The Development of an Alternative to Chapter 11 of the IRC 2000 for Use in Pennsylvania

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ABSTRACT

In late 1999, the Commonwealth of Pennsylvania passed legislation to adopt one or more statewide building codes. It is likely that the International Residential Code (IRC 2000) will be adopted for low-rise residential construction. The legislation permits the development of an alternative to Chapter 11, Energy Efficiency, in the IRC 2000 provided that equivalence, in terms of space conditioning energy, is maintained. The Pennsylvania Housing Research Center (PHRC) was asked to develop this alternative version of Chapter 11.

Our terms of reference required the development of an alternative, prescriptive, code chapter that would be simpler, more flexible, and Pennsylvania-focused. The PHRC alternative Chapter 11, together with six supplementary reports, was submitted in May 2000. The alternative energy code for Pennsylvania is a significant improvement over the IRC 2000.

Two studies—one on glazing ratios and the other on climate—permitted major simplifications with regard to the number of relevant climatic zones and the need for builders to determine glazing ratios for individual houses.

A study of light-gauge, cold-formed, steel-framed wall systems provided the basis for a set of more comprehensive recommendations for the selection and placement of thermal insulation to control both heat and moisture flow.

Prescriptive trade-offs for greater airtightness, the use of high-efficiency equipment, or both are introduced.

Equivalence, with regard to space conditioning energy consumption (conservation), is demonstrated in two studies. One study is confined to thermal envelope considerations and the other involves system (house or townhouse) analysis using POWER-DOE.

This paper discusses the changes and the reasons for introducing these changes to the IRC 2000 Code.

INTRODUCTION

In November 1999, the Pennsylvania Legislature passed the Uniform Construction Code (UCC) legislation into law, mandating a statewide building code across Pennsylvania. The act requires the Pennsylvania Department of Labor and Industry (DLI) to promulgate regulations to implement the requirements of the legislation and, in addition, to consider the development of alternative, prescriptive methods for energy conservation that account for the various climatic regions in the Commonwealth. In deriving these energy standards, the DLI was to seek to balance energy savings with initial construction costs.

It was evident that the International Code Council's International Residential Code (IRC) 2000 was to be adopted as the statewide code for low-rise housing in Pennsylvania. The energy provisions are covered in Chapter 11, Energy Efficiency. In December 1999, members of the PHRC Advisory Committee asked the Pennsylvania Housing Research Center (PHRC) to develop an alternative version of Chapter 11, Energy Efficiency, in the IRC 2000. In addition, we were asked to consider and evaluate another prescriptive version of the energy requirements in Chapter 11 that had been developed by the National Association of Home Builders (NAHB). This evaluation was to determine if the NAHB-proposed path

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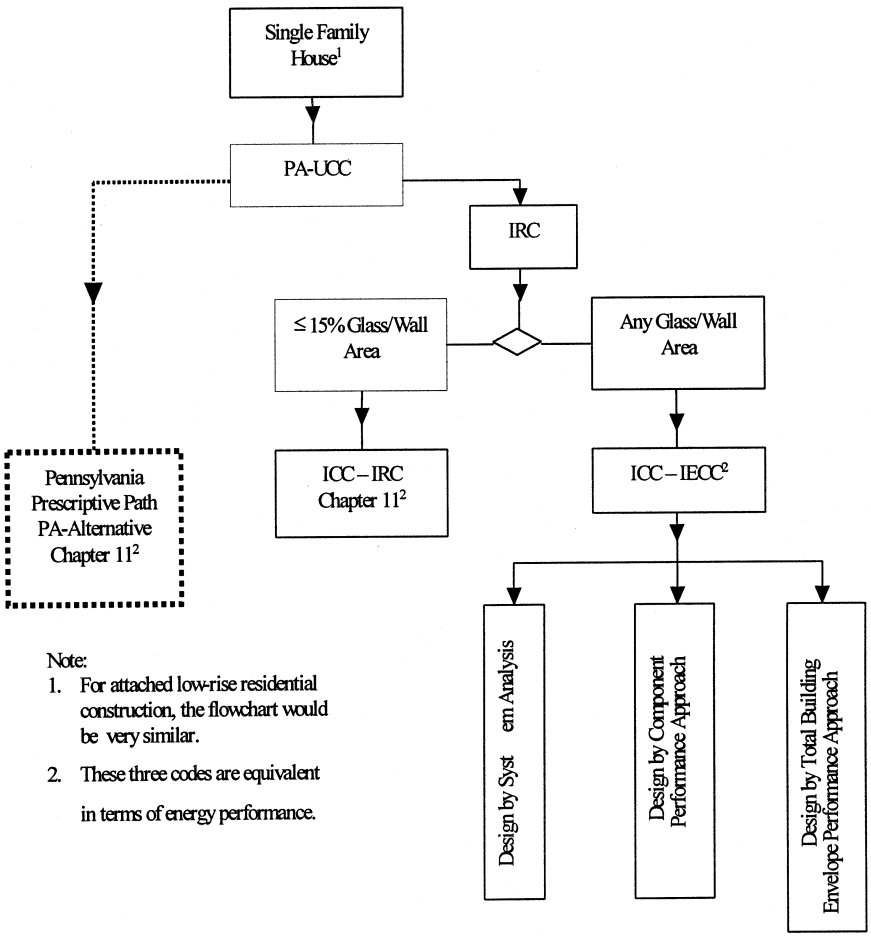

