (Lane County)	538	3.6
Beaverton (Washington County)	412	2.8
TOTAL	7,519	50.6

The ratios included in the appendix show the expected sample in each jurisdiction. These ratios compare the sample size to total sample (rat1), and the number of annual permits by jurisdiction to the total number of permits (rat2). When these ratios are compared (rat3), we can see how closely the sample represents actual construction distribution. Those jurisdictions with sampling ratios much less than 1.0 were oversampled as a result of the allocation of "extra" homes. In principle, this ratio could be used to correct over sampling biases. A review of the compliance results, however, did not reveal an appreciable difference between the oversampled small jurisdictions and the rest of the sample so the development of sample weight was abandoned and the sample was treated as a simple random sample of the population of single family residential permits in the state of Oregon.

2.1.3 Sampling in Jurisdictions

Jurisdictions were contacted in advance to discuss the project and secure their cooperation. The permit tracking and inspection system was discussed to set up the process and identify contacts for the field technician. Potential interview contacts were also identified.

Sampling within jurisdictions was accomplished by obtaining the list of projects which had requested inspections on the date of our visit to the jurisdiction. This system had several advantages. First, it gave a clear indication of the construction stage of the project, allowing us to select projects at cover or beyond. Second, by visiting a project on a day when an inspection was expected, field technicians were much more likely to gain access to the house, either because it was left unlocked for the inspector, or because the builder was at the site.

In larger jurisdictions, several projects were selected at random from the day's inspection requests. In smaller jurisdictions the inspection requests were less numerous, so our sample was, in essence, pre-selected.

The timing of the site visit affected the types of information which could be reviewed at any given house. Site visits were conducted at the following phases of construction:

23% at time of "insulation" inspection; insulation installed but not covered.

23% during "cover"; drywall partly or mostly installed.

54% at final inspection.

Blower door testing was conducted on 62 of the homes reviewed (22% of the homes in the sample). Initially this was meant to be one in every four field inspections, however, difficulties with levels of completion of each home made the allocation of blower door tests somewhat arbitrary throughout the sample. Appendix B shows the number of test in each jurisdiction.

2.2 Field Review/Protocol Development

Ecotope drew on multiple sources in the development of the field protocol. The goals of the project included the review of several different aspects of energy code compliance, as well as residential construction characterization. Documenting this variety of information required the development of a complex field protocol. The protocol was revised based on the results of the pilot study. A copy of the final protocol is included in Appendix C.

The primary guide for the development of the field protocol was the Oregon Residential Energy Code itself. The protocol is based on specific requirements of the code. In many instances the code sets forth a list of conditions under which certain construction types or performance levels are acceptable, such as the incorporation of R-21 vault ceilings covering less than 150 sq. ft. of floor area. The field protocol is designed to collect information on these conditions in order to allow compliance levels to be determined.

The energy code also sets up the basis for performance review of the buildings. To develop trade-offs between prescriptive requirements and overall building performance, a full building heat loss calculation was developed for each home. This involved an assessment of component areas as well as the heat loss rate of each component. In addition, efforts were made to assess the heating system type and efficiency.

The protocol was also developed to review and categorize residential construction characteristics including house size and orientation, materials, construction quality, product labeling, ventilation systems, etc.

3. Submittals and Enforcement

One of the goals of this study is to evaluate code enforcement procedure. In the course of the study, field inspectors visited over 62 different code jurisdictions. Interviewers contacted over 60 code officials from 40 different jurisdictions. This has provided a wealth of information about energy code enforcement issues in Oregon.

3.1 Data Collection

As discussed in the section 2.0, the number of annual permits reviewed by the jurisdictions studied varied widely from 10 to over 1500 permits per year. This range clearly has significant implications for organizational and staffing needs of various jurisdictions.

Virtually all of the jurisdictions contacted were cooperative and provided information in the course of this study. This cooperation was extremely important to the success of this study. Only two jurisdictions refused to cooperate with our field teams.

At the outset of each day at a jurisdiction, the field technician obtained the daily list of inspection requests. The inspection list reviewed included both "cover" and "final" inspections. Once this list was obtained the technician randomly selected two projects from the daily list for document review. By selecting projects which had requested an inspection, field visits could be conducted at a specific construction stage. Access to the house was much easier if the builder was already anticipating an inspection.

One aspect of this review was to characterize how thoroughly energy code compliance was documented on the drawings as submitted. Field technicians reviewed the method and extent of energy code review which was apparent on the drawings that had been reviewed by the code officials. This review was conducted prior to the field visit portions of the protocol. These characteristics are discussed below.

Interviews were conducted with building departments in about 60% of the jurisdictions in which sample houses were located. These interviews focused on procedures used in the jurisdiction to establish energy code compliance. The interviews were conducted separately from the code review and did not attempt to address specific problems which were identified in the field in that jurisdiction. Later the responses to questions were reviewed and compared to field compliance rates. In general, this did not result in added insights into compliance rates in any particular jurisdiction.

3.2 Paths in Sample

The Oregon Energy Code contains ten options, or paths, under which projects can be submitted to demonstrate compliance with the code. Nine of these paths are prescriptive, meaning that the code lists specific performance values for each potential component of the house, which the builder must comply with to meet the code requirements. Prescriptive Path One is considered the code baseline; the other paths were established as “energy-equivalent” alternatives to a Path One house.

Other prescriptive path options under the code were designed to allow the use of class 50 or class 60 windows, instead of class 40 windows required under Path One, by upgrading other building components to make up for window performance loss.

Four of the path variations are designated as "sun-tempered" options, designed to allow/encourage the incorporation of passive solar design by requiring solar exposure and that at least 50% of the windows in the house face south. Under these paths, a builder may use windows which are less energy efficient, or 2x4 wall construction, or other variations depending on which "sun-tempered" path is used. In practice these paths are limited in use, since they would require custom solar design, limit the use of standard spec plans, allow only certain lot orientations, and limit garage placement.

Two other paths allow less efficient windows in exchange for higher insulation levels at other house components. These options also require advanced framing to be used in walls and attic. At least with current window pricing and performance, builders do not elect to use these tradeoffs and alternative paths. This appears to be the result of the availability of high performance windows which can easily be incorporated into building designs and construction sequence. This development in the market has probably obviated the need for the additional prescriptive paths in the OREC.

One prescriptive path, Path 8, is considered to be the limited-income path, allowing more economical construction techniques (including 2x4 walls) for small houses with limited glazing area.

The other prescriptive path makes specific allowances for log home construction, and is not based on Path One performance values.

The final submittal option is the performance path. This option allows the applicant flexibility to make component performance trade-offs, provided overall heat loss performance does not exceed performance levels of the baseline. This type of submittal requires a calculation of a Target UA based on house configuration and specific required U-values. The project must demonstrate that it will have a UA no greater than the target. Using this option, there are no specific requirements for performance of any component if the entire house meets the performance requirement. Again, the target insulation and performance values are based on Path One construction.

Appendix A includes Oregon Energy Code Tables 53-O and 53-P which show the various submittal path options and the performance requirements associated with them.

Despite the variety of submittal paths available under the Oregon Energy Code, most of these paths are seldom, if ever, used. The vast majority of projects are submitted as Path 1. This path is also considered the default by most building code officials.

Table 3.1 shows the distribution of paths submitted for the sample. When Path One submittals are combined with submittals which did not indicate any path (assumed to be Path One in compliance evaluations), the total is 93% of all the projects in the sample.

TABLE 3.1
PATH DISTRIBUTION OF THE SAMPLE

Path	Number in Sample	Percent of Sample
1	189	66.8
None (assumed Path 1)	74	26.1
Total Path 1	263	92.9
Path 8	11	3.9
Performance	9	3.2
Total Sample	283	100

3.3 Information on Submittals

Most plan submittals attempted to demonstrate compliance on the drawings themselves, with no additional documentation. Only about 15% of the projects reviewed used a separate energy code compliance form to document compliance. This included the 3% of projects which were required to submit calculations for performance path compliance. For the rest of the projects, energy code compliance was therefore assumed to be documented within the plans themselves. Since these projects were submitted under one or another prescriptive path, which have specific performance requirements and limited variation, documentation of energy code compliance in the plans themselves is a relatively straightforward problem.

The most basic aspect of energy code compliance on the submittals is an indication of the prescriptive path option used by the builder to comply with the Oregon Residential Energy Code (OREC). This path determines the required insulation and performance levels of the various components of the house, and forms the basis for the plan reviewer's evaluation of energy code compliance. Many jurisdictions explicitly require a bold indication of submittal path on the plans, according to various permit information sheets and submittal checklists handed out to potential permits. Despite these requirements, 42% of projects in the study were submitted without any indication of which energy code path the project was being submitted under. In many of these cases, the plan reviewer designated "Path One" on the plans during review. Still, over 25% of the sample ended up with no path designation. (These were assumed to be Path 1 in the study.)

In addition to the compliance path designation, a variety of other types of information may be included on the plans, alone or in combination, to document various aspects of energy code compliance. Most commonly, wall or building sections and details contain information about insulation levels, window and door performance, or other energy code issues. Field technicians indicated that nearly half the plan sets seemed to rely on details to indicate performance levels for energy code compliance. Some plan sets included tables which listed various building components and their anticipated insulation or performance levels. 25% of the projects reviewed included tables with project-specific information about energy code compliance. Generic energy code tables (usually copies of Table 53-P) were included with 34% of the submitted projects, but did not necessarily specify which part of the table applied to the project.

Although many projects contained some combination of the above information, this information was often not cross referenced. At least 10% of the plans reviewed contained notes, details or tables which specifically conflicted with code requirements or insulation levels called out in other details. Furthermore, a number of plan sets included code tables or information from outdated energy codes, which did not reflect current code requirements. Other plans indicated energy code compliance with notes such as "insulate as required".

The combination of energy information presented usually leads to an incomplete picture of energy code compliance from the perspective of plan review. In reviewing compliance documentation of submitted files, field technicians found that only 25% of the plans reviewed contained enough information to verify that the projects complied with the requirements of the energy code. This is not to say that the other 75% of the projects did not comply with the requirements of the code, merely that they did not demonstrate this compliance on the plans. Chart 3.2 indicates the percentage of projects which did not indicate insulation or performance levels for the components listed. This table also indicates how frequently this information was required by the plan reviewer in these cases, as evidenced by redlines or other corrections on the plans. Although the files did not include these clarifications we assumed that the "red lines" were meant to flag issues to be reviewed in the field.

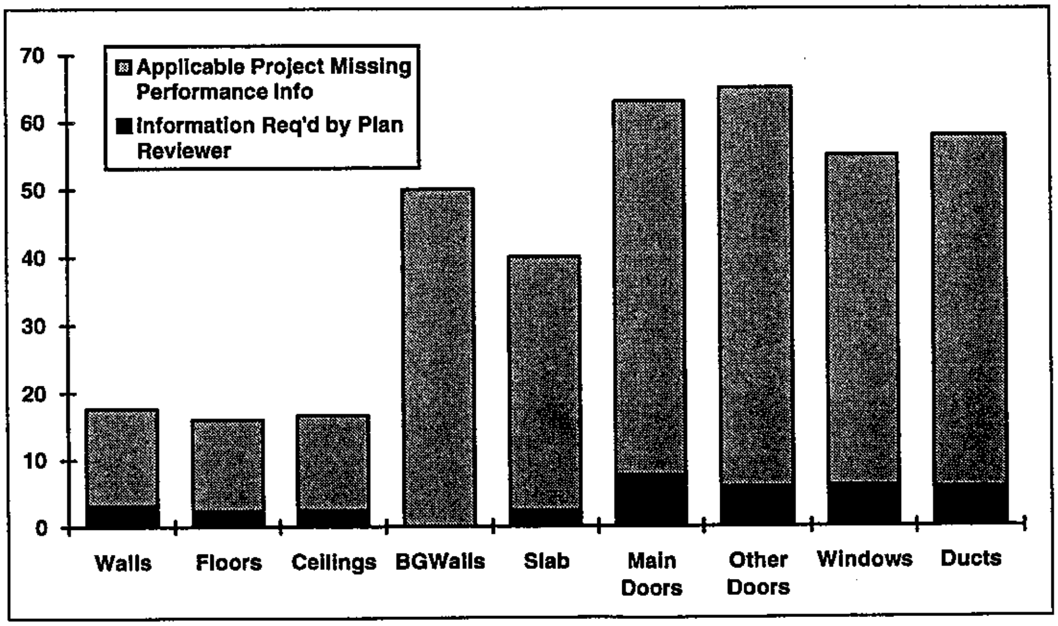
While some jurisdictions have specific checklists which are passed from plan reviewers to field inspectors, most rely on the redlined plan sets themselves to provide guidance to the field inspector.

The prescriptive nature of the code simplifies the job of the field inspector, since there just aren't that many variations available within the prescriptive guidelines.

Field enforcement of energy code requirements is complicated by a variety of factors, including changes to the project in the field, timing of the inspections, and the lack of labeling or other performance information. Frequently the inspector would have difficulty making a field review of particular components. Given the nature of this system overall compliance is dependent in large part on the construction practices and specification of the builder. It was apparent that there is substantial cooperation with the home building community on the overall compliance with the OREC even though some specific aspects may be lacking.

Chart 3.2
Documentation of Compliance of Components

This chart indicates the percent of each component which failed to provide any information on the submittal about the component insulation level or performance (% of projects which included that component), and the frequency with which the plan reviewer requested or identified this information when it was missing.



3.4 Field Enforcement

3.4.1 Field Changes

Over 40% of the houses visited by field teams had been modified in the field. Although not all of these changes necessarily had implications for energy code compliance, field changes certainly complicate the task of the field inspector in reviewing energy code compliance. Nearly 10% of the projects had changed the heated floor area of the project in some way, such as by adding heated "bonus rooms," or heated basements. In fact, of all the houses with heated basements, 20% were the result of field revisions. Changes to window area or type were encountered in 20% of all homes visited. A common modification was the replacement of opaque doors or windows with glazed swing doors. Changes to floor and window areas can certainly have implications for Path 8 projects which limit glazing areas, and changes to window types can have implications for all projects. Performance submittals are affected by any modifications to the project.

At least 16% of the houses had been reoriented or "mirrored" on the site. While this does not have implications for code compliance (except sun-tempered paths, which were not encountered), it does point out the frequency with which builders submit stock plans for permit, then customize the homes at the site.

3.4.2 Inspection Timing

Enforcement of the energy code is complicated by the fact that the timing of field inspections is not necessarily conducive to the enforcement of energy code provisions. Inspection timing becomes problematic for a variety of issues, most notably floor insulation levels. In order for an inspector to have full access to the floor insulation, it must be reviewed either before the decking is placed, or from the crawlspace at completion. A variety of moisture problems may ensue if floor insulation is installed before floor decking, while limited crawlspace access tends to deter or preclude inspections at the time of project completion. This issue is apparently the point of some contention among code officials and builders in Oregon.

Ceiling insulation inspection may face similar inspection difficulties. Portions of vaults and attics may be obscured by subsequent construction, or insulation may be damaged after installation. In many cases insulation levels for loose fill or unfaced batts are difficult to determine without reference materials.

Other requirements of the code apparently fall between the cracks in the inspection process. Low-flow water fixtures are typically not installed till project completion, well after the plumbing inspections which many jurisdictions rely on to enforce this requirement. Likewise IC rating requirements for recessed incandescent can lights may not be integrated into the electrical inspector's routine.

3.4.3 Product Labeling

Lack of product labeling makes field enforcement of energy code requirements significantly more problematic. During field reviews conducted for this project, only 30% of the window types encountered had any performance labeling whatsoever. Nearly 2/3 of these labels were AAMA labels which often give only a vague approximation of performance characteristics, such as "Class 40", or none at all. One third of the labeled windows used NFRC labels, which do provide the necessary performance information, and have now become the required standard.

Unlabeled windows often failed even to indicate construction characteristics such as spacing, coatings, or gas fill.

Glazed doors included rating labels of any sort only 8% of the time, while opaque doors included performance information in less than 5% of the cases.

Even insulation, when unfaced, can be difficult to evaluate in the field once the packaging is no longer on site. Insulation batts are labeled only on one side, so depending on installation, identification may not be possible.

Lack of performance labeling in the field did not necessarily mean a the product did not perform up to code standards. Compliance rates were much higher than "labeling" rates. This might tend to indicate that standard construction practice tends to follow code requirements for most components, regardless of whether or not compliance can be verified in the field by the building department.

4. Compliance

Using the methodology described in sections 1 and 2, each house in the sample was reviewed for compliance with the Oregon Residential Energy Code. Compliance evaluation focused on individual components and overall heat loss rates for the project, and compared these to required nominal component insulation levels (prescriptive compliance) and target component and project heat loss rates (performance compliance). Compliance with specific prescriptive requirements which were not directly related to energy performance was also evaluated. These evaluation strategies yielded markedly different compliance rates.

Each house was reviewed using documentation submitted with the building permit application, and as constructed in the field. Due to the frequency with which information necessary to the evaluation was missing from the submitted plan sets, most of the compliance review was based on field conditions encountered at the building site.

4.1 Compliance Assumptions

Not all aspects of the Oregon Energy Code are clearly and consistently interpreted among or within jurisdictions. There are certain provisions of the code which are not well documented, and are therefore open to some interpretation. In order to evaluate compliance, a consistent approach to these provisions had to be determined. These issues are discussed below.

4.1.1 Window Performance

Window performance issues have been a source of much confusion for code jurisdictions and builders alike. Only recently, standard testing and rating procedures developed by the National Fenestration Rating Council (NFRC) have been adopted as the code standard in Oregon as well as other jurisdictions. Leading up to this adoption there have been various phased applications of the system using default tables designed to provide window performance information in the absence of NFRC tests.

A brief recent history of window performance requirements of the Oregon Energy Code might best illustrate the source of confusion. Prior to 1992, window performance was typically rated by laboratory tests (AAMA standard 1503) of standard window types commissioned by various window manufacturers. In 1993, as a result of a federal lawsuit, a local testing laboratory was fined, and all tests conducted by the laboratory were deemed inaccurate. Tests values from this lab for certain window types were consistently indicating a higher level of window performance than any other accepted laboratory or simulation available. Not surprisingly, a large number of local window manufacturers and suppliers had recognized the value of tests from this particular lab, so when these tests were thrown out, there were very few alternative tests available. In order to provide some guidance to the construction industry and code officials, an interim ruling was developed which considered any vinyl framed window with double glazing and an argon gas fill to meet the requirements of the code for window performance. This type of window construction was typical in the region, partly as a result of the test results from the lab in question. The performance requirement in the code is a U-value of no more than 0.4. Based on NFRC data, vinyl argon windows actually have a U-value closer to 0.48, roughly 20% higher than the assumption. As the NFRC rating system became more standardized, a more comprehensive default U-value table was adopted to provide guidance for window performance ratings. This table, "Approved Window Default U-Values", Table 53-Q is included in Appendix A.

The changeover from the vinyl-argon default to the NFRC based default table officially occurred on January 1, 1994. Houses permitted after that date were not allowed to use the vinyl-argon default, but rather were to use the default table. The permit dates of the houses visited in this study span from 3/93 to 3/94, so some of the houses we visited should have responded to the change in the code. Unfortunately, it is difficult to judge how quickly various jurisdictions implemented these modifications.

We have typically provided performance and compliance information about windows using both the vinyl argon default (described as "deemed to satisfy") and the default table for comparison.

Although windows are required to be labeled in the field as to their construction and performance, these labels were not always present during our inspections. When information was not available, the field protocol was marked as such; we discouraged the field inspectors from guessing. We adopted the following guidelines in order to characterize window construction and performance in the absence of some or all of the needed information. Window frame material was easily determined in the field regardless of product labeling. Aluminum frames were assumed to have thermal breaks unless the inspector could clearly determine that this was not the case. Argon gas was assumed to be present (based on code default requirements) unless product labeling indicated otherwise. Each inspector carried a low-ε detector to test window units, but unless this device gave consistent readings indicating the presence of a coating, or the product labeling indicated it, we assumed that there was no low-ε coating present. In some cases NFRC rating labels were present, and these NFRC U-values for the windows were used in the compliance and heat loss evaluations.

4.1.2 Scissor Trusses

Scissor trusses are considered to be vaulted ceilings under the Oregon Energy Code. Although the prescriptive compliance path requires at least R-30 insulation for all vaulted ceilings (except a limited area of R-21), the performance of nominal R-30 rafter vaults is quite different from that of nominal R-30 scissor vaults.

This distinction becomes important when we compare the actual U-values of vaulted ceilings with the prescriptive R-value requirements. The prescriptive code does not distinguish between a scissor truss insulated with R-30 and an R-30 rafter-type vaulted ceiling. Under the guidelines of the performance path (Table 53-O, below) however, a nominal R-30 scissor vault has a U-value of 0.046, while a nominal R-30 rafter vault has a U-value of 0.033, a performance difference of nearly 30%. A house with a scissor vault insulated with R-30 which meets the prescriptive requirements will not meet the performance requirements of Table 53-O. which compares vault performance with component requirements. When evaluating prescriptive compliance, we considered scissor trusses with R-30 insulation to comply with code requirements despite their lower performance characteristics. For performance evaluation, these trusses were considered at a lower performance value, as indicated in the Oregon code.

4.1.3 Below-Grade Walls and Slabs

Below-grade walls are required by the prescriptive code to be insulated to R-21. Based on interpretations provided by the Oregon Building Codes Division, this requirement can also be met by installing R-15 insulation on the outside face of basement walls. In the performance requirements table however, there is no distinction between basement and above grade walls; all are required to have a U-value of 0.060. When a basement wall is buffered by the ground, however, the performance of the wall is significantly improved. The default U-values given for Table 53-O make no mention of below grade performance variations. Unfortunately, this leads to confusion when below grade wall performance is evaluated. In trying to determine requirements for below grade walls, some code officials assume that R-21 is the requirement under all circumstances, some allow R-15 exterior, and others take ground buffering into account.

Except in one of the performance evaluation variations, discussed in Section 6, we used default values for slabs which did not account for ground buffering effects. For below grade walls, performance based compliance was based on ground buffered U-values. Prescriptive compliance evaluation did not consider ground buffering effects.

4.1.4 Skylights

Skylights have been granted multiple exemptions to the performance requirements applied to windows under the Oregon Energy Code. These exemptions are based on size and type of manufacturer, number of skylights produced, date of production, frame material combinations, area of skylight installed, and a variety of other factors. There are four basic types of ratings for skylights: 1.) NFRC rating system; 2.) Calculated performance label based on ASHRAE standards. This option allows only a limited production of any given skylight model, and is infrequently used. 3.) Limited production default labels. Up to 1000 labels, with a default U-value of 0.5 Btuh/ft^2°F. 4.) Exempt labels. No U-value is provided on this label, and there is no limit to the number of labels allowed. The language regarding frame construction under this requirement is loose, placing few limits on skylight manufacture. These skylights are supposed to be glazed with double low-ε glazing or triple acrylic.

These requirements allow the use of a wide variety of skylight types, under the condition that such skylights are labeled with an official label, and that these labels remain on the product until the inspection process is complete. In practice, these labels do not seem to be applied consistently, making it difficult to determine the performance level of installed skylights. Due to this difficulty, we assumed that any skylights installed met code requirements unless they were clearly labeled to the contrary. Skylights were therefore assigned a performance U-value of 0.5 Btuh/ft^2°F. In the compliance evaluation skylights resulted in non-compliance only if they covered more than 2% of the heated floor area (this is allowed only if they have a U-value of 0.4 or better, but in these cases we required labeling to demonstrate such performance.)

4.1.5 General Assumptions

In addition to the issues discussed above, a number of guidelines were developed to handle cases where characterization information was missing or hidden by other construction. In general components were assumed to comply with code requirements in the absence of information to the contrary. Some of the specific issues are listed below.

Insulation which could not be inspected in field was assumed to be installed to the level indicated on plans. If insulation values were not indicated on plans in these cases, the component was assumed to comply with code requirements.

Slab and below grade insulation was assumed to be installed unless information to the contrary was available.

Water fixtures were assumed to comply with code flow requirements unless determined otherwise. Fixtures not yet installed were assumed to comply.

Recessed incandescent lights were assumed to comply with insulation contact rating requirements unless the inspector could examine the fixture thoroughly enough to determine the absence of required labeling.

4.2 Code Requirements

4.2.1 Prescriptive Code Requirements

For this discussion, prescriptive code requirements have been broken into two categories. Prescriptive *component* requirements describe actual insulation or performance levels for building components such as walls, floor roof, windows, etc. Compliance with these requirements has a quantifiable effect on building energy performance, and therefore also forms the basis for the performance compliance evaluation.

Non-component prescriptive requirements include a range of issues including duct insulation, vapor barriers, low-flow water fixtures, IC rated recessed can lights, and a host of other requirements. Not all of these requirements have a quantifiable effect on building energy performance, so they are discussed separately.

Table 53-P in the Oregon Energy Code lists the specific component requirements for projects submitted under any prescriptive path. Some of these requirements are qualified or modified by other sections of the energy code. These are discussed below. These requirements refer to Path One projects, which comprise 93% of the sample.

Components

Windows: unlimited area allowed, with a U-value of 0.4 Btuh/ft^2°F. As discussed in Section 4.2.1, window performance is based on either the "deemed to satisfy" ruling, or the requirements of the window default table. The implications of both are discussed in this section. Decorative single glazing may not be larger than 1% of the heated floor area.

Doors: the main entry door can be up to 24 ft^2 in area, and have a U-value of 0.54 Btuh/ft^2°F. This corresponds to virtually any wood panel door. Other doors must be insulated to a U-value of 0.2 Btuh/ft^2°F. In this analysis any insulated, unglazed door was assumed to meet this requirement. (Double entry doors may be used under certain conditions.)

Walls: must be insulated with R-21 fiberglass, or equivalent. In practice this requires the use of 2x6 studs, except in attic sidewalls or other locations where the insulation can protrude from the stud cavity. The code also allows the use of R-19 insulation with advanced framing or 2x4 studs with rigid insulation, as long as overall nominal R-value of the insulation is at least R-18.5. Below grade walls are also required to be insulated with R-21, although the use of R-15 exterior rigid insulation is widely accepted as equivalent.

Vaults: must be insulated to R-30. This includes scissor trusses as well as rafter vaults, although the performance of these two vault types is quite different as discussed above. If the vault area is more than 50% of the heated floor area, it must be insulated to at least R-38. A limited area of R-21 vaulted ceiling is also allowed; up to 150 ft^2.

Non-Component

Scattered throughout the energy code are a number of requirements for other aspects of the house. These requirements are not path specific. They are listed below.

Ducts must be insulated with R-8 insulation.

All openings must be sealed and weather-stripped.

If loose-fill ceiling insulation is installed, the roof slope must be at least 4:12, baffles must be installed, and there must be at least 44" of headroom at the ridge.

Vapor barriers must be installed at walls, floor, and ceiling. Ground cover must be installed in crawl space and under slab.

Recessed incandescent lights (can lights) must be insulation-contact (IC) rated. Rated cans are labeled on the fixture. Depending on the installation characteristics, it was not always possible to determine whether can lights were rated in the field. Unless the field teams could specifically determine that the light fixtures were not rated, they were assumed to comply with code requirements.

Heating system efficiency must be at least 78% (0.78 AFUE) for furnaces, or an H.S.P.F. of 6.8 for heat pumps. (For a full discussion of heating system efficiencies see Section 6.)

All heating systems must have thermostats.

All combustion appliances (fireplaces, wood stoves, etc.) must have an outside combustion air source.

Low flow water fixtures should be installed for faucets and shower heads. Compliance was assumed unless non-compliance could be definitely determined.

Water or heating system pipes must be insulated.