Figure 1 *Flowchart showing the various regulatory paths.*

was equivalent to the IRC 2000 and whether it was appropriate for Pennsylvania's climate and construction practices.

On January 6, 2000, the PHRC initiated work on the development of an alternative prescriptive version of Chapter 11 in the IRC 2000 that would be:

- simpler,
- more rational,
- more flexible,
- focused on Pennsylvania,
- equivalent to the provisions of the IRC 2000 in relation to space conditioning energy consumption, and
- independent, as far as possible, of other documents, specifically the IECC, NFRC, IBC, and other documents.

A draft of the Pennsylvania alternative to Chapter 11 of the IRC 2000, together with the draft versions of six supplementary reports, was submitted to DLI in May 2000. The development and publication of the IRC 2000 was a very important initiative for building codes and for housing in the U.S. Its statewide adoption in Pennsylvania is another important step for housing both within and outside the state. The objective of this paper is to identify and discuss some of the technical issues that had to be addressed. These issues and their resolution are important because they will impact the adoption of the IRC 2000 in Pennsylvania and possibly some other states with comparable climates.

STRATEGIES FOR COMPLIANCE

The chart in Figure 1 illustrates how the proposed alternative path fits into the overall regulatory structure for Pennsylvania's UCC. Note that either the IRC 2000 or the PA-Alternative can be chosen while the IECC 2000 code and its options could, if desired or preferred, always be used.

DEVELOPMENT

This project had six distinct parts. The following is a summary of those parts that are of technical interest.

Part 1—Glazing Ratio (PHRC Report #68)

Figure 1 shows that the glazing ratio (15% for detached houses, 25% for townhouses) is the major, up-front determinant as to whether the IRC Chapter 11 can be used. If greater

TABLE 1
Overall Glazing Area Ratios for Single-Family, Detached Homes without Heated Basements

Data Sets		TGA / TEWA	TGA / THFA
All single-family, detached homes without heated basements	**Size:**	N = 47	
	Average:	11.90%	12.30%
	Standard Deviation:	2.70%	2.90%
	Mean + 1*Standard Deviation:	14.60%	15.20%
Single-family, detached homes with heated basements	**Size:**	N = 13	
	Average:	14.28%	10.91%
	Standard Deviation:	3.22%	3.41%
	Mean + 1*Standard Deviation:	13.44%	14.55%
Townhouses (end-units)	**Size:**	N = 8	
	Average:	11.75%	12.11%
	Standard Deviation:	1.69%	2.44%
	Mean + 1*Standard Deviation:	13.44%	14.55%
Townhouses (mid-units)	**Size:**	N = 7	
	Average:	12.5%	7.62%
	Standard Deviation:	5.07%	2.62%
	Mean + 1*Standard Deviation:	17.57%	10.24%

TGA = Total Glazing Area: Includes area of frame edges and is not purely glazing area
TEWA = Total Exposed Wall Area.
THFA = Total Heated Floor Area.
A walkout basement with glass doors and/or large windows will tend to increase the glazing-to-wall ratio.

than 15% or 25%, a much more detailed and complex approach must be used. There are two problems with this—first, the builder has to do this up-front calculation, and second, these "national numbers" may have little relevance to Pennsylvania. This latter concern provided the impetus for a separate project.