4.2.2 Performance-Based Compliance Requirements

Performance Path compliance is evaluated by first developing a target UA for any given project, then comparing the project's actual UA to this target. Using the proposed project areas for each of the components listed in Table 53-O, multiplied by the target U-values listed in that table yields an overall target, or code UA which the project must meet. The same project component areas are then multiplied by the actual U-values of the construction assemblies used in the project for each component to determine a project UA. (Target values for Path 8 houses are modified appropriately.) If the project UA is less than or equal to the code UA, the house is deemed to meet code requirements. Furthermore, we can evaluate the ratio of the code UA to the project UA to evaluate how close to the code guidelines houses tend to perform.

It is important to keep in mind that under this analysis, a house may still be deemed to meet the intent of the code even if some components are technically in violation of the prescriptive requirements, since performance improvements in other components may more than make up for problem components.

It is in this type of performance analysis where vagaries of code interpretation become most pronounced. Issues discussed in Section 4.2 dealing with scissor-vault performance, below grade walls, and window and skylight performance become particularly important to the discussion in this section when we classify performance-based compliance

4.3 Summary of Compliance Rates

Prescriptive compliance is the basis of the Oregon Energy Code. Over 96% of the projects evaluated in this sample were submitted under one or another prescriptive path option. While this simplifies enforcement issues considerably, it implies that prescriptive compliance levels are an important part of any discussion of code enforcement.

When projects are reviewed under the requirements of the performance evaluation path, regardless of which path they were submitted under, compliance is based on the overall heat loss rate of the building. A project is credited for components which outperform code requirements, and penalized for components which do not fully comply. By this standard, the compliance rate is 79.2%. If we consider any project which has a heat loss rate which is within 5% of the code target UA to comply, the compliance rate is 98.4%.

The prescriptive paths and requirements of the Oregon Energy Code give relatively little margin for interpretation. Either a house complies exactly as required or it does not. This results in a low overall compliance rate. In general this compliance rate does not reflect the anticipated energy performance impact of these homes since often non-compliance is the result of a relatively minor variation between the code and the as built condition, or an aspect of the code which does not measurably affect energy performance, such as low flow water fixtures.

Compliance with the prescriptive aspects of the Oregon Residential Energy Code has been broken down into two categories. These categories reflect building envelope, or component requirements, and non-component requirements such as vapor barriers, low-flow fixtures, outside combustion air, etc. While these requirements may be important for the overall goals of the code, their impact on overall energy use is debatable. Compliance with non-component requirements is 54.5%. The prescriptive compliance rate for building envelope components and heating system requirements is 55.7%.

These prescriptive and performance-based compliance rates are shown in Table 4.1.

TABLE 4.1
SUMMARY OF COMPLIANCE

Performance-Based Compliance	
Compliance with Performance Analysis Requirements	79.2%
Compliance with Performance Requirements within 5%	98.4%
Prescriptive Compliance	
Requirements for building components and heating system	55.7%
Non-component requirements	54.5%

4.3.1 Jurisdiction Size

The impact of jurisdiction size on compliance was reviewed based on the total permits issued by the individual jurisdictions. To review this impact we used the weights from Appendix B and assumed a stratification at 75% of the sample. This division meant that the 28 largest jurisdictions were compared to the remaining jurisdictions. The comparison was made on both prescriptive compliance and performance-based compliance. This comparison is summarized in Table 4.2.

Table 4.2
Compliance by Jurisdiction Size

	#	% compliance	std. deviation	% compliance	std. deviation
Large jurisdictions	214	.517	.032	.793	.028
Small jurisdictions	69	.509	.043	.719	.037
Total	**283**	**.515**	**.027**	**.778**	**.023**

As can be seen there is very little difference between the prescriptive compliance rates in large and small jurisdictions. When performance compliance is reviewed there is about a 7% difference in compliance rates between the larger and smaller jurisdictions. This difference is not statistically significant at the 0.1 level, and for purposes of the rest of the study we have ignored jurisdiction size when discussing compliance.

4.4 Prescriptive Compliance

It is important to keep in mind that prescriptive compliance is a strict yes/no evaluation, which does not account for any performance improvements in complying components when designating other components as non-complying. Many projects comply with all but one or two of the prescriptive requirements, as can be seen in Table 4.3. This type of analysis also does not quantify either the magnitude or the implications of non-compliance.

4.4.1 Component Prescriptive Compliance

Table 4.3 indicates the distribution of houses by the number of components per house which do not comply with prescriptive requirements (for component requirements only). This table uses the more optimistic "deemed to satisfy" window values, which were acceptable under the code until January 1, 1994.

TABLE 4.3
Prescriptive Compliance by Number of Non-Complying Components

Number of components out of compliance with prescriptive requirements, per house	Number of houses in sample	Percent of projects (%)	Cumulative percent (of Path One houses) (%)
0	147	55.7	55.7.
1	77	29.2	84.9
2	29	11.0	95.8
3	10	3.8	99.6
4+	1	0.4	100

From this table we can see that 55.7% of projects comply with all prescriptive component requirements, while nearly 85% of projects comply with all but one of the prescriptive component requirements.

By reviewing prescriptive compliance rates for individual components, compliance problem areas may become more apparent. Specific prescriptive compliance rates for each component are presented in Table 4.4 The first column lists the component and the prescriptive requirements that were checked. The second column indicates the number of houses in the sample in which the component was installed. The third column shows the number of houses in which the listed component did *not* comply with the prescriptive requirements. The fourth column shows the non-compliance rate of the component, based on the total number of houses in which that component was installed. The fifth column indicates the percentage of non-compliance of the component based on the total sample size.

TABLE 4.4
Prescriptive Compliance Rate by Component

Component; prescriptive requirement	Number of houses	Number of houses with non-complying component	Percent non-compliance in houses with component (%)	Non-compliance as a percent of all Path One houses (%)
Vaulted Ceiling; R-30	201	10	5	4
Vaulted Ceiling; over 50% HFA - R-38	40	23	58	9
Attic: R-38	264	21	8	8
Floor: R-25	260	10	4	4
Slab; R-15 perimeter	33	5	15	2
Entry Door; 24 ft^2 @ U=0.54	264	7	3	3
Other Doors; U=0.20	264	21	8	8
Walls; R-21	264	9	3	3
Below Grade Wall; R-21	21	3	14	1
Windows; U=0.4 "deemed to satisfy"	264	25	10	10
Windows; U=0.4 "default table"	264	78	30	30
Glazed Doors; U=0.4	129	49	38	19

As can be seen from this table, certain components are much more problematic for prescriptive compliance than others. Vaulted ceilings, for example, have a fairly high compliance rate with prescriptive requirements for R-30 insulation. However, when the vaulted area is greater than half of the heated floor area, the prescriptive insulation requirement jumps to R-38. More than half of the houses in the sample which had vaulted ceiling areas over 50% of the heated floor area failed to upgrade insulation to this level. On the other hand, when compared to all of the houses, these houses represented only 9% of the total sample.

Glazed doors are also a prescriptive compliance problem area. The glazed door U-values used in this analysis are based on the default U-value table adopted in Oregon in early 1993. Glazed doors do not fall under the "deemed to satisfy" window option which assigns a U-value of 0.4 to any window with a vinyl frame and argon-filled double glazing. A variety of factors may contribute to the high rate of non-compliance for glazed doors, including the lack of a labeling program for doors, the frequency with which glazed doors are installed as project modifications in the field, and the fact that rating systems for doors are not yet standardized.

Table 4.4 above also provides a comparison of the prescriptive code impact of the "deemed to satisfy" window default vs. using performance values from the default table.

4.4.2 Non-Component Prescriptive Compliance

Table 4.5 indicates compliance rates with non-component requirements of the energy code. Only 54.5% of the projects in the sample met all of the prescriptive requirements for non-components. As described below, a number of factors contribute to this non-compliance rate. If we consider only non-component requirements for vapor barriers, insulated ducts, and ceiling configuration for loose fill insulation installation, 73.5% of the projects comply with this subset of requirements.

TABLE 4.5
Prescriptive Compliance with Non-Component Requirements

Element	Requirement	Number of non-complying houses	Percent non-compliance
Ducts	insulated to R-8	4	1
Vapor barriers	required at walls, floor, ground, vaults	46	16
Loose fill insulation	minimum 44" headroom, 4:12 or steeper roof slope, baffles	5	2
Recessed lights	fixtures rated for insulation contact	15	5
Single glazing	maximum area 1% of heated floor area	0	0
Combustion appliances	require outside combustion air source	50	18
Water fixtures	low flow fixtures required	55	20
Vault w/R-21	maximum 150 ft^2 of R-21 vault	4	1

Many of the non compliance rates for these requirements are much higher than prescriptive component compliance described in the sections above.

Vapor barriers were found to be missing in over 16% of the projects visited, even after we eliminated projects at which drywall was not yet installed. Floors had the highest rates of non-compliance with vapor barrier requirements.

Ducts were typically insulated as required by the code. Although 4 projects are listed as out of compliance in the table above, these projects had ducts which were insulated to some lesser degree than R-8. No projects were encountered which had failed to insulate the ducts to some degree.

Low flow fixture requirements seemed to be frequently ignored. Many projects had not yet installed fixtures, so the non-compliance rate could conceivably be much higher. Furthermore, fixtures are seldom labeled with flow rates, making determination of compliance all the more difficult. Many jurisdictions indicated that they left enforcement of this requirement up to plumbing inspectors. However, plumbing inspections typically occur long before fixture installation. At least one jurisdiction stamped the low-flow fixture requirement directly on the permit drawing set.

Like low-flow fixture requirements, enforcement of IC ratings for recessed lighting was often indicated to be the responsibility of a different inspector, in this case the electrical inspector. Again, compliance with this requirement was difficult to verify. Many fixtures were inaccessible, or labels had been painted over or otherwise obscured. Fixtures were considered not to comply only if they were clearly unlabeled. Because of these assumptions, compliance rates with this requirement may be lower than indicated here. The significance of this issue is also affected by the fact that over 90% of the houses visited had recessed incandescent lighting installed. In one case 16 unrated cans were installed into the attic space. This could have been a fire hazard from insulation contact except that the contractor had forgotten to insulate the attic itself. (The homeowner was notified of the problem.)

4.5 Performance-Based Compliance

The Oregon Energy Code was developed to encourage/mandate a cost effective level of energy conservation in residential construction. After evaluating construction techniques, costs and energy savings, a baseline construction type was developed which became the basis for Path One compliance. This baseline was modified to develop other compliance paths, as well as the performance path option. Theoretically, a house built to the Performance Path would use the same amount of energy as a house built to Path One.

For this reason project compliance can be evaluated on the basis of the Performance Path, in effect allowing some performance tradeoffs as long as target energy use complies with code guidelines. This section evaluates energy code compliance levels as if all houses were submitted under the Performance Path.

4.5.1 Project Compliance

When evaluated based on performance, compliance rates are significantly higher than compliance rates based on prescriptive requirements. After correcting for mathematical rounding errors, the compliance rate of the sample with performance target guidelines is 79.2%. Table 4.6 shows the compliance rate for projects submitted under each path.

TABLE 4.6
Performance-Based Compliance by Path Submitted

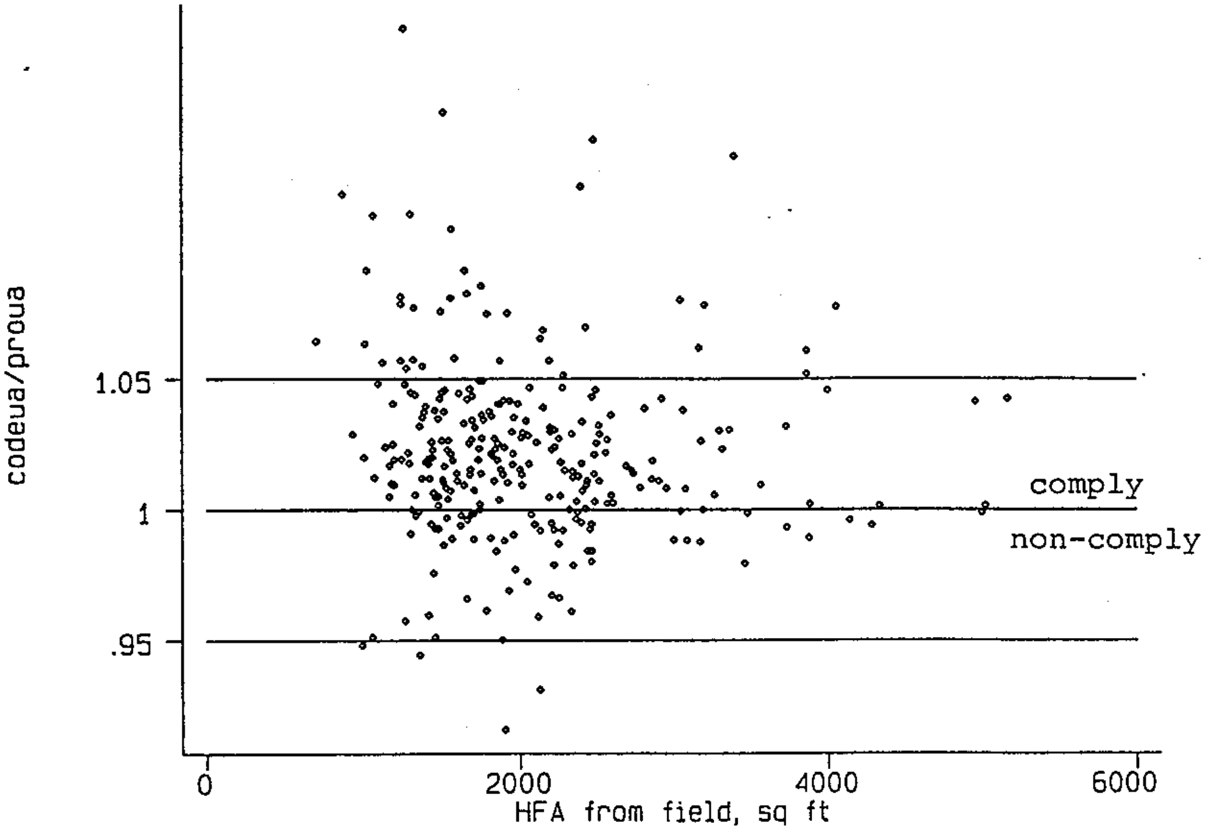
Path	Total Submitted		Compliance	
	#	% of Total	#	% of Path
Path 1	189	67	154	82
None	74	26	59	80
Assumed Path One, total	263	93	213	81
Path 8	11	4	8	73
Performance Path	9	3	3	33
Total	283	100	224	79

(Note that of the projects in the sample, those submitted as Performance Path in the first place are by far the least likely to comply with performance requirements.)

In order to evaluate Path 8 projects from a performance standpoint, the code UA target must be adjusted to account for different component performance requirements of Path 8 in Table 53-P. Even taking these performance adjustments into account, Path 8 houses are significantly less likely to meet performance requirements. This is due in part to the fact that over half (6 of 11) of the Path 8 houses exceed the 12% of heated floor area (HFA) maximum for glazing area imposed by the path. The mean glazed area for all Path 8 houses was 12.3%; only one of these houses exceeded 14% glazing.

Although the overall performance compliance rate in the table above is less than 80%, this conclusion is somewhat misleading. In evaluating prescriptive compliance it is reasonable to consider the simple yes/no question of whether the project meets code requirements. With performance evaluation however, it is important to evaluate the distribution of project performance around the code target. Figure 4.1 shows the distribution of the ratio of code target UAs to project UAs plotted against heated floor area. A project with a ratio of 1.0 is meeting code requirements exactly. Ratios of greater than 1.0 are performing better than the code target requirements, and projects with ratios less than 1.0 are exceeding the code target heat loss allowance for the project.

Figure 4.1
Distribution of Projects Around Target UA Performance by Heated Floor Area



From this figure it can be seen that although approximately 20% of the submitted projects are failing to meet code performance requirements, the majority of these are within 5% of the code requirements. Fully 98.6% of the projects reviewed are within 5% of the code target, or better. The mean performance ratio of the entire sample is 1.022. For only non-complying projects, the mean of this ratio is 0.979, while for only the complying projects, the mean ratio is 1.033.

Figure 4.1 also indicates with horizontal lines the ratio values within 5% plus or minus of the code target. Eighty-five percent of the projects reviewed fall within this band. This distribution tends to suggest that the energy code is in fact describing construction techniques that are fairly close to standard practice. (These data points do not include infiltration or heating system efficiency impacts.)

4.5.2 Individual Components

Table 4.7 shows how specific components perform relative to the component performance guidelines set forth in Table 53-O (corrected for Path 8 values where applicable). The first column lists the component in question; the second column shows the percent of the projects which installed the component; the third column indicates how many houses in the sample included the component with a performance level below the target; and the fourth column shows what percentage of the sample this represents. The fifth column indicates how many of the houses with a non-complying component were out of compliance with the overall target code UA requirement. Finally, the sixth column indicates the overall U-value of the component in the sample houses.

TABLE 4.7
Components That Fail to Meet Performance Targets

Component	% of houses with component	Percent of **all** houses with non-complying component	Percent of **non-complying** houses with non-complying component	Average U-value of components in sample
Frame Floor	95	5	12	0.032
Slab	12	7	2	0.56 (F)
Doors	100	9	24	0.28
Walls	100	4	7	0.060
Below Grade Walls	7	0.4	0	0.036
Windows (deemed to satisfy)	100	1	2	0.40
Windows (default table) *	100	25	53	0.40
Glazed Doors	46	7	12	0.39
Skylights	47	1	0	0.50
Vaulted Ceilings	76	32	34	0.033
Attics	96	7	14	0.031

* Default table windows were not used for in the total compliance ratio (bottom of table). These are provided to compare actual window performance with code requirements and windows accepted under the "deemed to satisfy" ruling.

One of the first issues apparent in this table is that many houses include components which do not meet code guidelines and yet still meet the overall UA requirements. This is because most houses have at least one component which exceeds the target performance, and therefore may make up for the lack of performance of another component.

Another aspect of the sample demonstrated by this table is that the average performance of most of the components listed is very close to the code component requirements. The average U-values listed in the last column of this table match very closely with the performance requirements listed by the code under Table 53-O. The notable exceptions are below grade walls, which actually perform better than above grade walls due to earth buffering effects, and glazed doors, which tend to be assigned better performance values in the default table.

The table also shows the comparison of windows rated by the "deemed to satisfy" ruling compared to the default table. Although a significantly larger number of houses have windows which exceed performance guidelines using the default table, the average U-value of all windows in the sample is virtually the same under either rating system.

4.6 Path 8

Prescriptive Path 8 provides what is considered a "low-income" alternative to the standard Path One. It allows the use of more economical 2x4 construction with R-15 wall insulation instead of the 2x6 with R-21 required by other prescriptive alternatives. Path 8 also limits overall house size to 1500 ft^2, and limits glazing area to 12% of the heated floor area.

Only 4% of the projects in the sample were submitted as prescriptive Path 8. This path tended to be utilized in more urban jurisdictions; more than half of the Path 8 submittals were in Portland, all but one of these projects were located in one of the five largest jurisdictions.

Like the rest of the sample, Path 8 houses were evaluated on the basis of two levels of compliance; compliance with prescriptive requirements as stated in Table 53-P, and compliance with performance goals associated with those requirements. In order to develop a target performance level for Path 8 houses, the prescriptive requirements of Path 8 for each component were assigned U-values based on the default U-values given under table 53-P. These U-values, with a maximum glazed area of 12% of heated floor area, were used to develop a Path 8 performance target UA.

Based on the more restrictive prescriptive component requirements for Path 8, only three of the eleven Path 8 projects complied with code requirements. This represents a compliance rate of only 27%. Six of these houses had glazing area in excess of the 12% of heated floor area maximum which is a key element of this path. Table 4.8 below shows the aspects of these houses which were out of compliance.

TABLE 4.8
Path 8 Non-Compliance Issues

Code Issue	Number of non-complying houses	Percent non-compliance, of Path 8 houses
Heated Floor Area over 1500 ft^2	0	0
Glazing area over 12% of HFA	6	55
Attics not insulated to R-49	2	18
Vaulted ceilings not insulated to R-38	3	27
Doors not insulated (U-value max.: 0.2)	2	18
Total non-compliance rate (houses with one or more of above out of compliance)	8	73

Overglazing is clearly a key issue in discussing compliance rates for Path 8 houses. When expressed as a percentage of heated floor area, glazing in Path 8 houses was as high as 14.3%, despite the 12% limit of the path. The average for Path 8 submittals was 12.4%, as opposed to the average for the rest of the sample of 16.2% of heated floor area.

On the other hand, none of the Path 8 submittals in the sample were over the 1500 ft^2 limit. The average for these submittals was 1241 ft^2, compared to 1877 ft^2 for the sample as a whole.

Ceilings were another problem area in Path 8 houses. Three of the houses failed to install R-38 insulation in vaulted ceilings, as required by the code. Two of the houses had underinsulated attics. (The code requires R-49). One of these had R-38 attic insulation installed, the other had simply failed to install as much loose fill as required to meet R-49 insulation levels, and ended up with R-43 instead.

Two of the projects had installed uninsulated wood doors for both main entry and other doors in the house, in clear violation of code requirements.

Walls installed in these houses all met code requirements of R-15 insulation. One house even used 2x6 wall construction with R-21 insulation.

Interestingly, none of the Path 8 houses had installed glazed swing doors. All of the windows in these houses met the "deemed to satisfy" window requirements.

When evaluated for performance-based compliance, three of the eleven Path 8 submittals did not meet performance goals. This represents a compliance rate of 73%. This compliance rate is significantly lower than the compliance rate of Path One houses. Two of these non-complying projects had installed a glazing area in excess of 12% of HFA.

4.7 Performance Path

Although performance path submittals comprised only a small percentage of the projects reviewed, they had abnormally high rate of code compliance problems relative to their distribution in the sample.

Over one third of the performance path projects were submitted to jurisdictions within Marion County. The reason for this was unclear. The rest of the performance path submittals were widely distributed among the jurisdictions sampled.

The performance path option allows a project to demonstrate "energy equivalence" with a target UA value. This target is based on the proposed house configuration, if it were built to the requirements of Path 1. A guideline for this calculation is provided by Table 53-O in the Oregon Energy Code.

Using this option allows a builder to under-insulate certain components of the house by making other components more efficient, or by installing window area less than 13% of heated floor area. In order to evaluate compliance, a building official must be able to evaluate both the appropriate code UA target, and the project's proposed UA. Not surprisingly, this process can be both time-consuming and confusing, especially if the information is poorly documented on the plans. During interviews, several code officials commented on the extra time required to evaluate performance path submittals.

Even if the documentation is clear and concise, and the plan reviewer is able to interpret the performance submittal correctly, there is still the problem of field enforcement. Performance submittals are typically included as separate sheets, which may or may not remain attached to the plan set they refer to. Since the project is not required to meet prescriptive insulation and window performance requirements, the field inspector has no specific basis by which to judge energy code compliance of the components unless the performance submittal is available at the time of inspection. Performance issues are further complicated by any field changes to the project which may occur. Typically, performance path submittals are designed to comply with code requirements by the slimmest of margins, so even minor changes can result in non-compliance with code requirements.

In this sample, 56% of the projects submitted as performance path were different in the field than indicated on the submittals. In several cases, window performance was well below the performance indicated on the submittal, including one case where windows were clearly labeled in the field with a U-value 20% higher than were indicated on the submittal, even though the submittal showed compliance with code requirements by less than 1/10th of one percent.

Of more significance than the field changes to performance path projects is the fact that nearly all of the performance submittals were incorrect. All but two of the performance path submittals reviewed contained calculation errors or omissions, ranging from minor mistakes in U-value assumptions to completely incorrect calculations. The most inaccurate performance path submittal was stamped and signed by a registered engineer. Several submittals claimed window U-values well below any accepted test standard, and these windows were never installed. Other submittals used incorrect U-values for walls or ceilings. Several projects failed to account wall area between house and garage.

Nearly 80% of the submittals contained mistakes; these mistakes invariably favored the applicant in demonstrating compliance.

For projects submitted as performance path, the compliance rate was 33%. Nearly 80% of the submittals were incorrect for one reason or another, while over 50% of the projects were built differently in the field than indicated in the submittal. Furthermore, only one of the performance path projects met other prescriptive requirements of the energy code.

Clearly these numbers demonstrate a significant problem with the performance path of the energy code. This information might be a cause for concern, except for the fact that only 3% of the sample were actually submitted using the performance path. Still, this path seems to contribute significantly to code officials' energy code enforcement workload.

4.8 Relative Impacts of Component Non-Compliance

From a theoretical standpoint, we can evaluate the energy impact associated with non-compliance of various building components. This evaluation can be used to compare the relative impact of non-compliance of various different components. It is important to keep in mind however, that these numbers are only relative, and do not reflect actual, recoverable energy use, since quite often these components are balanced by other components in the home which exceed code performance levels. Furthermore, the impact of infiltration rates and heating and distribution system efficiency would substantially modify both the relative and absolute impacts of these components if the houses were taken as a whole (see Section 7.0).

This evaluation is conducted by determining the difference in the average component UA of non-complying components from the required UA of the code component for those cases. This number, the ΔUA/component, is multiplied by the number of houses in the sample in which the component is out of compliance. This result indicates the magnitude of non-compliance for each component in terms of UA. This is then multiplied by the energy use associated with each unit of UA for houses in the sample. For this sample this energy use is 93.9 kBtu/UA. The result of this calculation is an approximation of the energy use above code guidelines by component, for all of the houses in the sample taken together.

The results of this approximation are presented in Table 4.9. The first column in this table lists the component in question, then the number of houses in the sample in which this component was out of compliance with performance guidelines. The third column shows the ΔUA between the average UA of non-complying components and code UA. The fourth column shows the average U-value of non-complying components in the sample. The fifth column indicates the energy use associated with this level of performance for each component.

This evaluation does not incorporate infiltration of heating and distribution efficiency.

TABLE 4.9
Approximate Energy Implications of Component Non-Compliance in Sample Homes

Component	# of components over code UA	ΔUA/component	Avg. U of non-complying components	KBTU (entire sample)
Vaults	89	6.56	0.044	54,817
Windows	60	6.37	0.421	35,885
Other Doors	42	6.39	0.388	25,198
Slabs	19	7.48	0.59(F)	13,344
Walls	11	9.57	0.065	9,884
Floors	15	6.30	0.037	8,873
Entry Doors	10	6.31	0.524	5,924
Attics	19	3.29	0.033	5,869
Glazed Doors	20	2.11	0.452	3,962
Below Grade Walls	1	4.40	0.070	413
Skylights	2	1.48	0.500	278

- From this table it is apparent that the performance loss associated with under insulated vaults is the most significant issue in this sample.
- Note that the window energy use number is based on the use of the window default table, which is not necessarily a code requirement for the houses in the sample.
- Energy use associated with doors is a result of the use of uninsulated doors, most typically found between the house and the garage.
- Finally, note that while slabs indicate a fairly high performance loss, this is in part because the code itself fails to account for ground buffering. The energy use associated with slabs would probably be counteracted by below grade wall performance improvements if the code correctly accounted these conditions.

4.9 Utility Incentive Programs

When reviewing the projects in the field, 31 projects had some indication that they were participating in utility incentive programs. This represents approximately 11% of the sample projects. The incentive programs listed were Super Good Cents, Natural Choice, and Energy Choice.

Not all of the projects which had some indication of participation in utility incentive programs necessarily completed all of the requirements of the program. Some number of these houses had apparently failed to meet program requirements, and dropped out of the program somewhere along the line, according to conversations with builders, homeowners, code officials, or other indications. It was impossible to verify the final status of utility programs for these projects.

Nevertheless, all of the houses identified as participating in utility incentive projects met the performance requirements of the energy code. Taken together, these 31 projects met the code performance requirements by an average of over 5%. This means that these projects were in the top 15% of all projects in the sample in terms of the percentage by which they met code. The best performing house in this group met code requirements by more than 18%.

On the other hand, 12 of the incentive projects failed to meet the prescriptive requirements of the code for component insulation levels, and 20 of them failed to comply with other non-component prescriptive requirements. These rates of prescriptive non-compliance are fairly consistent with prescriptive compliance rates for the sample as a whole.

The most common prescriptive compliance problem area for these projects was with glazed doors. Four of the projects included glazed doors which did not meet prescriptive code requirements.

Only nine of the 31 utility incentive projects contained enough information at the time of submittal for the plan reviewer to determine energy code compliance. This is again consistent with the documentation levels of the sample as a whole. Furthermore, although several interviewees felt that code officials treated utility incentive projects differently, only 7 of the 31 incentive projects identified in the field contained any indication on the plans that they were participating in utility incentives. This suggests that code officials are seldom made aware of such participation during plan review.

5. Interviews

Interview protocols were developed in order to attempt to standardize the responses received for comparison and evaluation purposes. A set of questions was developed which could be asked of both jurisdictions and builders, in order to compare different perspectives of the same issues. Appendix D includes the structured interview formats used for both building officials and builders.

Interview protocols were reviewed by a variety of Oregon building professionals including building officials, builder representatives, etc. Eventually these responses were collated into a standard interview form for jurisdictions and builders.

Interview formats for manufacturers, suppliers, and other groups were kept flexible and informal. These interviews tended to respond to issues identified during the more formal interview process. As interviews progressed, additional issues and questions were identified. These issues were incorporated into the interview forms already developed. In some cases newly identified issues led to follow up questions with jurisdictions or others who had already been interviewed.

5.1 Distribution

The distribution of completed interviews is listed in Table 5.1, below.

TABLE 5.1
Interview Distribution

Interview Type	**Number of Interviews**
Code Officials	62 (total)
Different Jurisdictions	39
Inspectors	22
Plan Review	36
Administrators	2
State Level Administrators	2
Building Trades	42 (total)
General Contractors	21
Architects/Engineers	5
Insulation Subs	3
Manufacturers/Suppliers	13

Roughly 60% of the interviews conducted were with code officials, representing nearly 40 different jurisdictions or offices. In most cases interviews were conducted with both plan review and field inspection staff members within a jurisdiction so that we could better evaluate the energy code enforcement process as the project moved through the various enforcement procedures.

Several interviews, conversations and clarifications were also conducted with various state level offices and code support agencies.

Approximately 30% of the interviews were conducted with builders and designers, and the remaining 10% of the interviews were conducted with suppliers and manufacturers.

5.2 Jurisdictions

There is a wide range in the number of annual permits reviewed by the jurisdictions in the sample, from as few as 20 to well over 1000. Despite this broad range, all of the jurisdictions interviewed indicated that only one to four staff members (full time equivalent) reviewed all of the residential permit applications for energy code compliance. The average number of staff cited by all respondents was 1.7. In the inspection category, the variation in manpower was more distinct, as might be expected. The largest jurisdictions had up to 20 full time inspectors whose responsibilities included the verification of energy code compliance in the field. The average number of inspectors was 3.2.

These staffing levels have implications for any increased enforcement levels, both in terms of what stage of the permit process the enforcement occurs, and the size of any target audience for training efforts.

5.2.1 Paths Submitted

The vast majority of projects are typically submitted under Path One. The average estimate of Path One submittals by all code officials interviewed was over 93% (this corresponds with the distribution of Path One in the sample). The range of estimates was between 75% and 100%. Over one third of the respondents indicated that Path One submittals were 99 to 100% of all projects.

Only eleven jurisdictions provided any estimate of the percentage of path eight submittals received. These estimates averaged 8.0%. On the other hand, 23 jurisdictions estimated a percentage for performance path submittals; these estimates averaged 3%.

Since not all respondents estimated submittal percentages for all of the available paths, the average percentages do not add up to 100%. However, from the response pattern, several things are clear. First of all, the vast majority of submittals utilize Path One. This conforms with the distribution of paths in the housing sample (see Table 3.1). Secondly, although not many jurisdictions see path eight submittals with any regularity, those jurisdictions that do see these submittals seem to get a fair number of them. Finally, while performance path submittals make up a relatively small percentage of the total, they are seen by a wide variety of jurisdictions, who are of course, expected to be able to review them.

In comparing the time required to review project submittals, approximately one-third of the respondents indicated that it took more time to review projects submitted under performance path or Path 8.

5.2.2 Compliance Forms

Standardized compliance forms can be used to demonstrate energy code compliance in a consistent format. Only three of the jurisdictions interviewed claimed to consistently require energy code compliance forms with a project submittal. Seven other jurisdictions required these forms only for performance path submittals.

5.2.3 Submittal Characteristics

Plan reviewers interviewed estimated that on average nearly 20% of submitted projects required some sort of training or assistance in order to demonstrate compliance with the residential energy code. (These estimates ranged from 0 to 80% of all projects) To improve the quality and completeness of submittals, all of the jurisdictions surveyed provided various types of information and support to builders, including telephone and in person support for code questions, and printed handouts. These are usually developed by the state.

Despite these efforts, plan reviewers estimated that over 27% of submitted projects required design modifications in order to bring about energy code compliance. These estimates varied widely, from 0 to 100% of all projects requiring modifications.

5.2.4 Enforcement Issues

Plan reviewers were asked to rate the enforcement priority of a variety of energy code issues. For each issue, the respondent was asked to describe enforcement priority as high (1), medium (2), low (3), or not enforced (4). The average of these responses to each issue is presented in Table 5.2.

TABLE 5.2
ENFORCEMENT PRIORITIES FOR PLAN REVIEWERS

Enforcement Issue	Priority
Insulation R-Value	
Walls	1.1
Ceilings	1.1
Floors	1.1
Slabs	1.1
Position of Slab Insulation	1.1
Wall Framing Size & Spacing	1.1
Compliance Path	1.3
Slab Edge Detailing	1.3
Window U-Value	1.5
Entry Door Size & U-Value	1.6
Moisture & Air Barriers	1.8
Weatherstripping	
Doors	3.0
Windows	3.1

As can be seen, building officials generally place the most emphasis on the building components and less emphasis on weatherstripping and vapor barriers. Areas cited as a lower enforcement priority were also areas where we observed more consistent non-compliance, even among homes that otherwise complied with code requirements.

5.2.5 Plan Review

In addition, plan reviewers were asked to describe enforcement issues which came up repeatedly during plan review. Issues which were cited by more than one respondent are described in Table 5.3 below:

TABLE 5.3
ENFORCEMENT ISSUES DURING PLAN REVIEW

Number of Responses	Description of consistent problem on code submittals
11	Problems with insulation, either lack of documentation, or improper R-values. (10) specifically cited vault insulation requirements, or lack of appropriate structural depth to meet code requirements. (5) cited outdated insulation levels, from previous versions of the energy code.
8	Incorrect, or complete lack of window performance information.
14	Door performance issues, including (7) incorrect entry door area, (4) door performance issues, and (3) specifically citing a conflict between energy code and fire rating requirements for doors into the garage.
2	Cited incomplete plans
2	Treatment of unheated spaces

A related question asked plan reviewers to discuss energy code requirements that are frequently misinterpreted or ignored by designers. These responses are summarized in Table 5.4 below.

TABLE 5.4
FREQUENTLY-MISINTERPRETED REQUIREMENTS

Number of Responses	**Description of code aspect misinterpreted or ignored by designers.**
8	Window performance information incorrect or missing.
8	Door performance information incorrect or missing.
5	Entry door exceeds allowable area for non-insulated doors.
5	Vault areas or performance levels ignored or incorrect.
6	Slab insulation missing
4	Structural framing depth not consistent with insulation R-value.
3	General unfamiliarity with the fundamentals of energy efficiency in buildings.
3	No information about sealant or air infiltration control.
2	No information about duct insulation.

While these areas may result in enforcement problems, the impact on overall prescriptive compliance does not appear to be significantly different than components not mentioned. When reviewed using this perspective it appears that the enforcement emphasis, taken from table 5.2 and 5.3 must have been effective.

5.2.6 Field Inspection

When problems are identified during plan review, corrections must be communicated both to the builder and to the field inspector, if they are to be followed up. The standard technique for this communication is through red lining the plan set. Ninety-seven percent of respondents indicated that redlines were the primary method for keeping track of energy code compliance issues. Some jurisdictions also use an in-house energy code compliance form to keep track of code requirements identified for this project. In smaller jurisdictions, the communication between plan review and field inspection is improved by the fact that this is often one and the same person.

Field inspectors were asked some specific questions about enforcement issues and problems. Nearly all inspectors claimed to look for window performance labels in the field. When asked about insulation quality, inspectors estimated that on the average, 22% of projects had damaged, missing, or poorly installed insulation. (Responses ranged from 5 to 50% of projects) There seemed to be no hard and fast guidelines as to when these problems led to a correction notice.

When corrections were required, a notice was typically left at the job site. Approximately half of the inspectors indicated that these corrections were tracked with the inspection file, some using a computer system. Most inspectors tried to review the corrections in subsequent inspections, although in the most egregious cases, additional inspections were required, often with additional inspection fees.

Inspectors indicated that changes to the project in the field affecting energy code compliance were encountered in over 11% of the projects. (Responses ranged from 1 to 50% of projects.)

Inspectors were also asked to indicate how consistently some specific energy code issues were enforced. These were to be rated as: always, sometimes, infrequently, or never enforced. Vapor barriers and duct insulation were rated by all but one inspector as always enforced. Enforcement of I/C ratings for can lights on the other hand was left up to the electrical inspector by more than 50% of the inspectors interviewed. Likewise, the requirement for low-flow water fixtures was left up to the plumbing inspector to enforce by nearly 40% of the inspectors interviewed.

When asked to describe frequently encountered field enforcement problems, field inspectors tended to identify a slightly different set of energy code issues than those indicated by plan reviewers. These issues are summarized in Table 5.5 below.

TABLE 5.5
ENFORCEMENT ISSUES
IDENTIFIED BY FIELD INSPECTORS

Number of Responses	Description of field enforcement issue
8	Missing or damaged insulation
5	Insufficient insulation R-value
5	Missing or damaged vapor barriers
3	Entry door area/insulation
2	Performance of other doors
2	Changes to window types, or lack of performance information labels
1	"Unheated" spaces

5.2.7 Compliance Issues

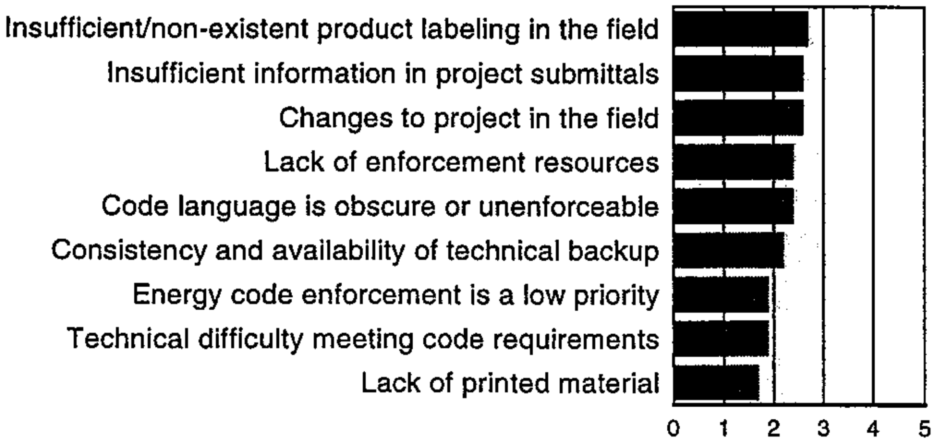
Estimated Compliance

Although a few respondents had a very pessimistic view of overall compliance levels, most code officials estimated that overall energy code compliance for all projects was in the range of 80 to 100%. Although responses ranged from 5 to 100% compliance, the average of these estimates was approximately 85% compliance for all new residential projects.

Enforcement Issues

Code officials were asked to rate how significantly a set of issues limited the effective enforcement of the energy code, on a scale of 1 to 5 (with 5 representing the biggest problem areas, 1 indicates the issue is not a problem). Table 5.6 below shows the averaged results of these questions.

Table 5.6
Enforcement Issues Identified by Code Officials



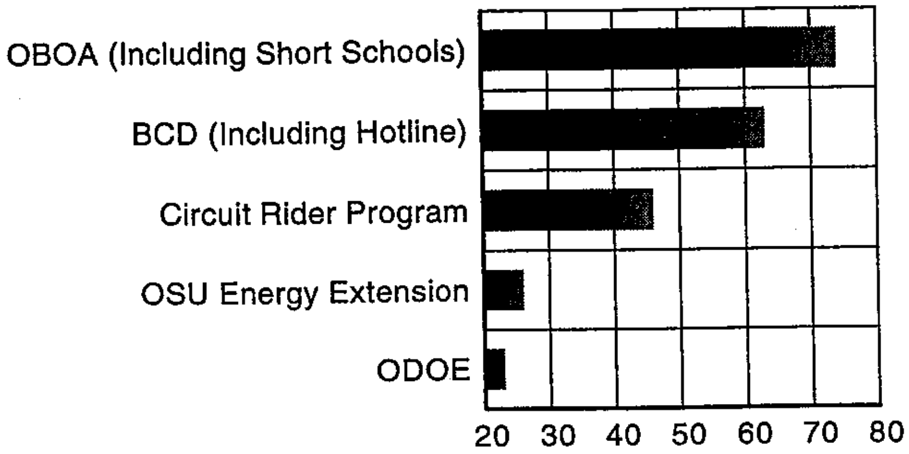
Although individual responses varied, taken together the code officials' responses to these issues seem to indicate that none of these issues stand out as significant problems. Furthermore, only the top three items listed exceeded the mid-point of the 1 to 5 range.

It was also mentioned by a few code officials that local building supply stores in the state sell products which do not meet energy code requirements, such as windows and insulation. While this problem typically has a larger impact on remodeling projects, the products occasionally show up in new construction.

5.2.8 Training/Improvements

Table 5.7 indicates the sources cited by code officials from which they received training.

Table 5.7
Training Sources Identified by Code Officials



Fully two-thirds of the code officials interviewed felt that additional resources would lead to an increase in energy code compliance. Table 5.8 indicates how code officials feel that additional resources should be allocated to improve code compliance. This is rated on a scale of 1 to 5 (with 5 representing the highest priority, and 1 the lowest priority).

TABLE 5.8
Suggested Allocation of Enforcement Resources Identified by Code Officials

Education for builders	4.3
More time per inspection	4.2
Education for code officials	4.0
More inspectors	3.8
Circuit Rider program	3.7
Improved code language	3.5
Technical support from state agencies or OBOA	3.4
More inspections	2.5

5.2.9 Comments

When asked to provide general comments on the energy code and the potential need to improve compliance, code officials provided a wide range of comments and suggestions. The most common comments indicated a need or desire for more education; not just for code officials, but for builders, consumers, retailers, and designers as well. Many commented that the code might go over better if more information were available about the potential paybacks of energy efficient construction.

Specific problem areas included moisture issues not addressed by the code (especially in vaulted ceilings), the difficulty of inspecting slab insulation, insulation issues with metal stud walls, and fire rating requirements for doors between the house and garage.

Not all code officials agreed with the need for the code, or with the performance levels required by the code. Some felt that the cost of code compliance outweighed the energy benefits of the code. Others commented that the code should be modified for the more temperate regions of the state.

A number of officials indicated that they felt the utilities, which have a large stake in energy code compliance, should be more involved in both financing and enforcing the energy code.

The complete text of these comments is provided in Appendix E.

5.3 Builders and Subcontractors

The interviewed builders were drawn from a list compiled by the field teams from houses in the sample. Thus, all of the builders interviewed had built at least one of the houses in the sample.

Builders were often difficult to contact. We attempted to contact approximately ten builders for each one we actually interviewed. Some builders simply declined the interview.

More than half of the builders interviewed worked in firms of five or fewer employees. Twenty percent of the firms contacted had over 10 employees, and one firm had 500 employees. The number of projects completed annually by these firms ranged from one to 100. The firms had an average of 14 years of experience building in Oregon. The price range of the homes constructed by this group was from $70,000 to $1,500,000, although none of the houses in our sample were in the upper end of this range.

All of the builders contacted submitted projects using Path 1 mostly or exclusively. Two of the builders used Super Good Cents documentation to demonstrate energy code compliance with some regularity. Nearly 50% of the builders claimed to participate in utility incentive programs on an occasional or regular basis. Several builders mentioned that jurisdictions tended to leave energy code enforcement up to the utilities when the project was participating in utility incentive programs. (Code officials tended to disagree, although some felt that utility programs made code review more straightforward.)

Although nearly all builders had to readjust their design, planning and construction techniques when the code was first adopted, most builders indicated that they had adjusted to the requirements by now. Nearly half of the builders interviewed indicated that the energy code had no impact on their projects during construction, while the rest mentioned that occasional modifications were necessary. Seventy-five percent of builders interviewed said the code had no effect on the length of time it takes to complete a project, while the rest considered the additional time required to be minimal. Most agreed that the energy code had increased the cost of any given home, with rough estimates ranging from a 2 to 8% impact on home costs. When provided, cost estimates of this impact ranged from $2000 to $5000 per home. These costs were attributed primarily to increased structural thickness requirements (especially 2x6 walls) and the time required to install them, to window costs, basement insulation, and increased insulation in general. Not all builders considered the cost impacts to be significant. Builders commonly agreed that the increased costs associated with the energy code were passed directly to the consumer.

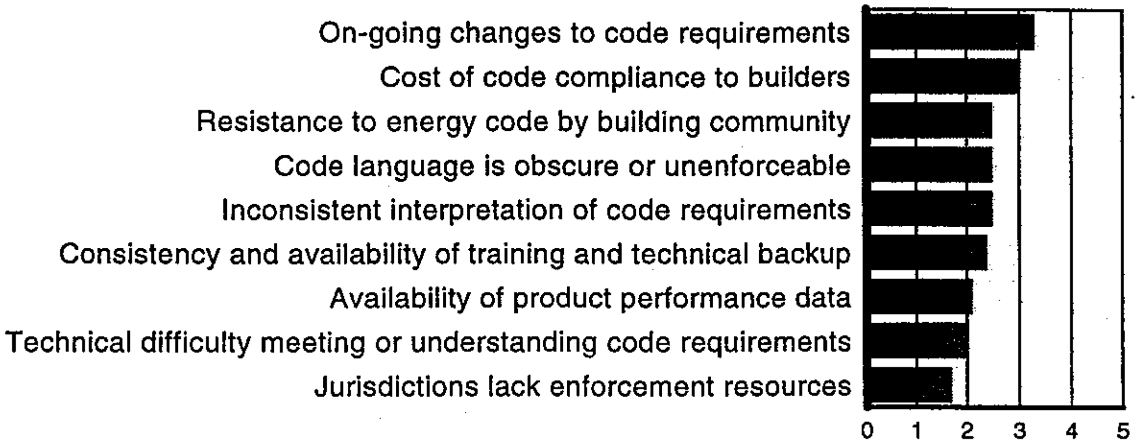
Despite various objections to the energy code, over 50% of builders interviewed indicated that their construction techniques would not differ in the absence of an energy code, now that they had adapted to the requirements. In other words, the code requirements were now considered standard construction. Thirty percent of the builders interviewed would reduce insulation levels, especially in walls, in the absence of an energy code. Some builders suggested that they would back off on window performance, given the option.

Of the builders interviewed, 80% were active in multiple code jurisdictions. Only two builders had encountered variations in energy code enforcement between different jurisdictions. These builders mentioned inconsistencies in the enforcement of vault insulation requirements, window performance standards, and basement wall insulation requirements.

Builders were asked how frequently energy code enforcement resulted in modifications to their project either in plan review or during construction. Eighty percent of the builders said that enforcement never led to modifications. One builder said he had never encountered any energy code enforcement on any project (this builder constructed 20 to 25 houses per year.) Three builders indicated that enforcement issues had declined over time, as builders had adjusted to code requirements. One builder cited a strict jurisdiction that almost always issued energy code corrections.

A series of issues were presented to builders and they were asked to rate them on a scale of 1 to 5 as to whether these issues represented problems with the energy code (with 5 representing the biggest problem areas). The average of their responses are presented in Table 5.9

Table 5.9
Enforcement Issues Identified by Builders



In general, builders felt that the greatest difficulties with the code were its costs and the ongoing changes being made to it. When given the opportunity to discuss energy code issues which concerned the builders, a variety of responses were received.

Several builders questioned whether the energy code was cost-effective. One builder suggested that furnace efficiency was the only aspect of residential construction that should be regulated for energy efficiency. Another felt that the utilities used the code in a self-serving manner to sell their power out of state. Many builders suggested simplifying the path system, especially for maximum area requirements that mandate different insulation level requirements (such as for vaults).

Several builders suggested loosening code requirements, especially for more temperate regions of the state. Despite these objections to the code, most builders seemed to have adjusted to the code in general, and suggested that resistance to the energy code had reduced considerably over the years since its adoption.

Some other concerns reported by builders included: indoor air quality and interior moisture problems, changing window performance requirements, and retailers selling products that could not be legally installed in new construction and most remodels. One builder suggested that non-uniform construction quality had an impact on both energy code enforcement and overall building efficiency.

More than half of the builders interviewed were interested in receiving additional training or support materials on energy code issues.

5.3.1 Insulation Subcontractors

Insulation subcontractors agreed with builders that the energy code had increased residential construction costs. They estimated that the impact was approximately a 20% increase in insulation cost per house. This group estimated that they were required to return to any given project 5 to 10% of the time as a result of energy code enforcement.

Several comments were received from builders, insulators, and others about problems with the requirements and inspection routines for floor insulation. Depending on when floor insulation is installed and inspected, the insulation is subject to damage from both the weather and from subsequent service and utilities installations. This led to problems with insulation quality, re-inspections, and insulation subcontractor call-backs. Apparently some jurisdictions are somewhat inflexible about the timing of floor insulation inspections. Other jurisdictions work with the contractors to avoid these problems.

Energy code issues were also discussed with several insulation industry representatives. They indicated that national demand for insulation would shortly outstrip supply, despite a projected 25% increase in manufacturing capacity nationwide. It is anticipated that this situation will lead to national price increases in insulation costs.

5.3.2 Field Observations

Field technicians were in a unique position to observe construction practice and discuss code requirements with builders and code officials. The following is a summary of conversations and observations provided by one of the field technicians on this project.

> During the course of the 1993 Oregon Energy Code study, the field technicians noted two distinct attitudes that building contractors had towards the energy code. Some contractors supported the code, and others disliked it intensely. Those who supported the energy code seemed to be more aware of ecological issues than did the code's detractors.
>
> Those contractors supporting the code seemed eager for suggestions on energy-efficient construction practices. They indicated that they could improve their construction practices if they had more information on costs and procedures. One builder in Florence had read about blower doors and was eager to have several of his recent projects tested. Another code supporter believed that the energy code, in combination with the building code, was a positive influence on the industry. Yet another builder pointed out that square footage is the most important

factor in profit margins, and so the added cost of the energy code requirements caused builders to increase the area of their houses. This actually *reduces* overall energy savings.

The builders who were opposed to the energy code cited its high costs, the difficulties in compliance due to the local climate (especially on the southern coast), "insane" increases in government regulation, and difficulties in compliance related to preferred building practices.

In attempting to meet the energy code, builders cited problems with particular components or building materials. Current lumber quality makes advanced wall framing difficult, since studs on 24" centers often twist and bow severely. Rigid foam wall sheathing is expensive and damaging to the ozone layer. Correct wall batt insulation makes sheetrock installation more difficult. Building inspectors often demand to see floor insulation before the floor is sheathed, exposing the insulation to rain.

The primary responsibility for the actual energy efficiency of most houses lies with the HVAC and insulation subcontractors. There are many HVAC component and installation issues associated with energy efficiency (or lack thereof). Flex ducts in a home may be crimped or inadequately supported; return air systems may be inadequate; or there may be little or no duct sealing and insulation. Additional HVAC problems include: poorly-sited and low-efficiency heating and cooling equipment; and poor placement of plenums, branches and registers. Some common insulation problems include poorly installed or missing vapor barriers, poorly installed batt insulation (resulting in reduced R-values at eaves), inadequately supported and improperly installed floor batts, and "short-bagged" attic blow-in insulation. It appears that many building officials are not very attentive to the details of HVAC and insulation installations; the local contractor's knowledge and integrity therefore become the determinants of installation quality and energy efficiency. HVAC and insulation problems on this scale suggest that many houses which meet the code "on paper" or in calculations will not perform as assumed.

Some subcontractors also complained of damage to homes' energy-efficient features caused by plumbers and electricians. For example, plumbers might tear up floor insulation around bathtubs or destroy ground sheets; electricians might compress attic insulation in order to gain access to a work area.

Many building officials expressed reluctance to fully enforce the energy code, citing difficulties with the local climate (especially on the southern coast), and the additional costs and time necessary for adequate enforcement. The officials also expressed the opinion that their primary focus is on health and safety issues. One building department official said that he does not "force" the energy code upon the unwilling, yet proudly stated that he levies $10,000 fines on owner/builders who do their own plumbing and wiring and subsequently try to sell their homes!

There are some aspects of energy efficiency which the current code does not fully address, and could be included. These include: glazing quantity, type and orientation; location of buffering spaces such as garages, and siting details. A major concern is the trend towards constructing homes of excessive size. Another interesting problem is that there are no "tradeoff" guidelines for performance path homes. One builder in Eugene used R-38 floors and little patches of rigid foam sheathing in the attic buffer and garage walls to just meet UA requirements. This builder also used 2x4 wall studs and non-complying windows.

5.4 Architects/Engineers

Like the builders, the architects and engineers we contacted were drawn from the projects in the housing sample which had been stamped by an architect/engineer for submittal. Drawing the sample in this way facilitated contacting the architects who develop large volumes of spec plans, rather than high-end custom residential architects.

Most of the architects we contacted claimed to be somewhat removed from the permit process; they usually left permitting issues to the general contractor. Most said that the code had impacted them at its adoption, since they had to revise their spec plans to incorporate thicker walls and higher insulation levels. At least one architect did not bother to update the plans, but provided an addendum with the plans describing what options the builder had for meeting the various energy code paths. How the builder carried these modifications out was not made clear to us.

Like the builders, the architects tended to use Path One submittals for the vast majority of their projects. All of the architects and engineers surveyed however did mention that they occasionally used performance path submittals.

More than half of the architects contacted indicated that they had problems detailing the slab edges to incorporate the slab edge insulation required by the code. Other comments suggested that the code should be simplified, and was too strict for temperate regions of the state. One architect suggested that building energy use was insignificant compared to other economic sectors such as transportation.

The sample size of interviews of architects and engineers was small, so it is difficult to draw general conclusions about how architects and engineers deal with the energy code. However, from those contacted, it appears that architects tend to leave energy code issues up to the builders on a project-by-project basis. Furthermore, architects seemed generally uninterested in further training on energy code issues.

5.5 Suppliers and Manufacturers

5.5.1 Windows

Few aspects of the energy code have undergone more revision than window and door performance requirements, and not surprisingly, window manufacturers have some of the strongest opinions about the energy code of any group we spoke with. Window manufacturers generally agreed that repeated changes to window performance requirements had led to widespread confusion among both builders and code officials. This confusion significantly reduced enforcement of and compliance with energy code requirements. It was also suggested that retailers contributed to the problem by stocking windows and skylights which did not meet energy code requirements.

Larger manufacturers pointed out that window manufacturers had spent millions of dollars to convert from aluminum to vinyl frames, as well as for National Fenestration Rating Council (NFRC) testing; therefore they have a vested interest in the code window performance requirements. These manufacturers had some objections to the small manufacturer exemptions, although most large manufacturers indicated that the impact of the exemptions on large window manufacturers was minimal.