The primary objective of this project was to establish representative values for glazing ratios for the different types of housing currently being built in Pennsylvania. A secondary objective was to develop and document any other pertinent glazing-related properties that the data set might yield.

Because of the very short time frame available for the development and promulgation of the new statewide building code, there was no time to undertake any sort of physical survey. It was decided to examine a set of Act 222 field data survey forms that were available from Penn College in Williamsport, Pennsylvania. Act 222 of 1980 is the Building Energy Conservation Act that established the energy code for Pennsylvania. These standards will be superseded by the UCC. Under Act 222, new homeowners can request that their home be inspected for compliance with Act 222's energy provisions. These fairly extensive examinations are conducted by the technical staff at the Weatherization Training Center at Penn College, which is associated with the PHRC. All the homes were less than three years old when surveyed.

The appropriate data were collected on January 27, 2000, and scrutinized for applicability. The database was found to be skewed toward the southeast of the state and also skewed toward larger homes. For instance, 96% of the houses were located in southeastern Pennsylvania, with some 87.5% being in the greater Philadelphia area. Only 4% of the houses were located in the Pittsburgh area. The southeast is the warmest part of the state and houses in warmer, sunnier areas tend to have larger glazing areas, especially houses that are larger than the norm. As a result, this data set is likely to produce values for glazing ratios that are on the high side. Thus, any average value derived from this data set will be representative of housing that has a greater proportion of fenestration than elsewhere in the state—certainly greater than state medians. Accordingly, these values will be conservative for the purposes of developing or checking any strategy for space conditioning energy conservation. Therefore, it was decided that, given the constraints on time and cost, the project would be limited to this data set.

The information provided in the completed Act 222 field data forms included, but was not limited to, the basement; first, second, and third floor exposed wall area; heated floor area—both above and below grade; total glazing areas on the north, south, east, and west facing walls; and total exterior door area. Computed information based on these data included the total exposed wall area, total heated floor area, total glazing area, percentages of glazing per elevation and wall area per floor, and ratios of total glazing area to both total exposed wall area and total heated floor area. The data set contained samples of two-story homes, with and without heated basements, as well as townhouses, both mid-units and end-units.

Table 1 summarizes the values of the ratios of total glazing area (TGA) to total heated floor area (THFA) and the ratios of total glazing area to total exposed wall area (TEWA) for the various data sets.

For the purpose of planning for space conditioning energy conservation, the survey data were more than sufficient to permit the following conclusions to be drawn:

- For new, detached, single-family houses in Pennsylvania, the average glazing ratio, irrespective of whether it is based on exposed wall area or heated floor, is significantly less than 15%, which is the target glazing ratio for Chapter 11 in the IRC 2000.
- An average value of about 12% would seem to be appropriate for a statewide glazing ratio (relative to total exposed wall area) for new housing in Pennsylvania.
- For both mid- and end-unit townhouses, the glazing ratios—both wall- and floor-based values—are less than 15% and thus much less than 25%—the target value used for Chapter 11 in the IRC 2000.

These data also produced some interesting findings:

- The determining factor in the decision as to where to place the windows in a house or townhouse is the orientation of the street. Solar advantage does not appear to be of much significance.
- In general, the largest proportion of the glazing is placed on the rear face of the house or townhouse unit. The front of the house or townhouse unit also has a large proportion of glazing, while the sides have much less.
- The colder the climate, the lower the average glazing ratio.
- The smaller and/or less costly the house, the lower the average glazing ratio.

While the data set may have been adequate to meet the primary objective of this project, it is also evident that, statistically, it was not large enough, nor was it representative of new housing across the state. It is also clear that over and above energy conservation planning, some knowledge of actual glazing practices would be of considerable value. After all, the production and sale and remediation of windows is a large business in Pennsylvania. There would be merit in conducting a much more comprehensive and better targeted study of glazing practices.

Part 2—Climatic Data (PHRC Report #69)

The IRC 2000 and the IECC identify climatic zones on the basis of heating degree-days (HDD). Accordingly, Pennsylvania is covered by six zones. The objective of this brief project was to review weather records and data on housing starts and, within the very tight constraints on time and funds, assess the IRC 2000 climatic criteria.

The issues involved are evident from Table 2 and the following findings are noteworthy:

1. The metropolitan areas of Philadelphia and Pittsburgh are critical in that they account for a significant proportion of all housing starts in Pennsylvania.
2. In the case of both Philadelphia and Pittsburgh, the listed HDD value is very close to a DOE climatic zone threshold value (e.g., 4954 [46 HDD from 5000] and 5957 [43 HDD from 6000], respectively—less than 1% in each case).
3. However, according to the *1981 ASHRAE Handbook—Fundamentals* data, the HDD values for both cities actually depend on which weather station is used. Further, if another station (e.g., the airport) were to be used, the HDD value would cross the HDD threshold between climatic zones. It is also worth noting that the measured HDD value for a city or urban location is usually lower than that at an airport location.
4. If recent data from the Pennsylvania Climatologist (web data source) were to be used then, as shown, the HDD values of at least four cities (Reading, Lancaster, Erie, and Bradford) would have to be revised, and in each case a climatic zone threshold would be crossed.
5. For energy conservation planning purposes, it might also be better to use the sum of HDD and CDD values rather than HDD alone. As shown in Table 2, the climatic zones 10 and 11 would range from a total DD value of 6000 to 6499, zones 12 and 13 from 6500 to 6999, and zones 14 and 15 from 7000 to 8500.

For the purposes of simplicity, brevity, and equity, there is every reason to support a reduction in the number of climatic zones in Pennsylvania from six to three "space conditioning energy consumption" zones. For the purposes of the revised, prescriptive, Pennsylvania-oriented Chapter 11, it is recommended that Table 3 be used. Figure 2 clearly shows the virtues of this climatic zone distribution.

Part 3—Code Development

This project comprised the drafting of the PHRC PA-Alternative Chapter 11, Code for the Conservation of Space Conditioning Energy for Housing in Pennsylvania. This alternative chapter has not yet been formally approved and is not discussed here.

Part 4—Code Comparison

This project involved the development of a clause-by-clause comparison of the International Residential Code, Chapter 11, Energy Conservation, and the PA-Alternative Chapter. This comparison is accompanied by relevant commentary and is a companion document to the PA Alternative Chapter 11 and, for that reason, is not discussed in this paper.

Part 5—Evaluation and Documentation of Equivalence

Thermal Envelope (PHRC Report #70). This report documents a study to compare the energy consumed for space conditioning by representative houses designed to meet five different energy codes, namely:

- **Act 222:** The Building Energy Conservation Act (Act 222 of 1980), and corresponding regulations that created the existing energy-efficiency requirements for buildings in Pennsylvania.
- **2000 IECC, Chapter 5:** Chapter 5, Residential Building Design by Component Performance Approach, Section 502.2.1. On an individual component basis, the 2000 IECC provides performance requirements for building components (walls, floors, ceiling, etc.). These requirements are for the entire component. For example, walls include walls, windows, and doors that are weighted by area to determine the combined thermal transmittance value. This section of the code for northern climates has remained basically unchanged since the 1992 Model Energy Code.

TABLE 2
Climate-Related Data for Pennsylvania

City	Used by DOE*				Proportion of Housing Starts		3 PA Climatic Zones (ΔHDD)	www.ems.psu.edu/PAClimatologist		
	HDD (65ºF)	Design Temp. (ºF)	Housing Starts	IRC 2000 Climatic Zones				HDD (Base 65ºF)	CDD (Base 3ºF)	ΣDD = HDD + CDD
Philadelphia	4,954	14	8,916	10	23%	56.5%	4,500 – 5,499 with Philadelphia at mid-range	4,954	1,101	6,055
Phoenixville	5,198	13	0	11	33.5 %					
Reading	5,198	13	1,303	11				5,796**	759	6,555** (5,957)
York	5,207	12	3,252	11				5,256	860	6,116
Carlisle	5,323	4	1,349	11						
Hanover	5,339	8	961	11						
Harrisburg	5,339	11	1,735	11				5,347	962	6,309
Lancaster	5,339	8	2,419	11				5,584**	780	6,364** (6,119)
West Chester	5,375	13	2,116	11						
Uniontown	5,393	9	91	11						
Chambersburg	5,600	8	1,397	12	28%	41%	5,500 – 6,499 with Pittsburgh at mid-range			
Coatesville	5,633	11	0	12						
Johnstown	5,772	2	314	12						
Allentown	5,815	9	3,143	12				5,785	773	6,558
New Castle	5,892	7	1,122	12						
Pittsburgh	5,957	5	4,937	12				5,968	654	6,622
Williamsport	6,053	7	316	13	13%			6,085	736	6,821
Indiana	6,164	-1	490	13						
Scranton	6,332	5	1,951	13				6,291	539	6,830
Wilkes-Barre	6,332	5	2,352	13						
Warren	6,634	4	175	14	2.5%	2.5%	6,500 – 8,000			
Erie	6,768	9	818	14				6,279**	350	6,629** (7,118)
Meadville	6,883	4	0	14						
Bradford	7,956	-7	0	15	0%			8,067**	136	8,203
			39,157							