NFRC testing requirements elicited mixed responses from window manufacturers, and seemed to be related to the size of the manufacturing operation. NFRC requirements were both lauded and described as too cumbersome, confusing, or time-consuming. Not surprisingly, larger manufacturers tended to feel that NFRC would provide a consistent method by which to rate products.

Most small manufacturers felt that in the absence of window performance requirements, the industry standard would be aluminum frames with single or double clear glazing. One manufacturer did not believe that the code performance requirements were cost-effective. Another manufacturer said that in the absence of a code, home buyers and owners need to understand the benefits of higher window performance, or they will not purchase better windows. Small manufacturers seemed to feel that the code was driving the industry, rather than the other way around, and from their standpoint this may be accurate. However, larger manufacturers pointed out that innovations would continue to dictate window performance improvements.

Window labeling requirements were the subject of much discussion in these interviews. Several manufacturers indicated that window labeling requirements were not enforced consistently. It was pointed out that since "deemed to satisfy" labels provided no accurate performance information, builders and consumers were unable to compare various models. A source close to the "limited production default" labeling process indicated that inconsistent enforcement resulted in abuse of the process. Since limited production default labels were limited to a specific number per manufacturer, manufacturers avoided affixing the labels until or unless code enforcement officials requested them to do so. When requested, a local representative or sales person could affix the labels in the field. Any time labels were not required by a jurisdiction, the manufacturer could increase the number of units produced. Of course, these interviews could not begin to determine whether this was a widespread practice. It was also pointed out that the skylight requirements for aluminum/vinyl frame combinations, intended to encourage thermal break frames, were too vague.

Several manufacturers indicated that energy code performance requirements for windows should be standardized among the various states in the region, especially Washington and Oregon. It was also suggested that better communication between regulatory agencies and manufacturers would be mutually beneficial.

5.5.2 Doors

Several door manufacturers were contacted to discuss energy code and performance issues. Although the NFRC is developing a standardized rating process for doors, there is currently no such standard. This makes regulating door performance a difficult issue. Furthermore, it was pointed out that door manufacturing typically takes place in a multi-vendor environment; that is, large door manufacturers sell door "blanks" to smaller manufacturers who customize them with windows or other features. These can then be incorporated into single or multi-door units, with or without sidelights or other features. Door manufacturers correctly pointed out that this process would make regulating any NFRC rating procedure for doors much more complicated than for windows alone.

6. Building Characteristics

6.1 Building Configuration

Much of the new home construction is Oregon is strikingly similar across the state. It is apparent from floor plans and photographs that a large number of builders use stock house plans, modifying them to suit individual sites or clients, and to provide a somewhat limited amount of neighborhood variety.

This study has provided a fairly comprehensive data set from which to derive a characterization of standard construction practices. The sample is, in effect, a simple random sample of 283 homes, or about 2.1% of all homes permitted in Oregon in 1993. The following sections describe this standard in detail. Discussion of compliance rates of houses and specific components are found in section 4.

The construction valuation of houses in the sample ranged from $47,000 to $277,000. The average of the permit valuations was $98,000. These values do not necessarily reflect the market value of the house.

The heated floor area in the sample ranged from 689 ft^2 to 5, 162 ft^2. The average house size was 1,877 ft^2. This was typically a three bedroom, two bath house. Nearly 80% of the houses in the sample had two-car garages, and 15% of the houses had three car garages. The garages were nearly always attached to the house. In 20% of the homes the garage was insulated, providing a buffer for at least a portion of the house. In five cases the garage was also heated, though this was not indicated on the submitted plans.

Over 83% of the houses in the sample were built in suburban areas. Only 10 houses (3.5% of the sample) were built in what the field reviewers considered urban areas. The remaining 13% of the houses were built in rural areas.

There was no apparent pattern to house orientation in the sample. Houses were much more likely to face in a cardinal direction, and slightly more likely to face north or west than south or east. It is difficult to attach much significance to this pattern. *(Further discussion of housing orientation and impacts can be found in ECOTOPE'S evaluation of Portland area solar access ordinances (Heller et al., 1993))*

6.2 Components/Construction

The houses in the sample were visited at various stages of construction. This distribution allowed the evaluation of a wider variety of issues than would be possible if houses were all at the same stage of construction. Most houses included several different types of walls, windows, and ceilings. For example, a house with a basement would include both above and below grade walls, with different insulation strategies. Sidewalls between attics and vaults would represent yet another wall type. In describing 'standard practice' below, primary construction types are described unless otherwise noted. However, secondary wall types may tend to affect the percentages listed in some cases.

6.2.1 Walls

Walls in Oregon homes were typically constructed of 2x6 studs insulated with high density R-21 batts, as required by the energy code. Fully 93% of the houses in the sample used R-21 walls as the primary wall insulation type. Approximately 7% of the houses also incorporated rigid insulation sheathing (not counting basement walls). Ten houses, or 3.5%, used 2x4 R-15 walls, as allowed under Path 8 which they were submitted under. Several houses were insulated with R-19 in the walls, although this practice was not widespread. The remaining homes included a combination of wall types which averaged out to be insulated with less than R-21. A number of houses which used R-21 as the primary exterior wall insulation used a lower value of insulation between the house and the garage.

Despite the fact that 2x6 construction allows for structural stud spacing of 24" on center, 75% of the houses were framed on 16" centers (this percentage includes the 2x4 walls). None of the houses in the sample used steel studs, or any other wall system except dimensional lumber.

Only 20 homes, or 7% of the sample incorporated advanced framing techniques into the walls. An additional 40 homes were framed on 2 ft. centers, but other advanced framing requirements such as insulated headers could not be verified.

When insulation was visible (houses reviewed before cover) field reviewers recorded any insulation installation quality issues that were apparent. This evaluation was conducted merely to identify potential problem areas. It was not used to modify any energy performance calculations or cite non-compliance with code requirements. The issues cited and the frequency with which they were reported were: short batts (10 homes); compressed insulation (21); utility penetrations left damaged insulation (8); side stapled batts (23), and other problems with wall insulation (6). In order to evaluate the magnitude of these problems, field reviewers were asked to estimate the percentage of the wall area which was underinsulated. In 40% of the homes, this estimate was zero. In ten percent of the homes it was 5% or more. The other 50% of the homes were considered underinsulated in less than 5% of the wall area.

In nearly 4% of the homes, the vapor barrier was missing from one or more walls.

6.2.2 Ceilings

Attics were part of 93% of the homes in the sample. 77% of attics were insulated to R-38. 14% were insulated to R-49. One attic was insulated to R-60. The remaining 9% of the attics fell somewhere in between these values, either because of the combination of batts installed, or because the loose-fill insulation was inadequate. Insulation depth and density was checked in 52% of the homes. Only 11% of these tests indicated that the R-value of the insulation was less than anticipated.

Vaulted ceilings were installed in 71% of the homes visited. 40 houses (14%) had vaults which covered more than half of the heated floor area. Over a third of the vaults were constructed with scissor trusses. Of these, 58% were insulated with R-30 insulation, and 38% with R-38 insulation. Three scissor vaults had installed R-49 insulation, although the impact of the narrow edges of the scissor truss typically reduce thermal performance considerably.

Nearly 70% of the houses used manufactured trusses for the roof structure. 53% of the ceilings were insulated with loose-fill insulation. 31% were insulated with fiberglass batts. 12% used cubed fiberglass, and the remainder were insulated with cellulose.

Only 5% of the houses incorporated advanced framing techniques into the ceilings including full depth truss heels. 12% of the houses included attic access hatches which were uninsulated.

6.2.3 Floors

All but 19 houses in the sample included insulated frame floors. Thirty-two homes (11%) included slabs; of these, 13 homes had both types of floor. Post and beam floors with 2x decking were installed in 42% of the homes. An additional 13.8% of the homes used post and beam floors with plywood decking. Floors were insulated to R-25 or better in 90% of the cases. R-25 was the most common floor insulation type. R-30 was used in 19 floors, and R-38 in 5 floors. Twenty homes used R-21 in the floor, including Path 8 homes, several Performance Path homes, and a few others. A few floors were insulated with R-19.

There were many floor installation quality problems observed in the field. Field inspectors noted that some part of the floor insulation was missing in over 30% of the homes visited. Over 16% of the floors were described by field reviewers as being underinsulated by more than 5% overall. Nearly 15% of the floors were missing vapor barriers at final inspection, including one house which had installed faced batts facing the wrong way. Crawlspace access doors were uninsulated in 20% of the floors. Ground cover sheets in crawlspaces were repeatedly described as damaged or incomplete, and in one case there were several inches of standing water in the crawlspace at final inspection.

Floor inspection timing and other issues were cited as problem areas by builders during interviews (see Section 5).

Slabs were difficult to evaluate, since slab insulation strategies are readily apparent only at the time of the concrete pour. Field inspections occurred well after that time in all cases. Slab insulation specifications were often not in the plans. Field inspectors were able to determine that at least two of the slabs inspected were not insulated, and at least three more were insulated with only R-8 or R-10, rather than the R-15 required by the code.

Fourteen of the slabs were at grade, while 18 were below grade, associated with basements or partial basements.

6.2.4 Below-Grade Walls

Like slabs, insulation strategies for below grade walls were difficult to determine. Only in one case could field inspectors determine that a below grade wall was uninsulated. There were 21 houses which incorporated below grade walls. Nineteen of these were associated with a full or partial basement that was heated. Three of these houses showed no indication of a heated basement on the submittal documents. Ten of the basements called for insulation on the plans.

6.2.5 Windows

Windows and sliding glass doors were evaluated together as window types. Glazed swing doors were evaluated separately. 61% of the houses in the sample incorporated sliding glass doors. Variations in glazing type and spacing, frame type, etc. led to variations in energy performance, and were evaluated as distinct window types. Just over half the sample (56%) used only one window type throughout the house (not including window operation variations). The rest of the sample included two or more distinct window types. One house included 11 different types of window.

Vinyl window frames comprised the vast majority of the window frame types installed in the sample, making up 93% of the total sample. The next most common frame type was wood, at 6%. Aluminum and clad wood window frames made up the balance of window frame types encountered.

Only 30% of the windows had any sort of label indicating their performance or glazing characteristics. Of these "labeled" windows, 61% were AAMA labels, which often give performance information only as a generic "class 40", which does not provide an actual performance level. NFRC labels made up 33% of the labeled windows. Ten window types included labels listing limited production default performance values, including one window type with a "deemed to satisfy" label.

Lack of consistent labeling or other markings forced us to develop a set of assumptions about glazing types, as discussed in Section 3. Table 6.1 shows the percentage of the various glazing strategies that made up the window types encountered in the sample.

TABLE 6.1
Window Glazing Types in Sample

Glazing Type	% of Windows
Double Glazed	5.0
Argon Fill	38.5
Low-ε Coating	17.5
Low-ε Coating with Argon Fill	38.7

The majority of glazing units incorporated at least a 1/2 inch air space. This was the case for over 90% of the window types encountered. Over 80% of the windows included a 3/4" air space. This condition is likely the result of previous testing (subsequently disallowed), which based optimistic performance results on this spacing.

Data regarding window frame material, glazing spacing, coatings and gas fill were compared to Table 53-Q; "Approved Window Default U-values" (see Appendix A) to assign a U-value of the window type. (NFRC labels were used when available). Table 6.2 shows the distribution of U-values for windows encountered in the sample.

TABLE 6.2
U-Value Distribution of Windows in Sample

U-value of Window (Btuh/ft^2°F)	% of Windows
<0.35	0.8
0.35-0.39	37.1
0.40	37.3
0.41-0.45	17.3
0.46-0.50	4.2
>0.50	3.4

6.2.6 Glazed Doors

Glazed doors were installed in 46.3% of the houses in the sample. In many cases these doors replaced what had been indicated as sliding glass doors on the plans. Across the sample, the average installed area of glazed doors was nearly double the area of glazed doors indicated on the plans.

The installed doors included only 12 with labeled performance ratings (8% of all glazed doors installed). Frame/door construction for glazed doors varied significantly from window frame construction: 36% were wood doors, 20% were clad wood, 27% were aluminum with insulation, and 18% were vinyl doors. These doors were also much less likely to incorporate higher performance glazing; approximately 50% of the glazed doors used only clear double glazing units. Low-ε coatings were found on 38% of the glazed doors, but only one third of these included argon fill as well. Argon fill alone was found in 7% of the glazed doors. One house had single glazing in a glazed door.

6.2.7 Doors

For evaluation purposes, doors were divided into two categories; wood panel-type doors and insulated doors. Although there are performance variations within these categories, at the time of this study there was no standard rating system for these doors. The Oregon Energy Code assigns

U-values of 0.54 Btuh/ft^2°F for wood entry type doors and 0.2 Btuh/ft^2°F for insulated doors to these categories.

Table 6.3 shows the distribution of doors within these categories broken down by door location. Discrepancies in the total door percentage are due to the presence at some houses of temporary doors for construction.

TABLE 6.3
DOOR TYPES

Location	Insulated Doors (%)	Solid Wood Doors (%)
Main Entry	64	36
Other	91	9
All Doors	75	22

- Less than 5% of the doors evaluated in this study were labeled with any performance information whatsoever.
- In sixteen houses (6% of the sample) solid wood doors were used for all of the exterior unglazed doors installed.
- Double entry doors were installed in 10 homes.

6.2.8 Skylights

Skylights were installed in 47% of the homes in the sample. The average installed skylight area was 12ft^2, and ranged from 4ft^2 to 48ft^2. Only 8 skylights in the 134 houses that installed them had rating labels of any sort, making any sort of performance categorization difficult.

6.3 Other Construction Characteristics

6.3.1 Heating System Configuration

Heating systems installed in the homes in the sample can be characterized by the type of fuel used, the type of heat delivery system (which was by and large air), and the characteristics of the duct heat delivery system. Each of these items have associated with them particular efficiencies which influence the overall performance of the building.

Heating System Type

88.9% of the sample used forced-air distribution systems as the primary heat distribution. These systems were fired by either electric or gas furnaces or air to air heat pumps. 8.6% of the sample used electric zone heat, usually wall heaters, providing separate thermostats for individual radiant sources in each room. The remaining 2.5% used some other combination of heating system, usually hydronic-based systems sometimes supplemented with solar heating systems. Table 6.4 shows the distribution of heating system types and fuel source in the sample.

TABLE 6.4
Heating System Types and Fuel Source

System Type	Fuel			Total
	Gas	Electric	Other	
Ducted Furnace	200	38	0	238
Hydronic	2	2	1	5
Heat Pump	0	10	0	10
Wall Heaters	0	24	0	24
Other	0	0	1	1
Total	202	74	2	278

Heating Fuel

72% of the homes in the sample were heated with gas-fired furnaces. 25.2% of the sample was heated with electric-fired furnaces, electric base boards or heat pumps. At least 30% of the electrically heated homes were located in neighborhoods where gas was available nearby.

The efficiency of these furnaces is controlled, by and large, by section 5305(c) describing minimum efficiency requirements for forced-air furnaces and heat pumps. The overall code efficiency requirements for gas furnaces was an AFUE rating of 78%. The average furnace efficiency in this sample was 80.7%. None of the furnaces reviewed failed to meet the code minimum AFUE rating. The efficiency requirements for heat pumps is HSPF of 6.8, this translates as a COP of 2.0. The average heat pump efficiency for the eight heat pumps in the sample was a COP of 2.10 and an HSPF of 7.16. None of the heat pumps failed to meet efficiency requirements. The remaining furnaces and electric resistance heaters have furnace operating efficiencies of 1.0.

It should be noted that many of these electric furnaces will probably be installed with heat pumps later on in the process. Since our review occurred well before occupancy and probably before sale of the home, and since heat pumps are typically and option selected by the owner, presumably a portion of the homes which were said to have electric furnaces will, in fact, receive a heat pump. Other studies have shown a 10-15% heat pump saturation in Pacific Northwest homes. Given this, we would expect up to 70% of the electric furnaces noted in this study to eventually be fitted with a heat pump by the ultimate owners. (In this case up to 27 of the 38 electric furnaces might be expected to be refitted with heat pumps.)

Heating Duct Systems

Furnace efficiency, of course, does not explain all of the efficiency associated with the heating system. The duct systems must also be taken into account. Work done in the recent past has shown duct efficiencies to range from about 95% delivery efficiency, in homes with all the ducts located inside the heated shell of the house, to 55% efficiency to ducts that are relatively leaky and located in unheated areas of the house. In this sample, duct location was collected by the field technicians as summarized in Table 7.2.

As can be seen, 74% of the sample had nearly 100% of their ducting systems outside the heated shell of the house. This generally is the result of furnaces located in a garage area, supply ducts located in the crawlspace and return ducts located in an attic. This results in a minimum impact on the floor plan and the living space, but also results in substantial duct losses. For purposes of this study we have assigned duct losses based on previous work done at ECOTOPE to various duct configurations. These must be taken as approximate since we gathered no additional information on duct leakage and since these assume that the insulation levels on the ducts are consistent with code throughout the duct runs.

As can be seen in Table 6.5, virtually all of the homes have a similar forced-air furnace configuration. The 17% which located a significant percentage of their duct system within the heated envelope have efficiencies ranging from .95 to .75. These represent a relatively small fraction of the total. It should also be pointed out that the impact of duct efficiency on overall furnace efficiency has the effect of reducing the delivery efficiency for gas furnaces from approximately 80% to 57.8% and reducing the efficiency of electric furnaces from 100% to 72.4%. Furthermore, in the case of heat pumps, COPs are reduced from approximately 2.1 to approximately 1.5 as a result of adjustments for duct efficiency.

In no case were duct efficiencies taken into account for purposes of assessing compliance with the Oregon Residential Energy Code since the code does not regulate duct location or duct leakage.

6.3.2 Infiltration and Blower Door Results

As part of the scope of work for this review of Oregon building practices, blower door tests were conducted on approximately one in every four buildings tested in the field. This process was intended to produce a reasonably random sample of approximately 60 homes that were new construction in Oregon and provide a picture, albeit somewhat abbreviated, of the air infiltration and air leakage characteristics of new Oregon buildings. The difficulty with this procedure is that when reviewing new construction it is possible, even likely, that buildings are not completely closed in even at the final inspection. Final air sealing and installation on such components as attic hatches, plumbing fixtures, and wood-burning appliances, all lead to somewhat higher leakage estimates using blower doors than might be apparent in a sample of new homes taken after initial occupancy. Nevertheless, the use of blower doors in this context does give a good indication of both the distribution and overall tightness of new construction in Oregon.

Blower Door Method

The blower door tests conducted used a two point blower door protocol developed by ECOTOPE for use in characterizing residential buildings throughout the Pacific Northwest. In this method the blower door pressurizes the building to two pressures, 50 Pascals and 25 Pascals, and approximately three separate measurements are taken at each pressure. From these measurements an estimate of the leakage characteristics are fit and an error estimate is made. The primary goal of this method is to derive and index value that can be used to characterize leakage. This index value has been shown in several works to be well correlated to actual infiltration rates, although the picture of the correlation varies from sample to sample. For this set we have used ACH 50, that is the air change rates when the building is depressurized to -50 Pascals. The relationship to this value and actual infiltration rate is somewhat variable depending on local climate conditions operating at occupancy. However, for purposes of indexing, this value has been divided by 20 to approximate the total infiltration rate. Again, this biases the result somewhat since it assumes a fairly large wind-driven infiltration rate which is not present generally in suburban and urban locations due to local wind shielding factors. We have characterized the building stock using this value, which has become a standard in the region for assessing overall building tightness and infiltration *(see for example, Palmiter/Brown, 1989).*

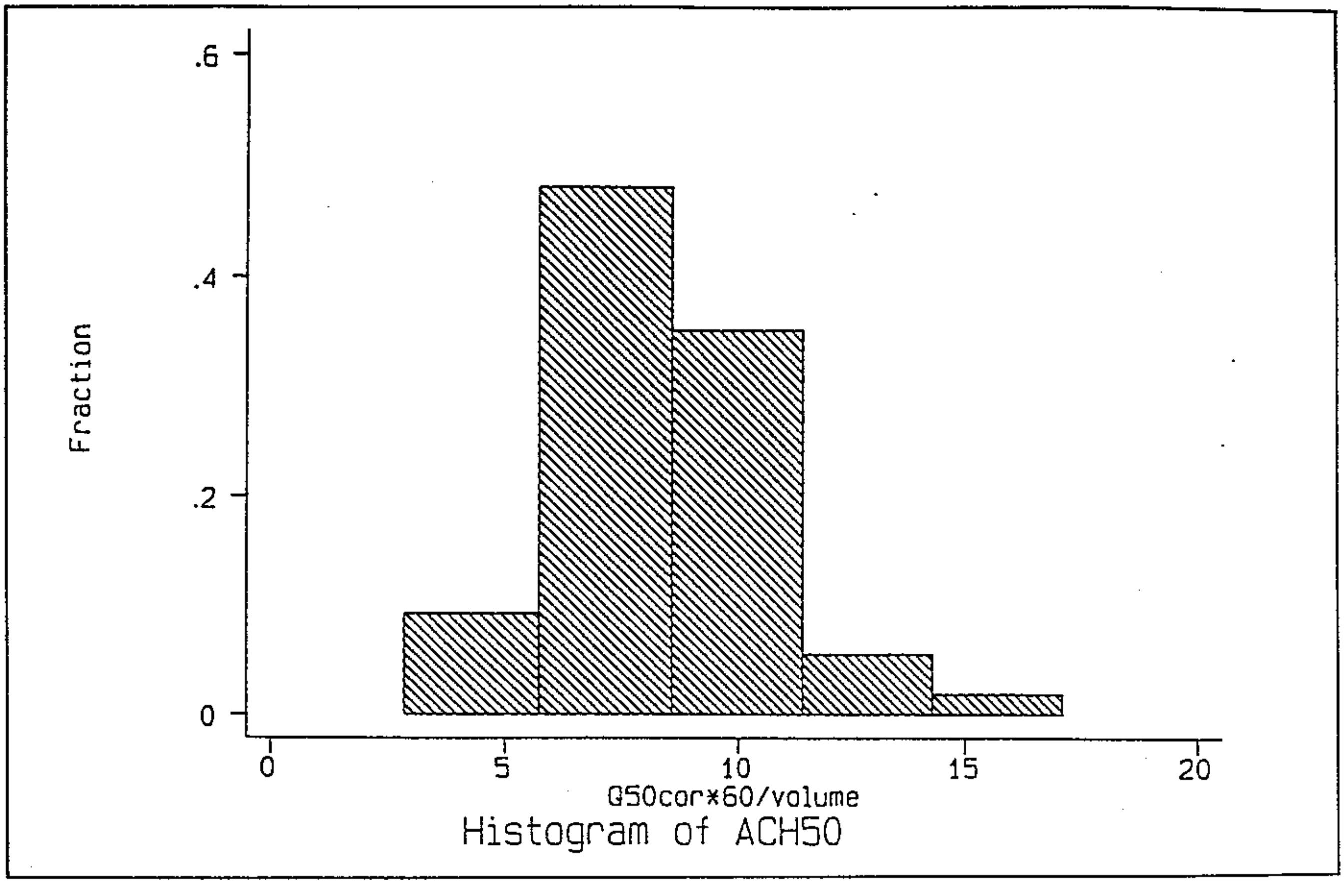
Site Selection

Site selection for the blower door testing was a good deal more ad hoc than was desirable. The field technicians were asked to assess the home when they arrived as to the degree of completion and the appropriateness of the home for blower door testing. Thus, often even when the field technician was arriving on the same day as the final inspection, some significant item in the home was not completed sufficiently to allow a blower door test without substantial modification, and the test was abandoned. Furthermore, because of limitations in time and resources, the number of blower doors available was not sufficient to supply all the field technicians at all times. Certain areas of the state did not receive blower door tests simply because a door was not available when those jurisdictions were reviewed. As a result of this, the sample collected is somewhat ad hoc with respect to the overall distribution of housing in Oregon.

Results

The results of the blower door tests are somewhat surprising given other work done in new construction. Figure 6.1 is a histogram of the ACH 50 for the sample of blower door tests. In order to evaluate this sample, blower door tests with anomalous readings were gleaned from the sample. These are largely due to testing problems with wind or other field factors which made the interpretation of the blower door data problematic. The total number of homes used to complete the evaluation was 54. Approximately 13% of tests were not considered valid. The mean air change rate at 50 Pascals for the sample was 8.6 air changes, and the mean natural air change rate derived from this value is .412 air changes per hour (ACH). Nearly 90% of the blower door tests were conducted in homes with forced air heating systems.

FIGURE 6.1
HISTOGRAM OF ACH50



As can be seen in Figure 6.1, the results are slightly skewed towards the low end. This is typical of distribution of blower door test data. In such a distribution the median is a more valid indicator. The median is the test value where half of the tests are greater and half the test is less. Given a skewed distribution this tends to give a more robust overall estimate of the leakage rate of this sample of homes than the mean.

In this case the median value is 7.76 ACH at 50 and the estimated natural air change rate median is .38 ACH. These values compare to an target value for new construction based on ASHRAE standard 62-89 and the BPA Super Good Cents residential programs of 7.0 ACH 50 and a natural air change rate of approximately .35 ACH. On average, blower door testing in this sample seem to indicate that the assumed infiltration rates are comparable with these assumptions.

In reviewing the distribution in somewhat more detail, 25% of the homes have air change rates below 7.0 air changes, and approximately 15% of the homes have air change rates sufficiently low to warrant concern. (This was approximately 4 to 5 air changes at 50 Pascals.) There are no ventilation criteria in the OREC. It would appear from this data that these systems could remain voluntary. Some builders with tighter homes might be well advised to consider added ventilation systems (such as air-to-air heat exchanger or furnace make-up air dampers), but in the absence of additional air sealing criteria in the code, it would appear that no general changes of this type are warranted.

As observed in other regional samples *(Palmiter, et al, 1991),* homes with ducted heating systems have somewhat larger infiltration rates than homes with zoned or hydronic heating in this sample. For homes with non-ducted heating systems the average blower door result was 7.04 ACH at 50 Pa., while the ducted systems showed an average blower door result of 8.47 ACH at 50 Pa. These results indicate a 20% increase in air leakage merely as a result of the duct system. Because of the small sample size, these results were not incorporated into the performance evaluation of the homes. If the infiltration rates were incorporated, the general result would be an increase of about 5% in the overall heat loss rate of homes with ducted heating systems.

We do not believe these results are particularly conclusive on the subject of ventilation infiltration in new Oregon residences. It does appear, however, that incidental tightness in Oregon buildings is not appreciably affected by the Oregon code and that values for infiltration derived for other regional studies are quite comparable to values shown in this sample *(See Palmiter and Brown, 1989).*

The development of the Oregon Energy Code assumed an overall infiltration rate of 0.5 ACH. This is approximately 30% higher than the assumption used in this analysis. Despite this variation, the analysis applied the same infiltration rate to both the code reference buildings and the homes as built. There was therefore no impact on compliance rates as a result of infiltration rate assumptions. Variations in infiltration rates would have an impact on the estimates of total energy consumption for the sector as a whole. For the sector energy use analysis we used the value of 0.35 ACH, which is the national standard for residential ventilation rates, and is more in line with the blower door test results for the sample than the 0.5 ACH originally used by the code.

Final Note On Blower Door Test Results.

These tests were done largely as an effort to provide an inexpensive review of air tightness and air sealing in new construction. The results of this review are somewhat anomalous, however, they do suggest that the air sealing required in the Oregon code is either fairly ineffective or not enforced. The net result is no particular increase in envelope tightness. Given the general lack of effective ventilation systems in new construction throughout the Pacific Northwest region it is difficult to argue that high infiltration rates are a serious problem.

These results can be compared to other regional studies of infiltration rates. When compared to a small sample of homes built to Super Good Cents standards in 1988, the Oregon sample suggests a 30% increase in natural ventilation rates over the SGC homes. *(Palmiter, Brown, Bond, 1990).* When compared to a region wide sample of homes built between 1980 and 1986, representing region-wide construction practice prior to 1987 *(Palmiter, Brown, 1989),* the Oregon sample represents a 20% decrease in infiltration rates from the previous study.

The protocol used in this test did not identify principal leak sources, although we suspect that the prevalence of forced air furnace systems and perhaps the nature of the crawlspace floor systems present in Oregon buildings contributes to this level of leakage.

6.3.3 Other Characteristics

All of the houses in the sample contained at least one fireplace or other combustion appliance. Nearly 40% of the homes contained one or more gas fireplaces. Over 25% of the homes included one or more wood fireplaces. About 3% of the homes included a wood or pellet stove.

Ventilation Systems

The majority of houses in the sample installed spot ventilation only for ventilation of the house. This was the case for 88.7% of the sample. 5.6% of the sample included no ventilation whatsoever. 2.5% included a whole house ventilation system. Two houses in the sample incorporated a heat recovery ventilation system.

Lighting

Recessed incandescent lights were installed in the building envelope in 90% of the houses in the sample. Homes submitted as Path 1 were likely to have the most recessed lights; Path 8 homes the least. Compact fluorescent lamps were seen in only 10 of the houses.

7 Performance Evaluation

One of the goals of the field research was to assess the energy impacts of current Oregon building practices for single-family residences. The field research was also useful for discovering the impact of non-compliance, if any, on energy consumption. Non-compliance by performance evaluation tends to be an excellent predictor of total energy use; thus, the impact of individual building performance can be represented by the overall UA. To more carefully quantify the energy impacts, SUNDAY runs were done for each building, using heat loss rates derived from the field evaluation and estimates of the infiltration rate.

7.1 Methodology

Four separate SUNDAY runs were conducted for each building. The results of the field evaluation were summarized and heat loss rates were obtained from a direct engineering analysis of the components. This was done as part of the evaluation of the performance path for code compliance. The results were easily transposed into an overall heat loss rate, exclusive of infiltration and ventilation. Four runs were conducted based on different methods of calculating the heat loss rates of individual components.

1. The first SUNDAY run used standard reference values for component heat loss performance based on the OREC (approved U-values for common assemblies) and other regional standards (heat loss reference manual, vols. 1-4). This included wall, ceiling, and floor insulation, and NFRC-based window default values for all windows in the building. This evaluation did not incorporate "deemed to satisfy" window values. This heat loss rate was treated as the "base case", and was used for all comparisons. The "base case" most closely represents the overall performance of the residential building sector according to regionally accepted performance standards. Infiltration and ventilation were assumed to contribute a load of 0.35 air changes per hour (ACH) to this SUNDAY run.

2. The second run used the same component U-values as the first run, but used modified infiltration rate values constructed from the blower door tests of approximately 25% of the sample. Blower door tests aid in establishing the total leakage rate of the building, but do not necessarily reflect the infiltration rate. The general rule used in the case of single-family residences is to divide the air change rate at a reference pressure by a constant. In this case, we used a total flow of 50 Pa of pressure difference across the house, divided by 20. The result of this analysis is presented in Section 6.3.2. The observed impact was an infiltration increase of about 20% greater than the assumed values in the code, or 0.42 ACH. Numerous studies (Palmiter, et al., 1988, and Palmiter and Bond, 1991) have pointed out the biases associated with this kind of correction. These biases involve issues such as wind regime, building height and configuration, and climate, and suggest that this approximation may contain errors. Approximations of this type tend to overestimate the infiltration rate in actual buildings. In the absence of a more detailed study, the approximation was used, and performance implications related to

infiltration rates were not developed. The resources and details available regarding infiltration rates were not sufficient to justify additional performance estimates.

3. The third heat loss rate used the same building component performance information as run #1 (including an infiltration rate of 0.35 ACH), except that for the window U-values were based on the "deemed to satisfy" values from the 1993 interim memos. These values tended to assume a higher performance level (lower U-values) for argon-filled glass 40 windows, and had the effect of improving performance assumption of the sample as a whole.

4. The final SUNDAY run used a heat loss rate developed using more generous U-values which might reasonably be assumed using prescriptive code requirements. These assumptions are discussed in Section 4.2.1, and include "deemed to satisfy" window U-values, no performance penalty for scissor-truss insulation performance, and concrete performance affected by depth characteristics. These defaults tend to reduce the assumed heat loss rate of the buildings and thus reduce the annual energy consumption predicted by SUNDAY.

5. These runs were all compared to a code run derived from the reference U-values in the Oregon Energy Code. These values were applied to the actual component in the home as built, resulting in an estimate of the home's performance that corresponded to the performance expected if the home had been built to code.

7.2 Weather

Standard weather files for SUNDAY and WATTSUN runs were used in the analysis. These weather stations are presented in Table 7.1 (below) with the number of buildings in each weather locality. The long-term TMY based weather files were used exclusively in this run. No corrections were made for particular years or variations in weather conditions. In general, the Portland or Salem sites were used for homes in the Willamette Valley, and account for 70% of the buildings surveyed. Astoria or North Bend were used for coastal locations, and Redmond was used for eastern Oregon.

TABLE 7.1
WEATHER STATIONS

Locality	Number of Sites	%
Astoria	18	6.4
Medford	27	9.5
North Bend	7	2.5
Portland	132	46.6
Redmond	34	12.0
Salem	65	23.0
TOTAL	283	100.0

7.3 Heating and Distribution Systems

The SUNDAY program is a loads model that develops the total load for the building independent of the heating and distribution systems' efficiencies. There were two sets of runs conducted to account for heating system impacts. The loads calculated by SUNDAY were multiplied by the heating system efficiency. The efficiency was usually the AFUE for gas furnaces, the seasonal COP for electric heat pumps, and an efficiency of 1.0 for electric furnaces and baseboards. Distribution system efficiency was more difficult to assess. Much preliminary work has been done to assess this efficiency, and general efficiencies have been derived from Olson, et al., 1993, and Davis, et al., 1994. Both of these studies attempted to assess the efficiency of heating distribution systems by direct measurements.

Table 7.2 (below) shows the impact of various duct configurations, characterized by the number of ducts outside the heated shell. Two duct configuration categories are used: supply and return ducts. As Table 7.3 (below) shows, heating system and plant efficiencies vary with the amount of supply and return duct located outside of the heated area. As can be seen, almost 90% of heating systems in this sample were ducted (usually with gas-fired furnaces). These systems were often located in crawlspaces, attics and garages with virtually all of the ductwork outside the heated building shell. Despite duct insulation, this configuration, when coupled with furnace efficiency, tends to increase the total expected energy use for space heating by a factor of almost 1.8. For systems with heat pumps, furnace system efficiency was positive, and this was the only case of such a finding. The total amount of improved efficiency associated with heat pump efficiency was reduced considerably when the effects of ducted heating systems were taken into account.

TABLE 7.2
DISTRIBUTION SYSTEM EFFICIENCIES (FORCED-AIR SYSTEMS)

% Ducts in Unheated Space		Duct Efficiency	Number of Sites	% of Sample
Supply	**Return**			
0 - 10	0 - 20	.95	4	1.4
10 - 50	0 - 20	.85	6	2.2
50 - 75	0 - 20	.80	2	0.8
75 - 100	0 - 20	.75	8	2.9
0 - 10	20 - 100	.90	4	1.4
10 - 50	20 - 100	.80	4	1.4
50 - 75	20 - 100	.75	15	5.4
75 - 100	20 - 100	.70	206	74.1
TOTAL		.718	249	89.6

TABLE 7.3
HEATING EFFICIENCY BY FUEL TYPE

Heating System	N	%	Average Plant Efficiency	Average System Efficiency
Gas Furnace	209	72.3	80.7	57.8
Electric Zoned	24	8.6	100.0	100.0
Electric Furnace	38	13.7	100.0	72.4
Heat Pump	8	2.9	209.9	152.2
Other	7	2.5	95.0	95.0

For purposes of assessing overall performance, the individual energy estimates were based on the as-built reference U-values calculated with NFRC-based window default tables, 0.35 ACH as the infiltration rate for the entire sector, and heating system efficiency offsets. This performance analysis is divided into electrically-heated systems (including heat pumps), and gas-fired systems (including propane).

The principal source of this impact is not duct leakage but duct *location*. Roughly 75% to 80% of the duct losses discovered during Ecotope's work (see Palmiter and Francisco, 1994; Olson, et al., 1993; and Davis, et al., 1994) were shown to be a function of the duct location.

In gas-heated homes, when taken in combination with the furnace AFUE, 55% to 60% of the energy to be delivered to the home was lost. Duct efficiency in this sample was determined by the location of the hot-air supply systems in crawlspaces. If these systems were relocated to heated spaces, the impact of furnace efficiency on heating system efficiency would decrease dramatically.

7.4 Performance Runs

The SUNDAY energy simulation program was run on each building in the sample, and modifications for system and duct efficiency were made separately and were applied on a house-by-house basis, depending upon the field review assessment. In addition to the base heat loss assumptions, other assumptions had to be made to complete the SUNDAY file; these were based on default assumptions used in the Oregon code's development. These assumptions included: a standard thermostat setpoint of 68° and a value for internal gains (from appliances, lights and occupants) of 3,000 BTUs per hour for each home regardless of size, and a mass assumption based on floor type, slab or frame. Solar effects were based on window orientation as found in the field, and shading coefficients, using standard assumptions for regional models (a base shading coefficient of 0.5 and additional shading coefficients based on window coatings and special glazings). Because actual orientation was used, some variation was introduced into the performance estimates besides that introduced by the heat loss rate of the entire building.

Table 7.4 (below) summarizes the results of the SUNDAY runs of the buildings as built and the code reference runs. The comparison between the code building and the actual building represents an overall improvement on code of about 3% for all the homes built in Oregon. The impact of heating systems on overall building energy use can also be inferred from Table 7.4. The duct system impacts were identical for both the code reference and the as-built runs for each building. Thus, ducting impacts do not affect compliance estimates. Heating plant efficiency is regulated by code and is included in the code reference from the OREC. The as-built runs include the rated efficiency of the furnace or heat pumps. The required H.S.P.F. was used in the reference runs, and the H.S.P.F. of the installed heat pumps was used in the as-built runs. The heat pump was only included if it could be observed during the filed review; so there may be cases in which heat pumps were not included but might be installed by a future occupant. Virtually all of the electric furnaces were designed to accommodate a heat pump, and this group represents 59% of the electrically-heated homes.

TABLE 7.4
ENERGY IMPACTS, ALL BUILDINGS

		All Buildings			**Electric Heat**			**Gas Heat**		
		N	MWH	%	N	MWH	%	N	K Therm	%
Heat Loss Load	Code	283	47.2		74	13.0		201	479	
	Built	283	45.8	-3.0	74	12.3	-5.3	201	470	-1.9
System Loss Load	Code	276	76.7		72	15.2		201	855	
	Built	276	72.4	-5.9	72	14.4	-5.5	201	809	-5.6

The performance by fuel type shows a consistent improvement between the code and the as-built homes. When heating systems are taken into account, the actual home represents an improvement of approximately 6%. The sources of this improvement are almost equally divided between improved furnace efficiency (particularly in gas-heated homes) and improved envelope efficiency (particularly in electrically-heated homes).

A better way to review the impact of code compliance is to study only those buildings that do not comply with the energy code. This method assumes that homes built to exceed the code would not be affected by improved enforcement, and that those homes that failed to meet the code would provide the additional savings associated with improved compliance. In Table 7.5, the sample is divided into two parts: buildings that complied with the code, and those that did not. Non-compliance results in an increased U-value (as compared to that produced by the code requirements). Only in cases where this increase results in an increase in overall heat loss rate (UA) does this non-compliance result in an energy impact. Buildings not meeting only the prescriptive codes only were not included in this summary, since the impact of this non-compliance did not result in a greater heat loss rate than that dictated by code requirements.

TABLE 7.5
ENERGY USE: HEAT LOSS LOAD VS. TOTAL SYSTEM LOAD

		COMPLYING		NON-COMPLYING					
				100% Performance			95% Performance		
		N	MBTU	N	MBTU	%	N	MBTU	%
Heat Loss Load	Code	221	47.0	58	47.9		4	35.2	
	Built	221	45.0	58	49.2	2.7	4	39.1	10.0
Total System Load	Code	218	75.3	58	81.9		4	55.0	
	Built	218	70.0	58	81.5	-0.5	4	60.0	8.3

Table 7.5 presents information on the energy performance impacts of non-complying buildings with and without the incorporation of heating system efficiencies. This can be interpreted as the net heating energy required of the building. The first columns indicate the number of buildings and average annual energy use of as-built compared to code buildings. The first two rows (heat load) show the energy implications based on heat loss rate alone, and the second two rows (system load) incorporate heating system efficiency characteristics (including duct impacts).

The next section of this table (non-complying) is broken down into two categories: 100% Performance and 95% Performance. These percentages refer to the ratio of the code heat loss rate to the as-built heat loss rate for each house. Houses in the 100% category have UA's which exceed the code allowance by 0.2% (to account for rounding errors). These houses represent 20.8% of the buildings surveyed. Houses in the 95% performance category exceed code allowances by at least 5%. These houses represent only 1.5% of the buildings surveyed.

From this table we can see that non-complying houses tend to exceed energy consumption of code houses by 2.7% when building UA alone is considered. However, due to the installation of heating systems which are more efficient than the code requires, these "non-complying" houses actually use less energy, by 0.5%, that the code house would use with code level heating efficiencies.

Houses which miss the UA target total more than 5% (95% Performance) exceeded code energy use by 10% based on UA alone, but only by 8.3% when system efficiency was considered.

7.5 Statewide Sector Impacts, Non-Compliance

In order to apply these results to the entire state, we have assumed that the sample drawn is a simple random sample. Modest oversampling in small jurisdictions was not taken into account, since it had no impact on the conclusions or on the sectors' energy estimates. We have assumed that this sample, drawn from buildings permitted in 1993, represents 14,000 homes. This is an approximation, since the field methods resulted in a sample of buildings permitted in both 1993 and 1994. For purposes of establishing sector-wide impacts, we have assumed that the building activity of 1993 is represented here. When the energy impacts of the code are calculated, the mean consumption represented by this sample is applied to all 14,000 homes. We have further assumed that the weighting schemes used to establish the sample correctly apply to the population as a whole. The sample for eastern Oregon underrepresented that area by about 3%. We attempted to compensate for this weighting, which had almost no impact on the final results, so we have ignored these effects for purposes of obtaining a statewide estimate.

Tables 7.6 and 7.7 show the heating energy impacts of the all residential buildings and of code non-compliance for the state as a whole. These values are based on a projection of the sample drawn for this study to all the homes permitted and built in the state in 1993. These tables have been divided into electricity and gas impacts and include the effects of heating and distribution system.

TABLE 7.6
SYSTEM SOURCE ENERGY IMPACT

FUEL		ALL BUILDINGS		NON-COMPLYING BUILDINGS							
				100% PERFORMANCE				95% PERFORMANCE			
		N	ENERGY	N	ENERGY	%	% OF SAMPLE	N	ENERGY	%	% OF SAMPLE
ELECTRIC (KWH)	CODE	72	15.2	10	15.7		13.9	1	20.1		1.4
	BUILT	72	14.4	10	16.3	3.8		1	22.7	12.9	
GAS (THERMS)	CODE	201	85.5	48	87.8		23.9	3	50.5		1.5
	BUILT	201	80.9	48	87.0	-0.9		3	54.2	7.3	

Table 7.6 shows that electrically heated, non-complying homes exceed code heating energy use by 3.8%, while non-complying gas homes outperform code by 0.9%. This discrepancy is based on the fact that while it is possible for gas heating systems to be more efficient than the code requires, this

is not the case for electric heat, which is always rated with a combustion efficiency of 1.0 (except heat pumps).

TABLE 7.7
SECTOR IMPACTS (ANNUAL PERMITS =14,000)(SPACE HEATING)

	Energy Units	Total Usage (all homes)	Non-Compliance Impact (100% Component Performance)		Non-Compliance Impact (95% Component Performance)	
			Energy	%	Energy	%
Gas	(K Therms)	924	- 2.0	- .2	1.0	0.1
Electric	(MWH)	57961	305	.5	104	0.2
	(Mw$_a$)	6.4	0.03		0.01	

Table 7.7 summarizes the impact of non-compliance by fuel source of homes in this sample. For electric homes, the impact of non-compliance (for the non-complying 14% of homes, relative to the total sample) was approximately three-hundredths of a megawatt, or a total of 305 megawatt hours per year. This represents approximately 5/10 of one percent of all electric energy use for space heating in a year's cohort of Oregon buildings. While it is true that a significant fraction of all electrically heated buildings did not comply, it is apparent that the impact of non-compliance on the overall energy use is minimal. When the effects of utility-based conservation programs and incidental consumer and builder decisions are taken into account, the actual energy use of electrically-heated homes is approximately 6% less than code. This effect is almost entirely the result of improved envelope performance, since the impact of heat pumps was minimal in both the code and proposed buildings.

For gas heated homes the impact is even less significant since the 3% improvement in furnace efficiency over code requirements more than compensates for non-compliance. In homes more than 5% out of compliance with envelope performance requirements, the furnace efficiency improvement does not compensate for the envelope heating energy lost, but the energy impact for this group when projected to the entire population of Oregon homes permitted in 1993 is only 1000 Therms, or about 1/10th of 1% of the total gas usage for this group.

7.5.1 Electric Energy Impacts

For purposes of this analysis, the impact of the Oregon code on specific electrical energy uses is confined to the electrically-heated homes. As seen in table 7.6, twenty-six percent of the homes reviewed in this sample were electrically-heated. Of these homes, a third of them used zone heat (usually wall heaters); 52% of them used electric furnaces with full ducted systems, and 11% of them used heat pumps with fully ducted systems. Heat pumps are often an option in houses, installed only after a buyer has specifically requested one. At the time of our inspections, these buyers were not yet involved; as a result, the number of heat pumps may be underestimated. There is no way of estimating the sample's total number of heat pumps after home occupancy. The impact of the code on total KWH usage was reviewed using the same techniques as were used for the comprehensive systems review. Duct efficiency was assigned to each building based on the duct configuration. Furnace efficiency was assigned as a value of 100% for all electric furnaces and for all baseboard or wall heaters. A heat pump COP was assigned on the basis of rated H.S.P.F. for the product installed. No duct losses were assigned to non-ducted heating systems (electric baseboard or wall heater systems). The level of non-compliance for all these systems together was about 14%. As in the sample as a whole, when a performance criteria of 95% of code target UA was used, the level of non-compliance fell to 1.5% for electrically-heated buildings. This illustrates the relatively limited impact of non-compliance on electric energy use for space heating.

7.5.2 Gas System Impacts

In the case of gas heating systems, the situation is similar although the levels of non-compliance are slightly higher. Twenty-four percent of the gas-heated homes failed to comply with the code. In all cases, this was the result of envelope inefficiencies; in no case was it the result of reduced furnace efficiency. As with electricity, only about 1.5% of all cases failed to meet the code by more than 5% of the anticipated heat loss rate.

When homes that failed to comply were studied separately, the impact of improved furnace efficiency (beyond that required by the code) more than counterbalanced the impact of any envelope deficiency. The sector-wide impact of code non-compliance for gas-heated homes is also summarized in Table 7.7. For all gas-heated homes failing to comply with the code, the amount of energy consumed by the buildings as proposed and reviewed was about 1400 therms *less* than if the homes were built with code-mandated heating systems (an improvement of 2/10 of a percent for this group of buildings). For gas homes as a whole, the improvement between performance under the code and performance as actually built was over 5%. In gas-heated homes, the impact of non-compliance was offset by the impact of furnace performance, since the observed furnace performance was 3.5% better than the code-mandated performance. Only 1.5% of the gas-heated homes reviewed did not meet the code by an excess of 5% of the anticipated heat loss rate (this represented a total of 3 homes in the entire sample). This particular group performed at a sub-code level, and taken separately represented an increase of 1/10 of 1% of the gas used by the entire sector, had this group been in compliance. It is probably an exaggeration to state that this group is significant, given the nature of our sampling and the nature of code compliance in general.

The code as written mandates and regulates envelope efficiency and heating plant efficiency (furnace or heat pump performance). The code does not appreciably regulate the distribution system efficiency. For gas-heated homes, the impact of this feature could be substantial. In general, the heating system efficiency adjustment as applied resulted in a 25% to 30% increase in predicted energy use for the homes. This means that the effect of all code compliance is a very small fraction (less than 1%) of the effect of distribution systems on overall performance. This is true for both gas- and electrically-heated homes, although the impact is not as great in electrically-heated homes due to the prevalence of zone heating. These effects have been included in the overall impacts in Tables 7.6 and 7.7.

8 Conclusions

8.1 Residential Energy Code Compliance

The energy code in Oregon appears to be delivering residential energy efficiency at a rate comparable to the reference values used for designing the code. On a UA basis, it appears that buildings are performing very close to or slightly better than code requirements. Energy savings from components which exceed code requirements generally offset energy use from components which do not comply with code requirements.

The energy code mainly consists of a prescriptive path describing the energy use characteristics of building components. This does not require builders and designers to provide additional details (such as total square footage, window area, etc.). Although there are numerous performance standards for builders to use, the prescriptive method is favored by most Oregon builders, and it is an excellent predictor of heat loss and insulation levels in the state's residential construction sector. However, this does not mean that a high level of energy code compliance is the rule in Oregon. A prescriptive code provides few tradeoffs, and this can result in minor code violations which, strictly defined, are non-compliance. These minor violations may have little or no effect on buildings' energy performance levels.

Prescriptive compliance with envelope requirements only was over 50%. Prescriptive compliance with non-component requirements was also in this range. When the definition of code compliance was changed to the performance equivalent of the reference path, the compliance level rose to 80%; and when the definition is changed to performance within 5% of the reference path, the level of compliance rises to 98.5%. This striking change between prescriptive compliance and performance compliance is reflected in the sector's predicted energy use.

It is important to note that despite the numerous prescriptive and performance options open to builders, Path One is the most commonly used by a substantial margin. Several of the other prescriptive paths have apparently been superseded by changes in window performance and construction practice.

The overall impacts of non-compliance rates are small. The obvious explanation for this finding is that the Oregon building industry has absorbed the principal features of the Oregon code. Common building practice within the state is no longer an issue of code compliance versus competitiveness or affordability for either the builders or the buyers. Even though insulation levels and window specifications do not always appear on the permit plans, and though building departments may not note Path One requirements for permits, actual houses may still have the appropriate insulation levels and window performance. This suggests a good understanding and use of the code as a building and inspection standard in the field.

8.2 Code Provisions and Issues

Despite what might be termed a limited energy impact of non-compliance with energy code requirements, there are still some problematic compliance issues. These problems result from vague code requirements, apparent mis-use or ignorance of code provisions, and lack of communication. Some of the key problem areas include:

- Ongoing changes to window performance rating system have made enforcement somewhat problematic for code officials, builders, and window suppliers. These changes have made compliance determination difficult, and have probably contributed to the lack of performance labeling seen in the field. At the same time, improvements in window technology have significantly improved the performance of "standard construction" windows. These improvements may have eliminated incentives to use prescriptive paths which allow a lower level of window performance. There is evidence that more and more window manufacturers are moving toward NFRC testing and labeling standards, which should simplify enforcement of window provisions.

- By the same token, glazed doors are infrequently labeled in the field, making performance standards difficult to enforce. Imminent testing and labeling standards from NFRC should allow more effective enforcement.

- Opaque doors seem to be an area where inspectors allow ad hoc modifications to compliance requirements. Considering how simple and straightforward compliance requirements for doors are, the rate of non-compliance seemed fairly high.

- Provisions regulating vaulted ceilings are somewhat vague and open to interpretation. Vaulted ceilings over 50% of the heated floor area are required to upgrade insulation levels to R-38. Compliance with this requirement is problematic. Furthermore, the prescriptive code makes no distinction between scissor trusses and rafters, despite the fact that these ceiling types have performance levels which vary by 20%.

- Basement insulation strategies are a source of some confusion, to both builders and building departments. This does not have a significant impact on compliance or overall performance, since relatively few homes in the study have basements. Most of these problems are associated with the expected amount of basement wall performance, and the presence or absence of thermal breaks at the slab edges (in either basements or garages). These provisions are difficult to enforce, and there may be some misunderstanding of them by builders and code officials.

- Another significant issue in the Oregon energy code is the performance path. It is notable that only 30% of the projects submitted under this path complied with code requirements. Meanwhile, over 80% of the projects submitted under the prescriptive path complied with the same level of performance requirements. This path is apparently used not as a legitimate trade-off of performance requirements, but rather as a loop hole in the enforcement process. The fact that most of the performance path submittals contained mistakes merely serves to emphasize this point. In this context more training for code officials would be desirable to improve compliance rates for this compliance path.

- Other issues, such as vapor barriers, low-flow fixtures, and IC rated recessed lighting also demonstrated significant levels of non-compliance. In part, this was apparently related to the timing and priority of inspections, which don't necessarily coincide with energy code requirements.

- Despite relatively high performance based compliance of Oregon homes, problem areas with the prescriptive code requirements suggest that there are improvements to be made in code language and implementation. Problem areas seem related mostly to uncertainties about code provisions, rather than any resistance to code requirements on the part of builders. At least a portion of the compliance problem seems to be related to the ready availability of products which do not meet code provisions from local suppliers.

8.3 Jurisdictions and Geographic Impacts

One noticeable finding of this review is that compliance in the state of Oregon is reasonably uniform throughout the state. No appreciable differences could be determined comparing large and small jurisdictions or by geographic area. We attempted to somewhat over-sample smaller jurisdictions so that we would be able to see if any distinctions might have occurred either geographically or by jurisdiction size and this does not seem to be the case. Furthermore, the comments from building officials and builders operating in these smaller jurisdictions do not seem to differ appreciably from the larger areas supporting the model that in effect this code has been reasonably accepted throughout the state of Oregon.

It should be pointed out that our sample did not include eastern Oregon outside of the Bend-Redmond-Prineville area. However, these areas have relatively few new single family residences permitted and even if they differed dramatically from the remainder of Oregon, it would not change this conclusion. Furthermore, when looking at outlying jurisdictions on the Oregon coast or southwestern Oregon no observable changes were noted in levels of compliance in those areas. This suggests that going to other smaller jurisdictions in eastern Oregon or would probably not reveal appreciable differences in compliance and enforcement procedures.

Despite what we consider to be relatively uniform compliance levels independent of jurisdiction size, there were definitely variations in enforcement strategies in individual jurisdictions. Builders cited specific jurisdictions which were both very strict about energy code enforcement, and in which they felt the code had never been enforced. Some jurisdictions were much more likely than others to enforce certain code requirements during plan review, and others consistently targeted energy code issues during field visits. Some builders and code officials from coastal regions felt that the energy code was either too strict or failed to address construction issues specific to environmental conditions in that region.

The relative conformity of construction characteristics to energy code requirements in the face of varying enforcement strategies, and widely varying opinions as to the merits of the code among the building community, tends to suggest that standard construction practice does, in fact, parallel the code requirements quite closely.

We believe that there may have been some ad hoc changes in the code made by local building officials, in certain jurisdictions, relaxing requirements for certain building components. In general, these provisions were either traded off by a somewhat more rigorous enforcement of other aspects of the code or resulted in such relatively small changes that were balanced by ad hoc improvements in other areas of the building. At this point, we do not believe that these decisions result in any particular increase in energy use in the building. It is however, important to note that these local building officials may find this necessary largely because of confusions or lack of clarity in particular provisions in the prescriptive path.