* See Report 69.
** Different climatic range from IRC 2000 HDD value.

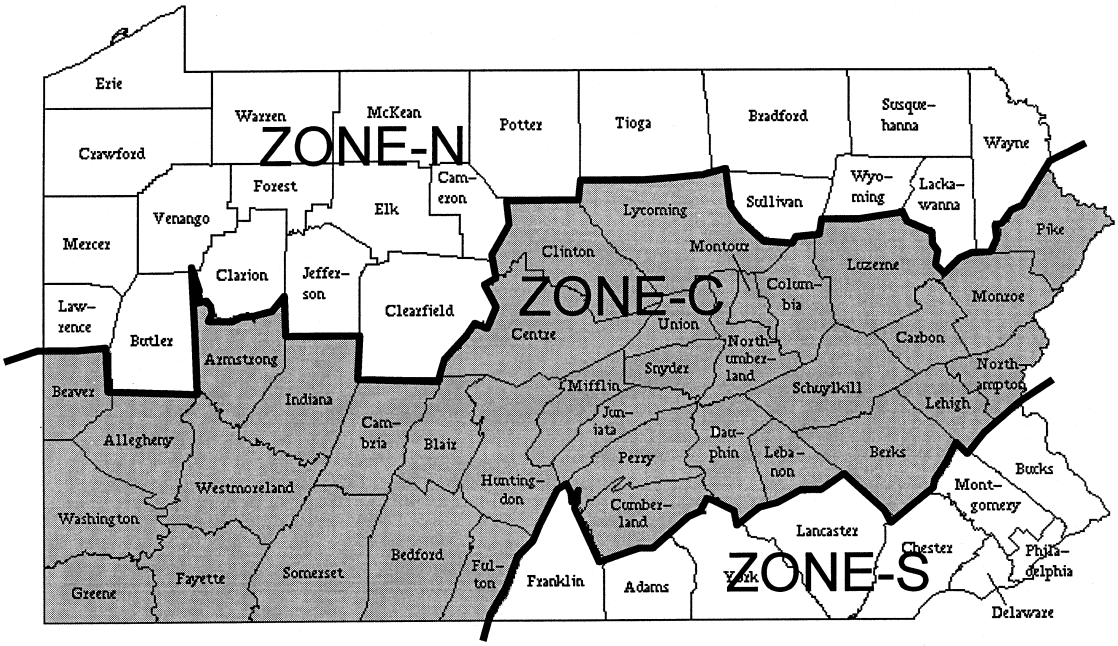

Figure 2 *Climate map for Pennsylvania.*

- **IRC 2000, Chapter 11:** Chapter 11, Energy Conservation, of the IRC 2000. This code is based on 15% window-to-wall area for detached houses and is essentially the same as Chapter 6, Simplified Prescriptive Requirements for Residential Buildings, Type A-1 and A-2, of the 2000 IECC.
- **NAHB Proposed Chapter 11:** The proposed code developed by the National Association of Home Builders (NAHB) as a replacement for the existing Chapter 11 of the IRC 2000.
- **PHRC PA-Alternative Chapter 11:** The PA-Alternative Chapter 11 developed by the PHRC.

The primary purpose of this study was to demonstrate equivalence between the PHRC PA-Alternative and Chapter 5 of the 2000 IECC and, thus, Chapter 11 of the IRC 2000.