8.4 Market Transformation and Other Issues

It should be clear from the work presented here, that compliance to the energy code of the state of Oregon, while somewhat low given absolute adherence to the prescriptive standards, has in fact met the performance goals set out when the code was developed. In fact, the use of high-density insulation batts (R-21 in the walls, for example) and the use of vinyl-frame windows (class 40) has become the usual part of Oregon residential building. As a result of these changes, even where non-compliance is a factor, the actual impact of this non-compliance is extremely low and has minimal impact on the overall performance of the house. In fact, only 1.5% of the homes reviewed varied significantly from code heat/loss rates, which suggests that in spite of certain details, the code not only works, but it works well.

8.4.1 Heating and Distribution System

It is useful to note the heating system compliance rates. There was 100% compliance with all heating equipment efficiency provisions of the code, for both heat pumps and furnaces. This seems to be due to a general shift upwards of all manufacturers of this equipment, making it essentially impossible to even purchase furnaces or heat pumps that do not comply with the Oregon code provisions. On the other side, the lack of direct guidance on distribution system, installation and location has a substantial impact on overall performance in Oregon residential buildings. By far the dominant system in Oregon buildings is a ducted furnace, usually gas-heated, which has supply ducts located in crawl space areas and return ducts located in garage or attic areas. This results in a substantial deterioration in the overall performance of these homes. Approximately 25% of the energy used by the home is the result of the duct system itself. This number is substantially higher than any level of non-compliance observed in any home in the sample and is about 100 times larger than the actual impact of non-compliance of the Oregon buildings.

8.4.2 Utility Programs

Approximately 10% of the homes in the sample participated in utility incentive programs. These programs are striking in three respects. The first is that 100% of the buildings using utility incentives complied with the code. About a third of the homes participating in utility programs were participating in gas heating based programs. The remaining two-thirds were participating in electric utility based programs which accounted for about 30% of all electric homes. The second aspect of these homes was that not only did they meet code performance guidelines, they exceeded this performance level by an average of 6%. Since these electric programs largely included heat pumps the overall improvement in performance from utility programs was about 12%. The third aspect of these houses is that approximately one third of the projects described as Super Good Cents homes by the builders apparently failed to meet the requirements of that program by the time they were completed. (These projects were reviewed by an experienced SGC inspector, and found out of compliance with program requirements. Field technicians did not try to determine whether any incentives had been provided by utilities to these projects.) Despite this, the evidence suggests that residential utility programs have a very positive impact both on compliance and on performance in the Oregon building sample and resulted in noticeable improvements in energy performance. We did not review utility standards to determine if this performance was consistent with utility goals.

8.5 Overview

In conclusion, it appears from this review that the Oregon energy code, as practiced in 1993-94 period, meets the basic performance goals of the code as designed. Although a certain level of compliance, particularly prescriptive compliance, could stand noticeable improvement, overall the code has proved simple enough to administer, understand and integrate into building practices in Oregon. Apparently, a very high percentage of Oregon buildings use this code as standard practice and as a result the residential market has been transformed to use more efficient windows, walls and other building components than was previously required. As a whole, it appears that this code serves as a good model to insure compliance to energy code provisions. It illustrates that a simple and enforceable energy code can in fact impact building practices in the residential sector.

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Appendix A

Oregon Residential Energy Code Tables

53-O
53-P
53-Q
53-R

TABLE NO. 53-O
RESIDENTIAL THERMAL PERFORMANCE CALCULATIONS

BUILDING COMPONENTS[1] (Areas from Plan Take-offs in sq. ft.)		U-VALUES					
		Base Path 1		Proposed Alternate			
	Areas[2]	U-Value	Areas x U	R-Value[3]	Areas[2]	U-Value[4]	Areas x U
Flat Ceilings Vaulted Ceilings[8] Opaque Walls Windows (Use A or B)[5]		0.031 0.033 0.060					
A. If glazing area is greater than 13% of heated space floor area:	Take-off Area	0.400		▨	Take-off Area		
B. If glazing area is less than 13% of heated space floor area and trade-off is desired:	13% of floor area	0.400		▨	Take-off Area		
Skylights Main entry door Other exterior doors Underfloor Slab Edge (perimeter ft.=	)	0.500 0.540 0.200 0.032 F=0.520[6]					

CODE UA =

Proposed UA[7] =

FOOTNOTES TO TABLE NO. 53-O

[1] Performance trade-offs are limited to those listed in Column 1. Heat plant efficiency, duct insulation levels, passive and active solar heating, and similar measures may not be considered in this method of calculation.

[2] Areas from plan take-offs. All areas must be the same for both Base Path 1 and proposed alternate, except for window areas allowed in Footnote 5 below. The vaulted ceiling area for Base Path 1 must be the actual area from the plan take-off not to exceed 50 percent of the heated space floor area. Any areas in excess of 5 percent for Base Path 1 must be entered at U-0.031 (R-38), with "flat ceiling" area. The skylight area for Base Path 1 must be the actual area from the plan take-off, not to exceed 2 percent of the heated space floor area. Any areas in excess of 2 percent for Base Path 1 must be entered at U-0.40, with "windows" area. The main entry door area for Base Path 1 must be the actual area from the plan take-off, not to exceed 24 square feet. Any areas in excess of 24 square feet for Base Path 1 must be entered at U-0.20 with "other exterior doors" area.

[3] Minimum component requirements: Walls R-15; floors R-21; flat ceilings R-38; vaults R-21; basement walls R-21; slab edge R-10; duct insulation R-8. R-values used in this table are nominal, for the insulation only and not for the entire assembly. Window and skylight U-values shall not exceed 0.65 (CL65). Door U-values shall not exceed 0.54 (nominal R-2). The wall component for Path 9 shall be a minimum solid log or timber wall thickness of 3.5 inches.

[4] U-values for wood frame ceilings, walls & floor assemblies shall be as listed below. U-values for other assemblies which may include brick or other masonry, stucco, etc., shall be calculated using standard ASHRAE procedures.

[5] Component U-values trade-offs may be made against window area in detached single family dwellings when window area is less than 13 percent of heated space floor area. The base window area in this case shall be set at 13 percent of the heated space floor area.

APPROVED U-VALUES FOR COMMON ASSEMBLIES										
Flat Ceilings		Vaulted Ceilings			Walls		Floors		
							Under floor	Slab Edge	
R-38	0.031	(rafter)	R-21	0.047	R-15	0.080	R-21		0.035
R-49	0.025	(rafter)	R-30	0.033	R-19	0.065	R-25		0.032
R-49A	0.020	(rafter)	R-38	0.027	R-19A	0.061	R-30		0.028
		(truss)	R-30	0.046	R-21	0.060		R-10	F=0.54[6]
		(truss)	R-38	0.042	R-21A	0.055		R-15	F=0.52[6]
					R-24A	0.044			

[6] F = The heat loss coefficient, Btu/hr./ft. /°F.^{2}per foot of perimeter.

[7] Proposed UA must be less than or equal to Code UA.

[8] Vaulted area, unless insulated to R-38, may not exceed 50 percent of the total heated space floor area.

TABLE NO. 53-P
PRESCRIPTIVE COMPLIANCE PATHS FOR RESIDENTIAL BUILDINGS [1,2,3]

Building Components	PATH 1	PATH 2 Sun Tempered[4]	PATH 3	PATH 4 Sun Tempered[4]	PATH 5	PATH 6 Sun Tempered[4]	PATH 7 Sun Tempered[4]	PATH 8 House Size Limited[5]	PATH 9 Log Homes/ Solid Timber
Maximum Allowable Window Area[6]	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	No Limit	12%	No Limit
Window Class[7]	U=0.40	U=0.40	U=0.50	U=0.50	U=0.60	U=0.60	U=0.60	U=0.40	U=0.40
Doors, Other Than Main Entry	U=0.20	U=0.20	U=0.20	U=0.20	U=0.20	U=0.20	U=0.20	U=0.20	U=0.54
Main Entry Door, maximum 24 sq. ft.	U=0.54	U=0.54	U=0.20	U=0.20	U=0.20	U=0.20	U=0.54	U=0.20	U=0.54
Wall Insulation	R-21[9]	R-15	R-21A[8]	R-15A[8]	R-24A[8]	R-21A[8]	R-21A[8]	R-15	—[3]
Underfloor Insulation	R-25	R-21	R-25	R-21	R-30	R-21	R-25	R-21	R-30
Flat Ceilings	R-38	R-49	R-49A[8]	R-38	R-49A[8]	R-49A[8]	R-49A[8]	R-49	R-49
Vaulted Ceilings[10]	R-30[11]	R-30[11]	R-30[11]	R-38	R-38	R-38	R-38	R-38	R-38
Skylight Class[7]	U=0.50	U=0.50	U=0.50	U=0.50	U=0.50	U=0.50	U=0.50	U=0.50	U=0.50
Skylight Area 12	< 2%	< 2%	< 2%	< 2%	< 2%	< 2%	< 2%	< 2%	< 2%
Basement Walls	R-21	R-21	R-21	R-21	R-21	R-21	R-21	R-21	R-21
Slab Floor Edge Insulation	R-15	R-15	R-15	R-15	R-15	R-15	R-15	R-15	R-15
Forced Air Duct Insulation	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8

Notes:

[1] Path 1 is based on cost-effectiveness. Paths 2-7 are based on energy equivalence with Path 1. Cost-effectiveness of Paths 2-9 not evaluated.

[2] As allowed in Section 5303(b), thermal performance of a component may be adjusted provided that overall heat loss does not exceed the total resulting from conformance to the required U-value standards. Calculations to document equivalent heat loss shall be performed using the procedure and approved U-values contained in Table No. 53-O.

[3] MINIMUM COMPONENT REQUIREMENTS: Walls R-15; Floors R-21; Flat Ceilings R-38; Vaults R-21; Basement Walls R-21; Slab Edge R-10; Duct Insulation R-8. R-values used in this table are nominal, for the insulation only and not for the entire assembly. Window and skylight U-values shall not exceed 0.65 (CL65). Door U-values shall not exceed 0.54 (Nominal R-2). The wall component for Path 9 shall be an minimum solid log or timber wall thickness of 3.5 inches.

[4] The sun-tempered house shall have one lot line which borders on a street oriented within 30 degrees of true east-west, and 50 percent or more of the total glazing area for the heated space on the south elevation. An approved alternate to street orientation based on solar design and access shall be accepted by the building official.

[5] Path 8 applies only to homes with less than 1,500 sq. ft. heated floor space AND glazing area less than 12 percent of heated space floor area.

[6] Reduced window area may not be used as a trade-off criterion for thermal performance of any component, except as noted in Table No. 53-O.

[7] Window and skylight U-values shall not exceed the number listed. U-values may also be listed as "class" on some windows and skylights (i.e., CL40 is same as U=0.40).

[8] A= advanced frame construction as defined in Section 5303(c)(3) for walls, and Section 5303(c)(4) for ceilings.

[9] R-19 Advanced Frame or 2 x 4 wall with rigid insulation may be substituted if total nominal insulation R-value is 18.5 or greater.

[10] Partially vaulted ceilings and ceilings totaling not more than 150 square feet in area for dormers, bay windows or similar architectural features may be reduced to not less than R-21. When reduced, the cavity shall be filled (except for required ventilation spaces), and a 0.5 perm (dry cup) vapor retarder installed.

[11] Vaulted area, unless insulated to R-38, may not exceed 50 percent of the total heated space floor area.

[12] The skylight area is a percentage of the heated space floor area. Any glazing in the roof/ceiling assembly above the conditioned space shall be considered a skylight.

TABLE 53-Q
APPROVED WINDOW DEFAULT U-VALUES[1,2]

DESCRIPTION[3,4,5,6,7]	FRAME TYPE[8]		
	ALUM. THERMAL BREAK[9]	WOOD/VINYL	ALUM. CLAD WOOD/ REINFORCED VINYL[10]
Double, Clear 1/4"	N/A	0.56	0.59
Double, Clear 1/4" + argon	0.63	0.53	0.56
Double, Low-*e4* 1/4"	0.61	0.52	0.54
Double, Low-*e2* 1/4"	0.58	0.49	0.51
Double, Low-*e1* 1/4"	0.55	0.47	0.49
Double, Low-*e4* 1/4", + argon	0.55	0.47	0.49
Double, Low-*e2* 1/4", + argon	0.52	0.43	0.46
Double, Low-*e1* 1/4", + argon	0.50	0.41	0.43
Double, Clear 3/8"	0.63	0.54	0.57
Double, Clear 3/8" + argon	0.60	0.51	0.54
Double, Low-*e4* 3/8"	0.57	0.48	0.51
Double, Low-*e2* 3/8"	0.54	0.45	0.48
Double, Low-*e1* 3/8"	0.51	0.43	0.46
Double, Low-*e4* 3/8", + argon	0.53	0.44	0.47
Double, Low-*e2* 3/8", + argon	0.49	0.41	0.44
Double, Low-*e1* 3/8", + argon	0.47	0.39	0.41
Double, Clear 1/2"	0.60	0.50	0.54
Double, Clear 1/2" + argon	0.58	0.48	0.51
Double, Low-*e4* 1/2"	0.53	0.44	0.47
Double, Low-*e2* 1/2"	0.50	0.41	0.44
Double, Low-*e1* 1/2"	0.47	0.39	0.42
Double, Low-*e4* 1/2", + argon	0.50	0.42	0.44
Double, Low-*e2* 1/2", + argon	0.46	0.37	0.40
Double, Low-*e1* 1/2", + argon	0.43	0.35	0.38
Triple, Clear 1/4"	0.52	0.42	0.44
Triple, Clear 1/4" + argon	0.49	0.39	0.42
Triple, Low-*e4* 1/4"	0.50	0.40	0.40
Triple, Low-*e2* 1/4"	0.48	0.39	0.41
Triple, Low-*e1* 1/4"	0.47	0.38	0.40
Triple, Low-*e4* 1/4", + argon	0.46	0.37	0.39
Triple, Low-*e2* 1/4", + argon	0.43	0.34	0.37
Triple, Low-*e1* 1/4", + argon	0.42	0.34	0.36
Triple, Clear 1/2"	0.46	0.37	0.40
Triple, Clear 1/2" + argon	0.45	0.36	0.38
Triple, Low-*e4* 1/2"	0.43	0.35	0.37
Triple, Low-*e2* 1/2"	0.41	0.32	0.35
Triple, Low-*e1* 1/2"	0.39	0.31	0.33
Triple, Low-*e4* 1/2", + argon	0.41	0.32	0.35
Triple, Low-*e2* 1/2", + argon	0.38	0.30	0.32
Triple, Low-*e1* 1/2", + argon	0.37	0.29	0.31

[1] Subtract 0.02 from the listed default U-value for insulated spacers. Insulated spacer material includes fiberglass, wood and butyl or other material with an equivalent K-value.

[2] Solariums may subtract 0.03 from the default U-value.

[3] 1/4" = a minimum dead air space of 0.25 inches between the panes of glass.
3/8" = a minimum dead air space of 0.375 inches between the panes of glass.
1/2" = a minimum dead air space of 0.5 inches between the panes of glass.
Products with air spaces different than those listed above shall use the value for next smaller air space; i.e. 3/4-inch = 1/2-inch U-values, 7/16-inch = 3/8-inch U-values, 5/16-inch = 1/4-inch U-values.

[4] Low-*e4* (emissivity) shall be 0.4 or less.
Low-*e2* (emissivity) shall be 0.2 or less.
Low-*e1* (emissivity) shall be 0.1 or less.

CONTINUED

[5] U-values listed for argon shall consist of sealed, gas-filled, insulated units for argon, CO_2, SF_6, and argon/SF_6 mixtures. The following conversion factor shall apply to Krypton gas-filled units:

1/4-inch or greater airspace with Krypton gas-fill = 1/2-inch airspace with Argon gas-fill

[6] Dividers placed between glazing: The U-values listed shall be used where the divider has a minimum gap of 1/8-inch between the divider and lite of each inside glass surface. Add 0.03 to the listed U-value for True Divided Lite windows.

[7] "Glass block" assemblies may use a U-value of 0.51.

[8] Insulated fiberglass framed products shall use wood/vinyl U-values.

[9] Alum. Thermal Break = An aluminum thermal break framed window shall incorporate the following minimum design characteristics:

a) The thermal conductivity of the thermal break material shall be not more than 3.6 Btu-in/hr/ft²/F°;

b) The thermal break material shall not be less than 0.210 inches; and

c) All metal framing members of the product to interior and exterior air must incorporate a thermal break meeting the criteria in a) and b) above.

[10] Aluminum clad wood windows shall use the U-values listed for Alum. Clad Wood/Reinforced Vinyl windows. Vinyl clad wood windows shall use the U-values listed for Wood/Vinyl windows. Any vinyl frame window with metal reinforcement in more than one rail shall use the U-values listed for Alum. Clad Wood/Reinforced Vinyl windows.

TABLE 53-R
APPROVED GLAZED DOOR DEFAULT U-VALUES[1]

	DOOR MATERIAL			
	INSULATED[6]		WOOD[7]	
DESCRIPTION[2,3,4,5]	Full-Lite[4,8]	Half-Lite[10,11]	Full-Lite[9]	Half-Lite[10]
Double, Clear 1/4"	0.39	0.31	0.47	0.42
Double, Clear 1/4" + argon	0.37	0.30	0.45	0.41
Double, Low-*e4* 1/4"	0.36	0.30	0.44	0.41
Double, Low-*e2* 1/4"	0.35	0.29	0.43	0.40
Double, Low-*e1* 1/4"	0.24	0.28	0.41	0.39
Double, Low-*e4* 1/4" + argon	0.33	0.28	0.41	0.39
Double, Low-*e2* 1/4" + argon	0.31	0.26	0.39	0.38
Double, Low-*e1* 1/4" + argon	0.31	0.26	0.38	0.37
Double, Clear 3/8"	0.37	0.30	0.45	0.41
Double, Clear 3/8" + argon	0.36	0.29	0.44	0.41
Double, Low-*e4* 3/8"	0.34	0.28	0.42	0.40
Double, Low-*e2* 3/8"	0.33	0.28	0.41	0.39
Double, Low-*e1* 3/8"	0.21	0.26	0.38	0.37
Double, Low-*e4* 3/8" + argon	0.32	0.27	0.40	0.38
Double, Low-*e2* 3/8" + argon	0.29	0.25	0.37	0.37
Double, Low-*e1* 3/8" + argon	0.29	0.25	0.36	0.36
Double, Clear 1/2"	0.36	0.29	0.44	0.41
Double, Clear 1/2" + argon	0.34	0.28	0.42	0.40
Double, Low-*e4* 1/2"	0.32	0.27	0.40	0.38
Double, Low-*e2* 1/2"	0.30	0.26	0.38	0.37
Double, Low-*e1* 1/2"	0.19	0.25	0.36	0.36
Double, Low-*e4* 1/2" + argon	0.30	0.26	0.38	0.37
Double, Low-*e2* 1/2" + argon	0.28	0.25	0.36	0.36
Double, Low-*e1* 1/2" + argon	0.28	0.24	0.34	0.35
Triple, Clear 1/4"	0.31	0.26	0.39	0.38
Triple, Clear 1/4" + argon	0.29	0.25	0.37	0.37
Triple, Low-*e4* 1/4"	0.30	0.26	0.38	0.37
Triple, Low-*e2* 1/4"	0.29	0.25	0.37	0.36
Triple, Low-*e4* 1/4" + argon	0.27	0.24	0.35	0.35
Triple, Low-*e2* 1/4" + argon	0.26	0.24	0.34	0.35

[1] Subtract 0.02 from the listed default U-value for insulated spacers. Insulated spacer material includes fiberglass, wood and butyl or other material with an equivalent K-value.

[2] 1/4" = a minimum dead air space of 0.25 inches between the panes of glass.
3/8" = a minimum dead air space of 0.375 inches between the panes of glass.
1/2" = a minimum dead air space of 0.5 inches between the panes of glass.
Products with air spaces different than those listed above shall use the value for next smaller air space; i.e. 3/4-inch = 1/2-inch U-values, 7/16-inch = 3/8-inch U-values, 5/16-inch = 1/4-inch U-values.

[3] Low-*e4* (emissivity) shall be 0.4 or less.
Low-*e2* (emissivity) shall be 0.2 or less.
Low-*e1* (emissivity) shall be 0.1 or less.

[4] U-values listed for argon shall consist of sealed, gas-filled, insulated units for argon, CO_2, SF_6, and argon/SF_6 mixtures. The following conversion factor shall apply to Krypton gas-filled units:
1/4-inch or greater airspace with Krypton gas-fill = 1/2-inch airspace with Argon gas-fill

[5] Dividers placed between glazing: The U-values listed shall be used where the divider has a minimum gap of 1/8-inch between the divider and lite of each inside glass surface. Add 0.03 to the listed U-value for True Divided Lite windows.

CONTINUED

[6] Insulated = Any urethane insulated foam core door with a thermal break. Thermal Break = A thermal break door shall incorporate the following minimum design characteristics:

a) The thermal conductivity of the thermal break material shall be not more than 3.6 Btu-in/hr/ft²/F°; and
b) The thermal break material shall not be less than 0.210 inches.

[7] Wood = Any wood door.

[8] Full Lite = A door that consists of more than 35 percent glazing.

[9] Add 0.05 to the listed U-value for Full-Lite values if the insulated door does not have a thermal break.

[10] Half Lite = A door that consists of 35 percent or less glazing.

[11] Add 0.06 to the listed U-value for Half-Lite values if the insulated door does not have a thermal break.

Appendix B

Housing Sample by Jurisdiction
Blower Door Sample

Oregon Residential Energy Code Compliance Evaluation
Sample Distribution

Rat1 = Permits/Total Permits
Rat2 = Sample/Total Sample
Rat3 = Rat1/Rat2

Jurisdiction #	County	Jurisdiction	Permits ('93)	Sample	Rat1	Rat2	Rat3	Permits(9/93)	Blower Doors
01	Washington	Washington	1735	30	0.1241	0.1060	1.1705	1183	3
02	Clackamas	Clackamas	795	16	0.0569	0.0565	1.0056	646	1
03	Multnomah	Portland	829	17	0.0593	0.0601	0.9869	633	6
04	Deschutes	Deschutes	558	12	0.0399	0.0424	0.9411	445	3
05	Marion	Marion	539	11	0.0385	0.0389	0.9917	442	1
06	Marion	Salem	598	11	0.0428	0.0389	1.1003	424	2
07	Washington	Tigard	451	13	0.0323	0.0459	0.7021	360	4
08	Deschutes	Bend	464	10	0.0332	0.0353	0.9391	349	5
09	Jackson	Medford	600	9	0.0429	0.0318	1.3493	347	3
10	Lane	Eugene	538	9	0.0385	0.0318	1.2098	344	2
11	Washington	Beaverton	412	10	0.0295	0.0353	0.8338	343	
12	Jackson	Jackson	313	6	0.0224	0.0212	1.0558	241	3
13	Multnomah	Gresham	318	6	0.0227	0.0212	1.0727	235	
14	Washington	Hillsboro	392	5	0.0280	0.0177	1.5867	207	
15	Deschutes	Redmond	254	4	0.0182	0.0141	1.2852	181	2
16	Lane	Springfield	323	4	0.0231	0.0141	1.6343	179	1
17	Lincoln	Lincoln	173	4	0.0124	0.0141	0.8753	170	
19	Josephine	Josephine	225	4	0.0161	0.0141	1.1384	164	2
20	Lane	Lane Co.	238	4	0.0170	0.0141	1.2042	161	2
21	Clackamas	Lake Oswego	236	4	0.0169	0.0141	1.1941	160	
22	Clackamas	West Linn	206	5	0.0147	0.0177	0.8338	157	3
23	Washington	Tualatin	213	4	0.0152	0.0141	1.0777	149	
24	Multnomah	Troutdale	193	4	0.0138	0.0141	0.9765	143	4
25	Washington	Sherwood	164	3	0.0117	0.0106	1.1064	135	
26	Linn	Albany	182	3	0.0130	0.0106	1.2278	130	
27	Jackson	Central Point	135	3	0.0097	0.0106	0.9107	120	1
28	Clackamas	Wilsonville	145	3	0.0104	0.0106	0.9782	117	1
29	Yamhill	Mcminnville	154	3	0.0110	0.0106	1.0389	115	
30	Benton	Corvallis	150	3	0.0107	0.0106	1.0119	105	
31	Columbia	Columbia Co.	137	3	0.0098	0.0106	0.9242	105	
32	Benton	Benton Co	133	2	0.0095	0.0071	1.3459	99	
33	Clackamas	Oregon City	168	2	0.0120	0.0071	1.7001	97	
34	Yamhill	Yamhill Co.	123	2	0.0088	0.0071	1.2447	96	
35	Yamhill	Newberg	135	2	0.0097	0.0071	1.3661	90	
36	Josephine	Grants Pass	106	2	0.0076	0.0071	1.0727	87	
37	Curry	Curry Co.	89	2	0.0064	0.0071	0.9006	80	
39	Linn	Linn Co.	99	2	0.0071	0.0071	1.0018	76	
40	Crook	Crook Co.	94	5	0.0067	0.0177	0.3805	74	3
41	Clackamas	Happy Valley	91	2	0.0065	0.0071	0.9209	64	
42	Jackson	Ashland	70	1	0.0050	0.0035	1.4167	55	
43	Yamhill	Dundee	68	1	0.0049	0.0035	1.3762	54	
44	Jefferson	Jefferson Co.	90	3	0.0064	0.0106	0.6072	50	1
45	Lane	Florence	63	2	0.0045	0.0071	0.6375	50	
46	Clackamas	Milwaukie	56	1	0.0040	0.0035	1.1334	46	
47	Clatsop	BCD (Clatsop Co.;	45	4	0.0032	0.0141	0.2277	41	1
48	Washington	Cornelius	57	1	0.0041	0.0035	1.1536	46	1
49	Lincoln	Lincoln City	79	1	0.0056	0.0035	1.5989	45	1
50	Linn	Lebanon	58	1	0.0041	0.0035	1.1739	44	1
51	Douglas	Douglass Co.	200	1	0.0143	0.0035	4.0478	43	
53	Douglas	Roseburg	52	1	0.0037	0.0035	1.0524	41	1
54	Clatsop	Seaside	37	3	0.0026	0.0106	0.2496	36	1
55	Tillamook	Tillamook Co.	37	3	0.0026	0.0106	0.2496	30	1
56	Curry	Brookings	37	1	0.0026	0.0035	0.7488	29	
57	Polk	Dallas	43	3	0.0031	0.0106	0.2901	29	
58	Washington	King City	33	1	0.0024	0.0035	0.6679	29	1
59	Clatsop	Warrenton	32	3	0.0023	0.0106	0.2159	27	
60	Lincoln	Newport	33	1	0.0024	0.0035	0.6679	27	
61	Washington	Forest Grove	33	1	0.0024	0.0035	0.6679	27	
62	Tillamook	Manzanita	34	1	0.0024	0.0035	0.6881	25	
63	Clackamas	Sandy	38	1	0.0027	0.0035	0.7691	24	
64	Clatsop	Cannon Beach	27	2	0.0019	0.0071	0.2732	24	
65	Polk	Polk Co.	53	2	0.0038	0.0071	0.5363	20	
		Totals	**13983**	**283**				**10095**	**61**

Appendix C

Field Protocol

Appendix C: Field Protocol

A primary goal of the organization of the field protocol was to ensure that the field personnel would be able to quickly recognize the information requirements, and to collect that information expeditiously and consistently. To simplify the organization of the form, a right and left column convention was adopted and adhered to throughout the form. To simplify this information, responses to questions about the plans were always entered on the left side of the form, and field verification questions were always entered on the right side of the form. This also simplified evaluation of the data, since variations between the plans and the field conditions could be quickly recognized. Presenting the data in columns made it easy for field personnel to glance quickly through the form and identify unanswered questions. This reduced the need to answer the questions in any particular order, improving field efficiency.