A comprehensive standard thermal envelope comparison was performed using the overall heat loss (U_o) calculations and methodology as presented in "Comparison of Current State Residential Energy Codes with the 1992 Model Energy Codes (MEC) for One and Two Family Dwellings: 1994," developed for DOE by Pacific Northwest Laboratories. This methodology had been used to determine whether the energy codes used in various states met or exceeded the MEC, as required under the Energy Conservation Act (42 USC 6831 et seq.), as amended by Section 101 of the Energy Policy Act of 1992 (EPAct, Public Law 102-486).

The methodology evaluates the overall heat loss coefficient (U_o-value) for two prescribed model houses. For Pennsylvania, the U_o values were then weighted by housing starts in 24 cities and towns across the Commonwealth and for three foundation types. In the PHRC evaluation, the PHRC PA-Alternative, the NAHB proposal, and the IRC 2000 Chapter 11 requirements were compared with the 2000 IECC.

TABLE 3
Table PA 1101.1 Pennsylvania Climatic Zones for Space Conditioning Energy Consumption

Region	HDD Range (65°F)	IRC 2000 Climatic Zones	∑DD Range (65°F)
S – South and Southeast	4,500 to 5,499	10 and 11	6,000 to 6,499
C – Central and Southwest	5,500 to 6,499	12 and 13	6,500 to 6,999
N – North and Northwest	≥ 6,500	14 and 15	≥ 7,000

In order to physically demonstrate the relative difference in overall thermal envelope performance as a result of applying the various codes, the U_o values are presented in Figure 3. Since one purpose of this evaluation was to determine whether the three proposed codes were equivalent to the 2000 IECC (Chapter 5, Residential Building Design by Component Performance Approach, Section 502.2.1, Compliance by performance on an individual component basis), the value for U_o obtained for the 2000 IECC (92 MEC) was used as the baseline, or zero, to establish the percentage difference in each case.

For all practical purposes, the thermal envelope provisions contained within each of the three versions of Chapter 11, namely, the IRC 2000, the NAHB, and the PHRC PA-Alternative, are essentially equivalent, and all exceed the IECC provisions for a glazing ratio of 14.2.

Relative to current practice in Pennsylvania, the adoption of the IRC 2000 and, thus, the 2000 IECC, will have a major impact (an energy savings of about 30%) not only on energy

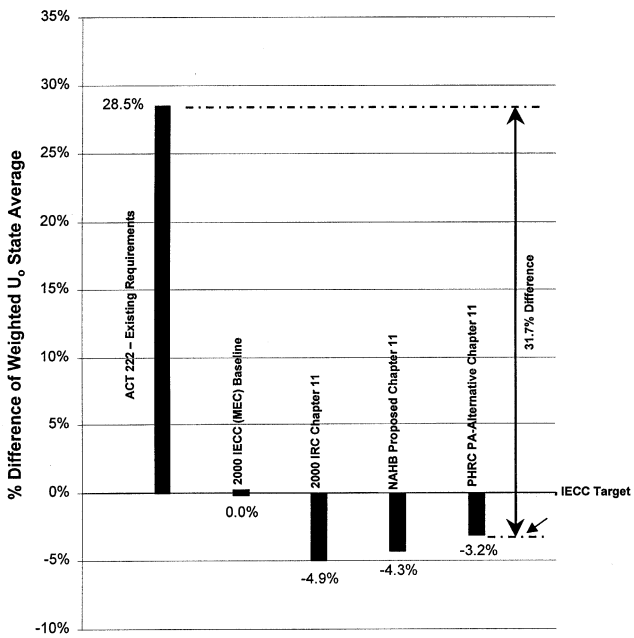

Figure 3 *Thermal envelope comparison—window-to-wall area ratio of 14.2% in all cases.*

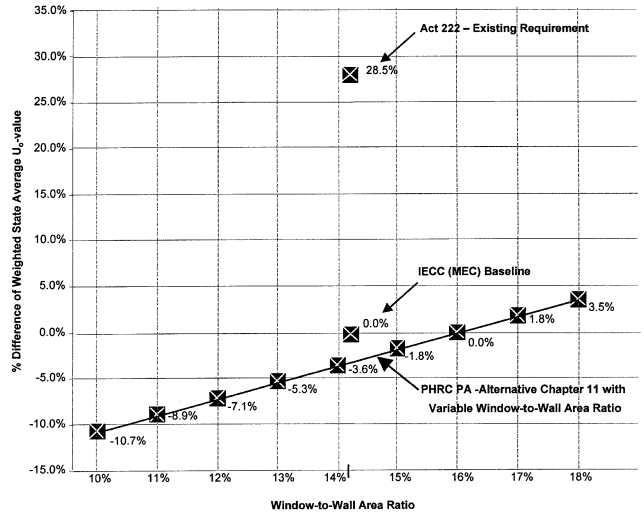

Figure 4 *Thermal envelope comparison for Pennsylvania's compressed climatic zones.*

conservation and construction practices but also on builders, regulators, home buyers, and homeowners.

Considering that the average statewide window-to-wall area ratio for new housing in Pennsylvania is significantly lower than 15% (and thus 14.2%), the energy performance of the thermal envelope of new housing could be expected to be even lower than that shown in Figure 3. To assess the significance of the window-to-wall area ratio with regard to space conditioning energy performance, refer to Figure 4.

For a window-to-wall-area ratio of 14.2%, the PHRC PA-Alternative is 3.2% (see Figure 3) better than (i.e., less than) the 2000 IECC. For a window-to-wall area ratio of 15% (the IRC 2000 threshold), the difference is 1.8%. In Pennsylvania, the average window areas are more likely to be in the 12% range. For a window-to-wall area ratio of 12%, under the PA-Alternative, the difference is -7.1%. These differences indicate that the PA-Alternative would in fact (because the average glazing for the state is probably about 12%) not only be "energy equivalent" to both the IRC 2000 and the 2000 IECC but would, by a not insignificant amount, surpass them. For PA, the extent of space-conditioned energy saving is even greater than the 2000 IECC and IRC 2000 requirements would suggest—some 35% relative to the current Act 222 requirements. Clearly, equivalence, at least for the thermal envelope, has been demonstrated.

Trade-Offs (PHRC Report #71). A number of trade-off opportunities were introduced in the PA Alternative Chapter 11, largely to encourage innovation and to reward enterprising builders/developers who attempt to provide a tighter enclosure and/or introduce high-efficiency appliances and equipment. With each trade-off, we had to ensure space-conditioning energy equivalence. The introduction of trade-offs is a significant improvement over the IRC 2000. The objective of this report was to demonstrate space-conditioning energy equivalence for each set of trade-offs.

The two sets of trade-offs to be evaluated were the following:

1. Low infiltration houses, with less than 0.35 air changes per hour, are permitted one of the following two options:
   - Reduced window and wall thermal resistance requirements
   - Reduced slab-on-grade foundation insulation requirements
2. The installation of high-efficiency HVAC equipment permits one of the following three options:
   - Reduced window and wall thermal resistance requirements
   - Reduced foundation insulation requirements
   - Elimination of basement insulation if basement walls have, on average, fewer than 12 in. exposed wall height above finished grade. This evaluation will apply to the basement regardless of whether the space is conditioned or unconditioned space.

The evaluation of each set of trade-offs for equivalency to the 2000 IECC was accomplished using the DOE-2 (Power-DOE) building performance modeling software, which permits system or whole house assessment. A detailed comparison of the effect of the various trade-offs in the PHRC PA Alternative was made. The effect of these regulatory trade-offs was assessed for five locations in Pennsylvania, including

Erie, Philadelphia, and Pittsburgh. Equivalence was demonstrated and details of this work are contained in a companion paper, presented at this conference.

Part 6 – Steel Stud Framing (PHRC Report #72)

Given the climatic and other conditions that currently prevail in Pennsylvania, it was considered that the design provisions of the IRC 2000 would yield steel-framed wall assemblies with a relatively high probability of a moisture problem. The problem would largely be due to air exfiltration and the accumulation of condensate within the stud space. This work is reported in greater detail in a companion paper presented at this conference.

CONCLUSIONS

The PHRC was offered the rare opportunity to critique and improve one very important chapter in a new national building code—the IRC 2000. In spite of being constrained by time and money and the singular responsibility of impartially and jointly serving the energy consumer and the Commonwealth of Pennsylvania as well as the home building industry, most of the objectives listed in the introduction have been met. The energy provisions contained in the PA-Alternative Chapter 11 are simpler, more rational, more flexible, and, thus, better for Pennsylvania. Moreover, space-conditioning energy equivalence with federal (DOE) strategic policy has been maintained.