The form was organized in several sections. First the project was characterized as to jurisdiction, project type, and house configuration. This information allowed us to characterize the projects by cost, style, jurisdiction, etc. In this section, the field reviewer was also directed to sketch the floor plan and photograph the house. The next section indicated the compliance path used by the project, and identified the extent and type of documentation submitted to demonstrate code compliance. Based on information gathered in this section, the field reviewer determined whether energy code compliance could be determined from the information submitted.

The "enforcement" section of the field protocol was geared toward the type of enforcement applied to this project. The questions in this section were necessarily fairly open, since the type of enforcement encountered can vary widely. Enforcement information from field inspections was also characterized here.

The next section of the form consisted of project component area takeoffs. These takeoffs were oriented to allow us to develop compliance and performance characterizations of the project. First the field reviewer determined the number and types of various building components present. For each of these components, a one page description form was filled out which described in detail the construction of each component, such as wall, floor, or ceiling. For windows, a more extensive characterization was required. In addition to the performance information about each window type, each individual window was listed by size and orientation, so that changes of area, configuration, or performance could be verified in the field. Doors were also given a more specific treatment with regard to performance and construction.

The field protocol specifically required field verification of all of the information generated in the takeoffs section. In many cases, this was not possible, since the field inspection occurred when the building was nearly complete and many components were no longer visible. In these cases, we generally assumed that the component was installed as documented, unless evidence to the contrary was observed.

For houses which were completed, the field teams were instructed to conduct a blower door test to evaluate air infiltration rates for the project. This information was used to assess the impact of air infiltration on the overall performance of Oregon homes.

The final section of the protocol directed the field reviewer through a list of specific characterizations of the project. These questions were based on specific code requirements and construction characteristics. This section included questions designed to characterize mechanical and ventilation systems installed in the house. There were also questions about the quality of insulation installation, and other insulation problems. Like other sections of the protocol, many of these questions were set up to compare plan information to field conditions.

Oregon Residential Energy Code Evaluation

Instructions for Field Protocol Form

General instructions for filling out the inspection protocol form:

Building Identification Number The building identification number should be completed as follows: The building identification number will be a five digit number; the first two digits will be the jurisdiction code number; the third digit will be the field team code number, and the fourth and fifth digits will be the house sequence number within that jurisdiction. For example;

Jurisdiction	02
Field Team number	3
House number within jurisdiction	14

Would have a building identification: 02314
(Be sure to include zeros where appropriate)

All of the blanks on this form should be filled out, checked, circled, or otherwise responded to in some way. If the necessary, fill in additional answers or question marks, etc. **All questions with check-boxes in the far left or right margins should be answered.** A small number of the questions are dependent on the answers to previous questions, and may not be applicable to all projects. These questions are typically indented from the left or right margin, below the question on which they depend.

The left hand column, and indented columns on the left contain blanks and boxes which should be filled out when the plan review is conducted. On the right are corresponding blanks to be filled out during the field visit. Most questions require a response during the plan review and a verification during the field visit.

The project identification number should be included at the bottom of each page of the protocol form.

The heated floor area calculation should include all floor areas within the heated envelope. Basements which are not heated but are not insulated from the heated space should be counted as heated space, but should be described more specifically in the HVAC section.

When completed, each field protocol should contain the following pieces:

- ☐ Inspection Protocol Form
- ☐ Sketch of Project Floor Plan
- ☐ Photographs of Site
- ☐ Window List - blue form
- ☐ Component Description Sheets for **each** component type
  - ☐ Walls - tan forms
  - ☐ Floors - green forms
  - ☐ Ceilings - yellow forms
  - ☐ Glazing - purple forms
  - ☐ Doors - orange forms

Depending on project characteristics, the package may also include the following:

- ☐ Blower Door Protocol Form
- ☐ Performance Path Summary Sheet
- ☐ Other forms or information collected

____

____

Project Identification

[ ] Jurisdiction Name: ______________________________
__________ Jurisdiction Code

__________ House number in this jurisdiction

[ ] Field Inspector Name: ______________________________
__________ Field Inspector Code

[ ] Project Address:

__________ City
__________ County

____/____/____ Permit Date

[ ] Permit #: ____________________

[ ] Building Valuation (if available): $____________

____/____/____ Document Review Date Field Review Date ____/____/____

[ ] Contractor Name: ______________________________
Phone Number: ______________________________

[y] [n] Plan set is stamped by a registered architect
If so, Name: ______________________________
Phone Number: ______________________________

Indicate the stage of construction of the house at the time of the field visit, and the status of the building department inspections. [ ]

Insulation not covered [ ]
Insulation covered, but house not yet sealed [ ]
Final Inspection, house fully sealed [ ]

Describe if necessary:
____
____

[ ] Sketch the floor plan of the house, or obtain a copy of the floor plan. Include a plan for each floor and the basement, if any. Be sure that each room is individually labeled for reference with window locations. [ ]

[ ] Number of stories above grade: ________
(For split level, describe below)

In the space below, describe the general configuration of the house (# of stories, style, spec. home or custom, unusual site conditions, etc.) [ ]

____

____

____

[ ] Rooms: # of bathrooms:______ # of bedrooms:______

Describe a notable feature of the house for future reference (Do no use generic descriptions) [ ]

____

Attached Garage; for ______ cars. [ ]

Garage insulated [y] [n] [?]
Garage heated [y] [n] [?]

Floor plan matches permit drawings [y] [n]

Describe any changes to floor plan encountered in field. [ ]

____

____

____

Indicate direction main entry faces (**n, ne, e, se, s, sw, w, nw**): ______ [ ]

Describe neighborhood density (circle) [ ]

urban suburban rural

Field review includes blower door test [y] [n]
If yes, be sure to include blower door protocol form

Describe each photograph taken of the project in the space below Be sure to include a photo of the exterior of the home and its surroundings. Include photos showing insulation or other construction problems, or perfect installations, if you find them. [ ]

Photo #	Description
______	______________________________
______	______________________________
______	______________________________
______	______________________________

Is gas available in this area? (In the field, check for nearby meters, pipeline markers, etc) **[y] [n] [?]**

Name of Electric utility ______________________________ [ ]
Name of Gas utility ______________________________ [ ]

[y] [n] Is there any indication of participation in Super Good Cents or other utility sponsored conservation programs? **[y] [n]**

[ ] Super Good Cents [ ]
[ ] Natural Choice [ ]
[ ] Other ______________________________ [ ]

Compliance Information in Documentation

☐ Check the Compliance Path Indicated on Plans

- ☐ **Prescriptive** Path (circle a path # below)
  1 2 3 4 5 6 7 8 9
- ☐ **Performance** Path
- ☐ **None** indicated

For all **prescriptive paths,** compliance path was indicated on plans by:

- ☐ **Builder**
- ☐ **Plans Examiner**

For **prescriptive path 2, 4, 6**, or **7**; (sun tempered) complete the following:

[y] [n] At least 50% of glazing area faces south [y] [n]
[y] [n] One lot line abuts street within 30° of east/west [y] [n]
Check below the amount of shading from nearby homes, trees, etc. to the south ☐
completely shaded ☐
mostly shaded ☐
partly shaded ☐
no shading ☐

For **prescriptive path 8**; (limited floor area/low income) complete the following:

[y] [n] Glazing area less than 12% of Heated Floor Area [y] [n]
[y] [n] Total Heated Floor Area is less than 1500 sq. ft. [y] [n]

☐ If the project was submitted as **performance path** compliance, or if other **component trade-offs** are used to demonstrate compliance; complete a **performance path summary sheet** and include it with this form. Do not use the performance path summary form for 'window averaging' unless window performance is traded for other house components.

For **all** projects, complete the following:

[y] [n] [?] Did the contractor submit calculations to show that the average U-value of the windows meets code window U-value requirements, rather than each individual window meeting the requirements?

[ ] Review the energy code compliance information presented on the plans and check all boxes below that apply. This question refers to the plans *as submitted*; energy code compliance notes made by the plan reviewer should be described elsewhere.

- [ ] Plans contain **no reference** to energy code compliance path
- [ ] **Compliance path** is indicated on the plans
- [ ] A **generic** energy code table which is not project specific is included on the plans (or **generic** notes or details describing compliance requirements)
- [ ] **Project-specific** notes or tables are included on the plans which specifically describe energy code compliance for this project.
- [ ] Energy code compliance information is provided on an 'official' **compliance form.**
- [ ] Information about project specific insulation levels is provided only in details/sections, not in table form.
- [ ] If the above descriptions do not accurately portray the way energy code compliance info is presented, describe here: ____________________

  ____

  ____

[y] [n] Does the information about insulation levels, etc. listed in compliance forms, tables, or standardized details above match the other details or descriptions in the plans? Describe any inconsistencies below:

____

____

[ ] Compliance information on drawings was apparently developed by:

- [ ] Builder (check here if no other is indicated)
- [ ] Architect
- [ ] Engineer
- [ ] Utility Consultant
- [ ] Plans Examiner
- [ ] Other: ____________________

For All Projects, answer the following:

Verify that insulation R- or U-values are specifically indicated in the plan set for each of the following components.

If the information is not on the plans; circle NO.

If the information is provided **only** in a **generic** code table; circle **no**.

If the information for the component is provided **only** by the **plan reviewer;** circle no, check the enforcement column, and describe the requirements.

Indicated on plans	Component	Enforcement	Requirements
[y] [n]	Walls	[ ]	____________
[y] [n] [n/a]	Floors	[ ]	____________
[y] [n]	Ceilings	[ ]	____________
[y] [n] [n/a]	Basement Walls	[ ]	____________
[y] [n] [n/a]	Slab Edge	[ ]	____________
[y] [n]	Entry Door	[ ]	____________
[y] [n] [n/a]	Other Doors	[ ]	____________
[y] [n]	Windows	[ ]	____________
[y] [n] [n/a]	Duct Insulation	[ ]	____________

Based on the answers to the questions above, did the plans **as submitted** include enough information to determine whether the project meets energy code requirements? (Not including information provided by plans examiner)

[y] [n]

If **no**, describe:

____

____

Code Enforcement Notes

Review the permit file for any indication of corrections required for energy code compliance, or other notes on energy code enforcement. Describe below any notes or other information in the file regarding energy code enforcement. Specific requirements which are identified as corrections required should be listed.

[ ] General notes on energy code enforcement:

[ ] List specific energy code notes/corrections indicated for this project by the code officials during the **plan review**. Look for these corrections in the field. [ ]

List specific energy code notes/corrections indicated for this project by the code officials during **field inspections**. (Review the inspection card if available) Look for these corrections in the field. [ ]

Did the corrections specifically require additional inspections? **[y] [n] [?]**

If yes, describe:

[y] [n] [?] Did the jurisdiction provide or require standard energy code compliance forms? If yes, describe:

Plan Take-offs

In this section, the component area take-offs and descriptions should be completed. Fill out the tables below for each component type. Each component area should be indicated, and a component description form should be filled out for each. Double check that all component types are accounted for before moving to the next section. In the first column, list the number of components of each type which are indicated on the plan set.

For opaque components (walls, floors, ceilings) the areas indicated should be gross areas; the areas of any windows, doors, or skylights occurring in that component should be **included** in the gross area.

Windows, doors, and skylights should be thoroughly described in the appropriate section.

All information should be verified during the field visit. If variations are discovered in the field, **make a note of new values and any construction changes,** on the component description forms. **Be sure to verify field areas below.**

__________ Floor Area listed on plans (if available)

__________ **Heated Floor Area (HFA) ft^2**
Do not use area listed on plans; calculate for each house. If there is a basement, be sure to determine if it is part of the *heated* space, or just a buffer space. Verify this information in the field.

Verify Heated Floor Area in field: __________

__________ **House Volume ft^3** [ ]

Verify House Volume in field: __________

WALLS

________ **Number of Wall Types**
Include walls with different insulation types, basement walls, vault walls, walls between heated space and attics/garages, etc. as distinct types. Calculate gross wall areas, then account for windows in the window section. Fill out a wall component form **(tan)** for each wall type.

Type #	Description/location (for cross-reference with component sheets)	Plan Area (gross)	Field Area (gross)

FLOORS

________ **Number of Floor Types**

Frame floors should be separated from slab floors. Slab floor area should be calculated as a perimeter. Separate slab on grade from below grade slabs. Fill out floor component form **(green)** for each floor type.

For **slabs**, indicate **perimeter** instead of area.

Type #	Description/location (for cross reference with component sheets)	Plan Area (slab perim.)	Field Area (slab perim.)

CEILINGS

________ **Number of Ceiling Types**

Separate vaulted ceiling area from attic areas. For vaults, calculate area of vault, not floor area it covers. Be sure to calculate vaulted ceilings at dormers, bay windows, etc. Separate areas with different insulation strategies. Calculate gross areas, then indicate skylights in the appropriate section. Fill out a ceiling component form **(yellow)** for each ceiling type.

Type #	Description/location (for cross reference with component sheets)	Plan Area (gross)	Field Area (gross)

[ ] For vaulted ceilings at dormers, bay windows, or elsewhere, try to determine the structural depth and insulation levels specified for those areas. If there is indication on plans or in field that part of the ceiling will be insulated to only R-21 or less; [ ]

Indicate the area of R-21 vaulted ceiling: __________

WINDOWS

In addition to the information below, window take offs for each project should include the following:

- A completed window list identifying type and location of each window in the house (blue form)
- A completed glazing type form for each window type (purple form)

__________ Total number of window types in this project. List these types in the table below.

Each of the following should be counted as a separate window type:

Windows of different frame material
Custom 'stopped-in' glazing
Sliding glass doors
Single glazing **with** low-ε and storm windows
(Do not count 'ornamental' or other single glazing here)

- Glazed 'swing' doors should be described in the door types section.
- If some windows have low-ε coatings and others do not, count these as two separate window types.
- If a new window type is encountered in the field, fill out a new glazing type form.
- Skylights should be counted in the skylight section.

[ ]	**Type #**	Description
	____	____________________
	____	____________________
	____	____________________
	____	____________________
	____	____________________
	____	____________________
	____	____________________

[ ] For each type listed above, fill out a glazing type description form **(purple)**.

[y] [n] Do plans include 'ornamental' single glazing? Single glazing in field **[y] [n] [?]**

______ Area of single glazing (single glazing in doors should be counted on door worksheet) ______

Identify location of single glazing for field verification: [ ]

____

DOORS

In addition to the information below, door take offs for each project should include the following:

- A completed door type form for each opaque door type (orange form)
- A completed glazing type form for each glazed door type, as defined below (purple form)

__________ Total number of exterior door types in this project

Each of the following should be counted as a separate door type:

Main entry doors

Each different type of entry door between heated and unheated space

Doors which have more than 2.5 sq. ft. of glazing area
(sliding glass doors should be counted as windows)
Do not mix full and half glazed doors in one door type

[ ] For each opaque door type fill out a door type description sheet (**orange**).
For glazed 'swing' doors, fill out a glazing type description (**purple**)

[y] [n] Entry door includes 'ornamental' single glazing on plans — Single glazing present in field [y] [n] [?]

______ Area of single glazing on plans — in field: ______

[y] [n] Double entry door is indicated on plans — Double entry door installed in field [y] [n]

Indicate total door area by type in the table below. Verify this information in the field.

OPAQUE DOORS

Door	**Wall**	**Plans**		**Field**	
Description (Wood, metal, insulated, etc.)	**Type**	**Dr. type #**	**Area**	**Dr. type #**	**Area**

GLAZED 'SWING' DOORS

sketch	**Glazed Doors**		**Wall**	**Plans**		**Field**	
#	**Description**	**Dir.**	**Type**	**Gl. Type#**	**Area**	**Gl Type #**	**Area**

Skylights

[y] [n] Plans include **skylights**

Skylights present in field [y] [n] [?]

For each skylight type, fill out a glazing description form **(purple)**.

The following should be listed as separate skylight types

- Each different type of skylight construction
- Any skylight with an 'exempt' or 'deemed to satisfy' label

Also fill out the table below for skylights

Sketch #	**Location**	**In roof type**	**Glazing type #**	**Plan area**	**Field Area**

Envelope

After developing envelope takeoffs, answer the questions below:

Ceilings

[y] [n] Advanced Framing is indicated/installed in the ceiling (If **yes**, answer the following) [y] [n] [?]

______	Rafter spacing	________
______	Rafter depth at walls	________
[y] [n]	Ceiling fully insulated at perimeter (above exterior walls)	[y] [n] [?]
	Describe (full depth heels, use of rigid insul, etc.): ________________________________	

[y] [n] Loose fill insulation is indicated/installed in the ceiling (If **yes**, answer the following) [y] [n] [?]

[y] [n]	Roof slope is 4:12 or steeper	[y] [n] [?]
[y] [n] [?]	Headroom at ridge is at least 44"	[y] [n] [?]
[y] [n] [?]	Baffles are indicated/installed	[y] [n] [?]
______	Depth of insulation specified	

Check all structural systems installed in roof [ ]

dimensional lumber	[ ]
manufactured trusses-dimensional lumber	[ ]
manufactured trusses-manufactured lumber	[ ]
steel members	[ ]
stress-skin panels	[ ]
other ________________________	[ ]

Walls

[y] [n] Advanced Framing is indicated in the walls (For plan takeoffs, answer the following only if advanced framing is indicated; in the field, answer these questions in either case.)

[y] [n]	Stud spacing 2 ft.	[y] [n] [?]
[y] [n]	Headers insulated	[y] [n] [?]
[y] [n]	Corners insulated	[y] [n] [?]

[y] [n] Insulation on outside of partition wall intersections [y] [n] [?]

Check all wall structural systems installed [ ]

dimensional lumber [ ]
manufactured lumber [ ]
steel studs [ ]
stress-skin panels [ ]
other ______________________________ [ ]

Floors

Check all floor structural systems installed [ ]

post & beam w/ plywood decking [ ]
post & beam w/ 'car decking' [ ]
dimensional lumber joist system [ ]
manufactured lumber joist system [ ]
slab [ ]
other ______________________________ [ ]

For projects with basements, answer the following

[y] [n] [?] Do submitted plans indicate that the basement is heated?

In the field, basement is part of heated space [y] [n] [?]

(Answer **yes** if any of the following is true:)

The primary heating system supplies the basement.
A secondary heating system supplies the basement.
The floor between the basement and the living space above is uninsulated.
The basement stairway is open to the floor above.

If the answer to above is **yes**, be sure that component descriptions of the basement walls, windows, doors, floor are filled out, and revise component lists to indicate basement component areas. [ ]

[y] [n] [?] Do submitted plans indicate that the basement is insulated?

Describe how the basement is insulated from the house above, and from the outside. [ ]

____

____

Describe how the basement is heated, if at all? [ ]

____

____

Insulation Quality

Insulation installed in the field should be compared with notes on the component worksheets to verify component performance. In addition, the following questions should be answered in the field with regard to the insulation itself.

Attic

Indicate the type of insulation installed in the attic: [ ]
(No attic [ ])

Ceiling type checked (component type #): ________

Fiberglass Batt [ ]
BIBS [ ]
Blown Fiberglass; pink or yellow cubes [ ]
Blown Fiberglass; pink [ ]
Blown Fiberglass; white [ ]
Cellulose [ ]
Mineral Wool [ ]
Other [ ]

____

Is there an insulation certificate? [y] [n] [?]

If so, describe specs:

____

____

For loose fill insulation answer the following: [ ]

(No loose fill [ ])

Ceiling type checked (component type #): ________

Are depth indicator strips installed? [y] [n] [?]

Circle the consistency of insulation depth [ ]

even **somewhat uneven** **very uneven**

Insulation Density test performed? [y] [n]

Measured insulation depth: __________ [ ]

Weight per sq. ft. of insulation: _________ [ ]

For batt insulation, answer the following: [ ]

(No batts in attic [ ])

Are truss bottom chords covered by insulation? [y] [n] [?]

Is attic hatch insulated to same level as attic? [y] [n] [?] **[n/a]**

Describe any missing insulation or other problems: [ ]

____

____

Walls

Describe how much of the wall insulation you are able to review (i.e., how much is covered vs. accessible) [ ]

____

____

Review each wall component description sheet and verify that the wall insulation is accurately characterized. Then answer the questions below. [ ]

Look for the following insulation problems, and check boxes if found: [ ]

Short batts [ ]
Compressed insulation [ ]
Utility cuts [ ]
Batts inside stapled, not lapped [ ]
Other ____________________ [ ]

Describe the extent of these problems: [ ]

____

____

____

For houses with an upper floor, check for insulation at the perimeter (rim joist). Is this area insulated? [y] [n] [?] [n/a]

Based on the above questions, estimate the percent of wall area which is underinsulated: __________

Floors

For floors over unheated space or crawlspace, answer the following: [ ]

(Not applicable [ ])

Depth of floor joists __________

Describe how underfloor insulation is supported: ______________________ [ ]

____

Underfloor insulation installed flush to 'warm side' of floor [y] [n] [?]

Is any insulation missing, or hanging down out of floor joists? [y] [n] [?]

If the crawlspace access hatch is inside the house, is it insulated to the same level as the rest of the floor? [y] [n] [?]

Based on the answers above, estimate the percent of floor that is underinsulated: ________

Perimeter of crawl space is insulated [y] [n] [?]

If yes, **R-value:** ________

Crawlspace is ventilated (screened vents to outside) [y] [n] [?]

Crawlspace access: [ ]
[ ] outside stem wall [ ] closet floor [ ] under stairs
[ ] other: ______________________________

Vapor Barriers

[ ] For each of the components below, indicate whether the plans call for vapor barriers. In the field verify vapor barrier installation. Beneath each component, indicate the type of vapor barrier installed. [ ]

Indicated on plans	Component	Installed in field
[y] [n]	**Walls**	[y] [n] [?]
		type: ____________
[y] [n]	**Vaulted Ceiling**	[y] [n] [?]
		type: ____________
[y] [n]	**Floor**	[y] [n] [?]
		type: ____________
[y] [n] [n/a]	Ground cover in crawlspace (continuous)	[y] [n] [n/a]
[y] [n] [n/a]	Vapor barrier under slab	[y] [n] [n/a] [?]

Describe any problems with vapor barrier installation here:

____

____

For each of the locations listed below, indicate whether sealant/weather-stripping was installed. [ ]

Location	Installed
Window edges	[y] [n] [?]
Door frame edges	[y] [n] [?]
Door weather-stripping	[y] [n] [?]
Wall seams	[y] [n] [?]
Floor seams	[y] [n] [?]
Utility penetrations	[y] [n] [?]
Shower/Tub	[y] [n] [?]
Attic/crawl space access doors	[y] [n] [?]

[y] [n/a] If sealant type and/or application is described in general terms on the plans, include the description below.

____

____

____

Lighting

Recessed light fixtures are installed in field [y] [n] [?]

Number of recessed fixtures (Count only fixtures installed through insulated ceiling, not between floors) __________

[y] [n] IC rating indicated [y] [n] [?]

Are any compact fluorescent lamps installed in the house? [y] [n]

HVAC

The questions about heating and cooling systems below need only be answered once; that is, what is installed in the field is the information we want. It is worth checking the plans for information which might not be apparent in the field, but field installation characteristics take priority.

[ ] [?] **Primary Heating system type** [ ]

- [ ] Ducted Furnace [ ]
- [ ] Hydronic [ ]
- [ ] Wall Heaters/Electric Baseboard [ ]
- [ ] Heat Pump (ducted) [ ]
- [ ] Other ______________________ [ ]

[ ] [?] Fuel [ ]

- [ ] Electric [ ]
- [ ] Gas [ ]
- [ ] Propane [ ]
- [ ] Oil [ ]
- [ ] Other ______________________ [ ]

[ ] [?] Make/Model ________________________________ [ ]

[ ] [?] Model Number: ________________________________ [ ]

[ ] [?] Total capacity (fill in all that apply) [ ]

- [ ] Input ______________(BTU/hr.) [ ]
- [ ] Output ______________(BTU/hr.) [ ]
- [ ] kW ______________(kW) [ ]
- [ ] Other ______________(units?) [ ]

[ ] [?] Efficiency __________ [ ]

- [ ] AFUE
- [ ] Steady State
- [ ] HSPF
- [ ] COP
- [ ] Electric (Efficiency=1)
- [ ] Other ______________________

[ ] [?] If there is a secondary system, describe type and size: [ ] **[n/a]**

____

____

For Heat Pumps, indicate make/model and capacity of outdoor unit [ ] **[n/a]**

____

List the number fireplaces or other wood burning appliances below [ ]

gas fireplace _____(#)
wood fireplace _____(#)
fireplace insert _____(#)
woodstove _____(#)
pellet stove _____(#)

Of these, how many definitely have no outside air source: ______(#)

For combustion furnaces, does the flue include a forced-draft system? [y] [n]

Indicate location of heating system (for example, attic, crawl space, interior closet, garage, basement) [ ]

____

Thermostat Type [ ]

Programmable [ ]
Simple Setback [ ]
Single Temperature [ ]
Zoned/Unit by Unit [ ]
None [ ]
Other [ ]

____

Number of Thermostats ________

Cooling system type [ ] [none]
(Obtain this information in the field unless it is readily available on plans.)

Central A/C [ ]
Heat Pump [ ]
Swamp Cooler [ ]
Zoned Thru-wall A/C [ ]
Other [ ]
____

Describe cooling system changeover control: [ ]

Cooling system must be **manually switched** to cooling mode (e.g. switch on thermostat) [ ]
Thermostat provides **automatic switching** to cooling mode based on temperature setting [ ]
Other:____________________ [ ]
____

Capacity [ ]
____

Make/Model [ ]
____

Model Number [ ]
____

Efficiency [ ]
____

EER [ ]
SEER [ ]
Other [ ]
____

Location of cooling system (describe indoor and outdoor components) [ ]
____

Located within insulated space [y] [n]

Ductwork

Where and What are the Supply and Return Ducts? Describe the **location** and **construction** of the ductwork. Distinguish location between supply and return: ☐

____

____

____

____

Describe any obvious leaks or problems with the duct system, and whether any attempt has been made to seal the ductwork for air leakage. ☐

____

____

Check all types of ductwork present below ☐

Sheet Metal ☐
Flex Duct ☐
Duct board ☐
Framing cavity used for ducting; **supply** ☐
Framing cavity used for ducting; **return** ☐
Other ☐

____

Indicate the R-value installed for ductwork insulation __________

Estimate the percentage of the total length of supply ductwork located in **unheated** space. __________

Estimate the percentage of the total length of return ductwork in **unheated** space. __________

Pipes/Hot Water

[y] [n] Is pipe insulation indicated/installed for water system pipes? [y] [n] [?]

Type: ______________________________ [ ]

Insulation under hot water tank installed? [y] [n] [?]

Use information on the '**Energyguide**' label on the hot water tank to answer the following: [ ]

Fuel type: __________

Annual operating cost for this model: ($)__________

National average fuel cost: ($)__________ per (units)__________

[y] [n] Low-flow shower heads indicated/installed? [y] [n] [?]

Any indication of flow? __________

Ventilation System

Indicate the type of ventilation system installed. [ ]

None [ ]
Spot ventilation [ ]
Whole house fan (without heat recovery) [ ]
Air-to-air heat exchanger [ ]
Other type of heat recovery ventilation [ ]
Other [ ]

____

____

Site Visit Summary

[ ]

Describe general observations or issues you noticed during the site visit which might affect longevity or energy performance. Also discuss any obvious energy code compliance issues you encountered. Use back if necessary:

____

____

____

____

____

Window List (BLUE FORM) **Building Identification Number**__________

Using the window types defined on the window worksheet, list **each** window by size and location, using room names/numbers on sketch. Verify this list in the field and note any modifications. Use additional sheets if necessary. Do not list skylights or glazed 'swing' doors here.

Location Info				**Plan Info**				**Field Info**				
Win # from sketch	**Location**	**Direc tion**	**Wall Type**	**Window Type (#)**	**Opera tion***	**Size (width x height)**	**Area**	**(✓) if same in field**	**Window Type (#)**	**Opera tion***	**Size (width x height)**	**Area**

* **Window operation:** (f):fixed (c):casement (s):slider (sh,dh):single or double hung (a):awning (sd):sliding door

WALLS **Component Description Form** (TAN FORM)

________ Wall type

Wall construction different in field (if so, indicate changes below) [y] [n] [?]

[ ] Above grade
[ ] Buffer
[ ] Below grade; average depth at base: ______

Location

____

Stud spacing: **[16"] [24"] [other]**

Wall thickness: **[2x4] [2x6] [other]**

________ **Insulation on plans** **Insulation in field:** ________

If insulation R-value is not apparent, look for coding stripes, and describe brand, color, and thickness: [ ]

____

____

[y] [n] Is there rigid insulation indicated on plans?

Is there rigid insulation installed in field? [y] [n] [?]

If yes, describe:
R-value:________
Thickness, brand, etc:
____

Description of wall construction (materials, finishes)

[ ] plans:

____

____

field: [ ]

____

____

Insulated headers: [y] [n] [?]

__________ **Building Identification Number** (Study Protocol 07/13/94)

FLOORS Component Description Form (GREEN FORM)

________ Floor type

Floor construction different in field (if so, indicate changes below) [y] [n] [?]

[ ] Frame
[ ] Slab

Location

____

For **slabs:**

Slab depth below grade (0, 3.5, 7 ft): ________________
Describe slab insulation strategy: ________________
Describe connection between slab and foundation wall, if any:

____

________ **Insulation on plans** **Insulation in field:** ________

If insulation R-value is not apparent, look for coding stripes, and describe brand, color, and thickness: [ ]

____

____

Description of floor construction (thickness, materials, finishes)

[ ] plans:

____

____

field: [ ]

____

____

Joist spacing: ________

________ **Building Identification Number** (Study Protocol 07/13/94)

CEILINGS **Component Description Form** (YELLOW FORM)

________ Ceiling type

Ceiling construction different in field (if so, indicate changes below) **[y] [n] [?]**

[ ] Attic
[ ] Vault - Scissor
[ ] Vault - Rafter

Location

____

For vaults, indicate structural depth: ________

________ **Insulation on plans** **Insulation in field:** ________

Batt [ ]
BIBS [ ]
Loose fill [ ]

If insulation R-value is not apparent, look for coding stripes, and describe brand, color, and thickness: [ ]

____
____

Description of ceiling construction (materials, finishes)

[ ] plans:
____
____

field: [ ]
____
____

Rafter spacing: ________

________ **Building Identification Number** (Study Protocol 07/13/94)

GLAZING Type Description (PURPLE FORM)

Fill out a description for each window, glazed door or skylight type.

During plan review, answer as many of the plan side questions as possible. In the field, verify, add, or change information **in the field column only**. If additional window types or variations are found in the field, fill out a **new** window description form, and update the window list.

__________ **Glazing Type (#)** Glazing type in field is different from plans [y] [n] [?]
(If yes, fill in modifications below)

[ ] Window
[ ] Skylight
[ ] Sliding Glass Door
[ ] Glazed 'Swing' Door: [ ] half-light [ ] full-light

Glazing type description:____
____

Plans		**Field**
[wood] [vinyl] [alum] [clad]	Frame material	[wood] [vinyl] [alum] [clad]
[y] [n] [?] [n/a]	Insulated glazed door or Thermal break alum. frame?	[y] [n] [?] [n/a]
	Glazing layers (#)	[1] [2] [3]
	Tint	[y] [n] [?]
__________	Spacing	__________
[y] [n] [?]	Low-ε coating	[y] [n] [?]
[y] [n] [?]	Argon filled	[y] [n] [?]

Manufacturer: [ ]

[y] [n] Performance specs. on plans Performance labels present in field [y] [n]

If yes, U-value indicated: ______ If yes, labeled U-value:________

Type of rating:
[ ] NFRC [ ] AAMA [ ] Limited. production default
[ ] Sigma, custom glazing [ ] Exempt [ ] Other (describe)

__________ **Building Identification Number** (Study Protocol 07/13/94)

DOORS Type Description (ORANGE FORM)

Fill out a description for each door type. If the information cannot be determined, describe why not.

__________ **Door Type (#)**

Door type in field is different from plans (If **yes**, indicate changes in the **field** section below) [y] [n] [?]

[ ] Main Entry Door
[ ] Other Opaque Door

[ ] Location: ____________________

[ ] Description of construction:

plans: ____________________

field: ____________________

Manufacturer: [ ]

[y] [n] Door thermal specification on plans
Specified U-value: __________

Door labels present in field [y] [n]
U-value on label: __________

__________ **Building Identification Number** (Study Protocol 07/13/94)

________ Building Identification Number

____/____/____ Date

BLOWER DOOR TEST

Describe construction status of house, with particular attention to sealant, weather-stripping, and other issues which might effect the outcome of the blower door test.

____

____

____

____

Set-up: Close all windows and doors to the outside. Open all interior doors, close all dampers and doors on wood stoves and fireplaces. Ensure that furnace and water heater can not come on during test. Make sure all fans are off.

House Volume _________

Reference Pressure ______ Plug fan hole and record pressure difference across the door

Turn blower door on and depressurize house to 25 PA from reference pressure.

Negative house pressure _______Pa
Ring size (O,A,B,C) _______
Flow pressure _______Pa
CFM _______

Turn blower door on and depressurize house to 50 PA from reference pressure.

Negative house pressure ______Pa
Ring size (O,A,B,C) ______
Flow pressure ______Pa
CFM ______

Restore doors, flues, and equipment to condition you found them in.

__________ Building Identification Number

Performance Path Summary

Fill out this form for each project submitted under **performance** compliance path. Include this form with the fiel
forms.

[ ] UA Calculations

______ Indicate the **proposed UA** shown for the project
in the calculations

______ Indicate the **target UA** shown for the project.

Using the performance information in the submittal, fill out the components and their areas and U-values in the table below. In the field, verify that these components were constructed as indicated, or note any changes.

[ ] Using the performance submittal, fill out the components (walls, windows, doors, floors, ceilings) and their areas and U-values in the table below. In the field, verify that these components were constructed as indicated, or note any changes.

Component	**#**	**Description**	**Area**	**U-value**	**Verify**
					[ ]
					[ ]
					[ ]
					[ ]
					[ ]
					[ ]
					[ ]
					[ ]
					[ ]
					[ ]
					[ ]
					[ ]
					[ ]
					[ ]
					[ ]
					[ ]
					[ ]

__________ Building Identification Number

Performance Path Summary, pg 2

☐ Compare the take-offs in the submittal to the take-offs developed from the permit set. Discuss any discrepancies or variations below.

Compare the take-offs in the submittal to the construction types found in the field. Discuss any discrepancies or variations below. ☐

☐ Review the component U-values and try to determine why the performance path was used. Check if tradeoffs below are used, or describe others.

- ☐ front door area >24 ft.^{2} (double entry door)
- ☐ skylight area >2% of HFA
- ☐ efficient windows used
- ☐ other:______________________________

Appendix D

Interview Protocols

Residential Buildings Energy Code Survey

Building Code Officials Questionnaire

Interviewer Name __________________________________ Date ________________

Jurisdiction Name: ____________________________________ Code: ________________

Comments:

Hello, I'm _________ from ECOTOPE, Inc. a energy research firm. We are conducting a survey for the Oregon Building Officials Association, in conjunction with the Oregon Department of Energy about the Energy Code for Residential Building. Part of this study includes interviewing building officials at jurisdictions around the state. Information collected in these interviews will remain confidential, and specific jurisdictions will not be identified. The interview takes approximately ____ minutes. I would like to speak with someone responsible for plan review and someone responsible for field inspection of residential buildings. Can you direct me to those people.?

Plan Review

Name:

Title:

Phone:

Field Inspection

Name:

Title:

Phone:

A. Jurisdiction Information (fill out once for each jurisdiction)

A-1. What is the total number of staff that review residential buildings **plans** (distinguish from electrical, mechanical, plumbing)? _________

A-2. What is the total number of staff that **inspect** residential buildings? (distinguish from electrical, mechanical, plumbing)? _________

B. Plans Reviewer Section (ask of plan reviewers only)

Plan Reviewer Name: ______________________

Interview Date: ______________________

Jurisdiction: ______________________

B-1. What percent of submitted projects require training or assistance with the residential energy code in order to demonstrate compliance? ______

B-2. What percent of submitted projects require design modifications to bring about energy code compliance.? ______

B-3. What type of technical support or training do you provide to builders for energy code questions?

a. Phone support

b. Over the counter (in person)

c. Printed handouts

d. Other ____________________________

B-4. What is the enforcement priority for the following energy code issues? (high, medium, low, not enforced)

	Enforcement Priority:	**High**	**Medium**	**Low**	**Not enforced**
a.	Compliance Path (1-9) Identified	☐	☐	☐	☐
b.	Insulation R-value for walls	☐	☐	☐	☐
c.	Insulation R-value for roofs	☐	☐	☐	☐
d.	Insulation R-value for floors	☐	☐	☐	☐
e.	Insulation R-value for slabs	☐	☐	☐	☐
f.	U-value for windows	☐	☐	☐	☐
g.	Moisture and air barriers	☐	☐	☐	☐
h.	Air leakage rate or weatherstripping for doors	☐	☐	☐	☐
i.	Air leakage rate for windows	☐	☐	☐	☐

j.	Position of the slab insulation	[ ]	[ ]	[ ]	[ ]
k.	Wall frame size and spacing	[ ]	[ ]	[ ]	[ ]
l.	Entry door size with correct U-value	[ ]	[ ]	[ ]	[ ]
m.	Slab edge detailing	[ ]	[ ]	[ ]	[ ]

B-5. Does your jurisdiction require energy code compliance forms for a residential project to demonstrate energy code compliance?

B-6. Describe the percentage breakdown of project submittals by path submitted

Path: 1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____

Performance Path ____

Systems Analysis ____

B-7. Does the review process vary for different submittal paths?

B-8. How are plan review energy code corrections followed up?

B-9. What are the most common enforcement or compliance issues which come up during plans examination?

B-10. What parts of the energy code are frequently misinterpreted or ignored by designers.

C. Field Inspectors (ask of field inspectors only)

Inspector Name: ______________________

Interview Date: ______________________

Jurisdiction: ______________________

C-1. How are energy code compliance issues identified during plan review communicated to the field inspector?

Briefly describe the typical inspection sequence and the major energy code issues examined during each inspection.

How consistently are the following energy code issues enforced **during inspection?**

I/C rating for can lights
Vapor Barriers
Duct insulation
Pipe insulation
Low-flow fixtures

How are window performance requirements verified/enforced?

What percent of projects do you find damaged, missing, or poorly installed insulation? How is this treated with respect to code enforcement?

What percent of projects have field changes which affect energy code compliance?

What energy code issues are most frequently encountered in the field?

How are field enforcement issues recorded/followed up?

C-3. On what percent of projects do you find energy code compliance problems in the field?

.______

C-4. What types of energy code compliance issues are most frequently encountered in the field?

D. Compliance Issues (for all interviews)

D-1. On a scale of 1 to 5, please rate how significantly the following issues limit the effective enforcement of the energy code. (with 5 representing the biggest problem areas)

[ ] Energy code enforcement has a low priority (if so discuss)

[ ] Obscure or unenforceable code language

[ ] Lack of enforcement resources

[ ] Consistency and availability of technical backup from code support agencies

[ ] Technical difficulty in meeting code requirements

[ ] Lack of printed material (technical support)

[ ] Changes to projects in the field

[ ] Insufficient information in project submittals

[ ] Insufficient/nonexistent product labeling in field

[ ] Other: ________________________________

D-2. What errors or ambiguities have you encountered in the code which complicate energy code enforcement?

E. Training (for all interviews)

E-1. Do you receive assistance from the following agencies for energy code enforcement?

a. OBOA (including short schools)

b. Circuit Rider Program

b. BCD (including hotline and Alan Seymour)

c. ODOE

d. OSU Extension Energy Program

E-2. What improvements to energy code training and support programs would you suggest?

F. Follow up (for all interviews)

F-1. What percent of new residential projects would you estimate comply with energy code requirements? _______

F-2. How would you go about improving energy code compliance levels?

F-3. Would additional enforcement resources affect energy code compliance?

F-4. On a scale of 1 to 5, what would be the most effective use of resources to improve energy code compliance levels? (with 5 being the most effective)

[ ] Education for builders
[ ] Education for code officials
[ ] Improved code language
[ ] More inspectors
[ ] More time/inspection
[ ] More inspections
[ ] Technical support from state agencies or OBOA
[ ] Circuit rider program

F-5. Do you have any other comments or suggestions

(Thanks for your time)

Residential Buildings Energy Code Survey

Building Professional Questionnaire

Interviewer Name ______________________________ Date ________________

Interview Number __________

Comments:

(Arrange contact with a project manager)

Hello, I'm __________ from ECOTOPE, Inc. an energy research firm. We are conducting a survey about the Residential Energy Code. This study is being reviewed by the Association of Oregon Homebuilders, the Oregon Building Officials Association, and the Oregon Department of Energy. Part of this study includes interviewing builders around the state. Information collected in these interviews will remain confidential; specific builders and projects will not be identified. Would it be possible for me to talk to you for about 20 minutes about the residential energy code? (If not a convenient time, try to arrange another)

General Information

Name of Interviewee: ________________________

Title: ________________________

Profession: ________________________

Firm Name: ________________________

Type of Firm: ________________________

Phone Number: ________________________

Size of Firm (# of employees): ______________

How many residential projects do you complete annually. _____

How long have you been building in Oregon? _______

What is the price range of your residential construction projects.

____

In which jurisdictions are you active.

Do you participate in utility sponsored incentive programs? (discuss)

Process

How do you document energy code compliance?

Impacts

How does the energy code affect the following phases of your projects?

Design and planning

Construction phase

Project cost

Describe **specific** aspects of the code which have significant impacts to project cost?

Does the energy code affect the length of time it takes to complete a project?

How frequently (% of projects) does energy code enforcement result in modifications to your projects during plan review?

During construction?

How would your construction techniques differ in the absence of an energy code?

What percentage of all new residential projects (not just your own) would you estimate comply with energy code requirements?

Code Enforcement and Building Department Interactions

Do you encounter variations in energy code enforcement between/within jurisdictions?

Are there specific energy code measures which are interpreted or enforced inconsistently?

Are there specific problems you find with energy code requirements?

Do all subcontractors share the responsibility for meeting code requirements, or does the general contractor have to follow up energy code issues?

Please rate whether the following issues represent problems with the energy code; (on a scale of 1 to 5, one is not a problem, 5 is a significant problem)

General

[ ] Code language is obscure or unenforceable
[ ] Jurisdictions lack enforcement resources
[ ] There is resistance to energy code requirements by the building community
[ ] The cost of energy code compliance to builders
[ ] Inconsistent interpretation of energy code requirements by jurisdictions
[ ] Time involved to assure energy code compliance
[ ] Ongoing changes to energy code requirements

Technical

[ ] Technical difficulty in meeting or understanding code requirements
[ ] Consistency and availability of training and technical backup materials
[ ] Availability of window performance data
[ ] Availability of other performance data (insulation, equipment efficiency, low flow fixtures, IC can lights, etc)

Are there any other issues affecting compliance which I have not covered?

What type of training or technical support is currently available to you for energy code questions?

Have you participated in any of the available training?

Are additional energy code training or technical support resources needed?

Improvements you suggest to energy code:

(Thanks for your time)

Appendix E

Interview Comments and Responses

Summary of Responses
to
Residential Energy Code Survey Interview

B3d: What type of technical support or training do you provide to builders for energy code questions?

(2) Checklist, Newsletter (Quarterly)

B7: Does the review process vary for different submittal paths?

(8) N/A

(6) No

(1) Slightly

(8) Performance path requires more time.

(3) Path 8 requires more time for floor and window calculations.

B8: How are plan review energy code corrections followed up?

(21) Plans examiner red-lines the plans.

(1) Checklist to contractor/builder.

(4) Red-line the plans and checklist.

(1) Notes on plans or over the phone. Sometimes a letter is sent.

(1) Red-line the plans and attach copy of Table 53-P.

(1) Red-line plans and ensure plans are on the job site.

(1) Red-line the plans and contact the contractor.

B9: What are the most common enforcement or compliance issues which come up during plan examinations?

(5) None

(2) Incomplete information on plans.

Door between garage and house with 20 min. fire rating, depth of vaulted ceilings, and trade-offs between components.

Area limit on main door.

Double entry door and insulation for basement.

Improper insulation values, improper doors/windows, too large of door area, and defining an unheated space.

If the plans shows path 1, this shows compliance.

Double door size limiting, garden window with U=0.4. Labeling for the windows (without labeling), door between garage and house does not comply with both fire and energy code requiremwnts.

The performance value for path 1.

In remodels, the reuse of windows. Plans are not consistant with the path indicated.

Glazing area for path 8.

No performance information on the windows and doors.

Slab edge between heated and unheated spaces. Rigid insulation on the face of the insulation. Vented air space with vaulted ceilings.

Vaulted ceiling.

Double door issue. Added glass block.

Insulated door between the garage and house, and doors with too much windows.

U-value for windows and insulation values for vaults.

Double door issue. Some of the vaulted ceiling area.

Skylight and door U-value and door sizes.

Out dated plans that shows 2 x 4 walls with R-11 and others.

Insulation thickness does not match frame thickness.

Wall insulation. Most applicate wants to put in R-19.

R-values listed on out-of-state or older plans. R-value for the vaulted ceilings.

Lack of information of the plans including the path. Older plans shows older performance values.

Vented space for vaults.

Slab edge insulation between the slab and garage. Normally we require other insulation measures.

Older plans which shows the wrong frame and insulation levels.

The plans calls for R-19 with 16 inches on center for walls. The R-30 called out where it should be R-38. Area limitation for the vaulted ceilings.

B10: What parts of the energy code are frequently misinterpreted or ignored by designers?

(5) None.

Lack of understanding of U-values of windows and doors.

Area limit on main door. Larger structure members to accomidate the insulation.

Wall framing. 50 percent on vaulted ceiling. Slab-on-grade insulation.

Entry door opening size, glass block U-values, slab-edge detailing, and path 8 sizing.

Window and door U-values are not identified on the plans.

Main door area and U-value.

Area of vaulted ceilings.

Older plans shows 2 x 4 walls with R-11 etc. Architectural windows exceeding 1%. Double main door.

Window and door U-values. The designer doesn't understand the area limits.

150sf of R-21 for the vaulted ceiling.

Infiltration and sealant information.

Same as B-9.

Limit of area for vaulted ceilings are often ignored.

Duct insulation is never noted.

Windows and air leakage, moisture barrier. Plans lack information about the windows.

Seldom have information on air leakage, and required U-value for the door between garage and house.

U-value for the doors and U-values for the windows are often missing.

Often insulation for basement walls and slab-on-grade floors. Sand cover for the vapor of the slab-on-grade floor is missing.

U-values for the doors and windows not shown on the plans.

Garage door U-value.

Air infiltration requirements.

Duct insulation.

Ventilation for vaulted. Slab edge insulation. Insulation for the basement walls. Area limitation for vaulted ceilings.

The fundimentals of energy loss.

Insulation for a slab-on-grade rock installation. Impossible to install per code.

Slab insulation, vapor barrier under the slab.

Advance framing requirments.

C1: How are energy code compliance issues identified during plan review communicated to the field inspector?

Plans examiner fills in a form which states the insulation values, doors, and skylights.

Compliance path is noted on inspection card.

Plans examiner marks the plans and inspection notice with the path..

Plans examiner redlines the plans.

The path number is writen on the plans by architect.

Plans reviewer identifies on the plans the compliance path.

Plans reviewer and inspector is the same. Each project has Table 53-P.

Path 1 is writen on the plans, otherwise the calculations are attached to the plans.

Plans are line plans. Often the inspector is also Plans Examiner.

Red lines on the plans by the plans examiner.

Often we are the plans examiner. Assume path 1.

Plan examiner and inspector are the same person.

C2: Briefly describe the typical inspection msequence and the major energy code issues examined during each inspection.

Floor insulation at final. Windows at framing. Doors at final. Skylight at framing. Blow-in insulation at final.

Framing - Window/Door, Insulation - Wall and pipe insulation, Final - Roof insulation.

Floor insulation at post and beam inspection (or on rainy days at final). Window at insulation inspection. Doors at final.

Insulation (floor, wall, ceiling), final (ceiling)

Final inspection (Floor and doors), post and beam (Floor), Faming (Windows)

Floor insulation (at final or at post and deck), Windows at framing. Doors at final. Blown-in at final.

Floor insulation is a separate inspection. Windows during framing. Doors during framing. Blow-in at final. Vaulted ceiling at insulation.

Slab (insulation), Post/beam (Mechanical Insulation), Framing (Windows), Insulation (walls, vault, ceiling), Final (Floor, Blow-in)

Underfloor inspection - floor insulation & pipe insulation. Final - Blow-in, attic doors, and duct/pipe insulation.

Underfloor - floor insulation and vapor barrier. Cover - wall insulation, window sealed. Final - Gasket and sealed for air infilstration

Floor insulation at insulation inspection or final. Windows at framing inspection. Doors at final. Blow-in at final.

C7: What energy code issues are most frequently encountered in the field?

Unheated basements. Double doors. Attic doors.

Floor insulation is compressed or without full contact with floor.

Other doors are usully missed. Default stickers have expired.

None.

Insulation around windows, pipes and wiring.

R-30 vaulted ceilings area limit. Oversized main door.

Wrong insulation in the walls. Damaged or missing vapor barrier. Failing or missing insulation in the floors, under stairs and landing. Rim insulation for the walls.

Compression of insulation. Damaged vapor barriers.

Vapor barrier requirements for vaulted ceilings.

Vapor barrier requirements. Perm rating is incorrect.

Baffels for the underfloor space.

Often the different windows show up with various U-values. Caulking is often missed.

Missing blow-in insulation. Confusion on the R-value for vaulted ceilings.

Performance value for vaulted and ceiling insulation.

Double door – we don't regulate 24 sf door area limitation

Slab insulation. Confusion on insulation values for roof.

Lack of sealant between crawl or attic to the attic space. Compression of insulation and vapor barrier.

C8: How are field enforcement issues recorded/followed up?

Corrections are noted on the inspection form, The copy of the form is left on the job. Nonconformance is tracked through a computer system.

Inspection correction card.

Correction notice is writen and left on the job site. A computer tracks the nonconformances.

Correction notice is writen up and given to the contractor. Individual inspector tracks the corrections.

Correction notice is writen and given to the contractor. Computer system tracks the non-conformances.

Correction notices left on the job. Nonconformances are tracked at the jurisdiction.

Correction notice is left on the job site. We track non-conformance with the file.

Writen up on a correction notice. Computer system tracks the non-conformance.

Hand writen correction notice. A computer tracks the correction.

Writen on an inspection notice. Call for additional inspection. Charged on the third inspection.

If they are given a correction notice left on the job. It is tracked by a computer system.

Correction notice is left on the project. The file tracks the non-conformances.

Write a correction notice to the builder.

D1: Other significant issues that limit the effective enforcement of the energy code.

Current products stocked in local stores do not meet the code.

E2: What improvements to energy code training and support programs would you suggest?

(5) None

Simplify training levels for builders.

Training for the advance framing for plans examiner and builders.

Training for builders. Classes for the small designer or individual home owners.

Hold training program for contractors.

Simplification on window and door ratings.

Training for code officials. Identification of unfaced insulation.

Circuit rider program.

More training at the short school.

Good Shape

Support for unusual buildings such as metal stud home, dome or mixed construction log and stick.

Education to the public.

Uniformed enforcement amoung the jurisdictions. Perhaps a class that deals with code issues.

More readable handouts for the contractors.

Train the builders. Train the suppliers so they understand the requirements.

Class on the performance path.

Provide resources and reimbursement for staff time and registration.

More training on intepretations for residential.

Provide review classes for code officials.

Education for the code official to have uniform enforcement among the jurisdictions.

More classes at the OBOA short school.

More time for training.

It is difficult to contact the people with questions.

More extensive training program.

Training for inspectors.

More training for code officials at OBOA short school. Alternative and problems - how to enforce the energy code.

Train the inspectors for the quality of the insulation installation. Good technique inspection.

More number of training. I would be useful for a course on energy code interpretations.

More educating for everone.

Training on path 1 for builders and code officials.

Improve the publication of interpretations.

General education for the code official.

Teleconference or self-study course for continuing education.

Simplication of the path 1 requirements.

F2: How would you go about improving energy code compliance levels?

(6) None

(3) Simplify the code.

(5) Education for the insulation contractor.

(5) Education/training for the builder.

(4) Education for code officials.

(2) Utility companies should enforce the code.

We should match the size of the insulation for the structure.

Clarify the code on indoor air quality. Product availiblity on doors.

Provide better handouts materials.

Provide update information for contractors.

Utility program which provides money.

I question the uniform insulation level throughout the state.

Building in flexibility for additions and renovations so we can trade off between components. Keep measures simple. Insulate existing homes. Public training on energy conservation.

Make Chapter 53 more readible and understandable. Train builders on Chapter 53.

Education.

More inspectors. Improved code language.

The utility program should be the same as the energy code.

Provide handouts to the general public (lumber suppliers and general homeowners.)

Educate the designers.

Have the unfaced insulation labelled on both sides.

Provide support for Path 1 builders,

Additional staff. A specialist in the field of energy conservation.

Education for inspection of quality control of insulation.

Aditional funding for code inforcement would help.

Have an energy specialist that just inspects for energy.

Provide information on the air infiltration for walls "why don't we vent this space." Provide information on cost effectiveness. What is the total energy used on building the house.

Give the reasons for having the energy code.

Provide guidelines for the performance path.

Simplify the lanquage. Publish the purpose of the energy code.

Levels are good.

Education for the industry. Improve the quality of the installed insulation. Increase number inspection to improve the quality of the installed insulation. Look at the foaming around the window insulation.

F3: Would additional enforcement resources affect energy code compliance?

(18) Yes

(8) No

(1) Don't know

Yes. If the compliance is low.

We are getting a resonable level of compliance. The industry understand the requirements. Overall the answer is no.

Only for remodels and addionals.

Yes, in the field and training.

No. Dumping money into resources may not have a pay back.

F5: Do you have any other comments or suggestions?

We would appreciate the state supporting the training for building officials.

Clarify the cost of these measure, are they justified?

Highly recommend support with the circuit rider program.

Enough is enough, the consumer must take responsibility.

Utilities should enforce the energy code. Response from Alan Seymour is too slow to respond.

Better labelling for unfaced insulation. Lable both side with consistant labling.

Doors are without U-values. Hard to enforce the requirements.

Metal buildings, air infiltrations, and improper baffling details are often a problem.

We need quality controls standards for the installation of insulation.

I feel that energy conservation is important.

If a circuit rider program was made available to train inspectors in the field, it would be valuable.

The door between the garage and house may not comply with both energy and fire requirements.

More time for plans review. General education for the designers and contractors.

Better labeling system and product data for doors and windows to identify the label with the window.

We should limit the use of street lighting with motion sensors We should limit the use of sign lighting.

Condense the code, reduce the number of paths, and vary the performance requirements by climate.

More money.

Ground Cover - We don't enforce it because of the high rain fall during construction. Good draining. Vapor barrier - Ensure that the vapor barrier paint is good. Vapor barrier - 100% vapor

The temperate areas of Oregon should require lesser performance. It should be cost effective.

1. Energy Code should be voluntary. 2. The vapor barrier requirements do not work at the beach. Often, the humidity is high and at the same time it's hot. This cause moisture to penetrate the exterior and condense inside the walls. 3. Utilities should pay for the enforcement of the energy code.

We need more support staff. The state should track new inspectors and plans examiners to provide assistance.

Resource the use of alternate fuels.