Energy Policy 44 (2012) 1–9

Contents lists available at SciVerse ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

# Impact of window selection on the energy performance of residential buildings in South Korea

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ARTICLE INFO

*Article history:*
Received 15 April 2011
Accepted 19 August 2011
Available online 16 February 2012

*Keywords:*
Glazing type
Residential buildings
Solar heat gain coefficient

ABSTRACT

With rapidly increasing energy consumption attributed to residential buildings in South Korea, there is a need to update requirements of the building energy code in order to improve the energy performance of buildings. This paper provides some guidelines to improve the building energy code to better select glazing types that minimize total energy use of residential buildings in Korea. In particular, detailed energy simulation analyses coupled with economical and environmental assessments are carried out to assess the thermal, economical, and environmental impacts of glazing thermal characteristics as well as window sizes associated with housing units in various representative climates within South Korea. The results of the analyses have clearly indicated that selecting glazing with low solar heat gain coefficient is highly beneficial especially for large windows and for mild climates. In particular, it is found that using any double-pane low-e glazing would provide better performance for windows in residential buildings than the clear double-pane glazing, currently required by the Korean building energy code.


## 1. Introduction

In South Korea, 24% (i.e., 1.62 quads, 1.7 EJ) of the total national energy consumption (about 6.78 quads, 7.15 EJ) is used by the building section. In particular, residential buildings consume more than 55% (i.e., 0.92 quads, 0.97 EJ) of the energy used in buildings in South Korea (KEEI, 2006). Windows contribute significantly to both heating and cooling energy consumption of residential buildings. Indeed, a study has estimated that almost 30% (or 0.11 quads, 0.12 EJ) of the total energy needed to condition residential buildings is attributable to heat transfer through windows (Yoo et al., 2005).

The existing building energy code of South Korea requires threshold thermal performance for specific building envelope components (including exterior walls, roofs, floors, interior walls, windows, and doors) for three climatic zones (Central, Southern, and Cheju Island) as illustrated in Fig. 1. The current Korean energy efficiency code is applicable to any building type including commercial, residential, or mixed-use buildings. For windows, the code specifies *U*-factor requirements for the combined glazing and framing using a total window *U*-value. In particular, the current code requirements for total window *U*-values are 0.52 Btu/h ft$^2$ °F (3.0 W/m$^2$ K) for the central regions, 0.58 Btu/h ft$^2$ °F (3.3 W/m$^2$ K) for the southern regions, and 0.74 Btu/h ft$^2$ °F (4.2 W/m$^2$ K) for the Cheju Island region. In the future, the South Korean government plans to develop a building energy code specific to residential buildings and may impose the use of low-e and triple glazing.

For any building, windows can provide visual amenity to occupants and improve esthetic and good appearance to the building exterior. In terms of thermal impact, windows can either decrease or increase space heating loads through solar heat gains or conduction heat losses, respectively. In South Korea, several newly constructed buildings are characterized by large windows and high window to wall ratios. In order to reduce the thermal impact of these large windows, there is a tendency to use low-e glazing for new constructions. Low-e glazing with high solar heat gain coefficient is suitable for the heating dominated climates. However, glazing with low heat gain coefficient is desirable for cooling dominated climates.

Several studies have been reported to help designers select suitable window systems for buildings. A study by Apte et al. (2003) indicated that low-e windows typically saved about 40% of building energy use attributable to windows in most US climates. The same study found that dynamic and ultra-efficient windows (with a *U*-factor of about 0.10 Btu/h ft$^2$ °F (0.57 W/m$^2$ K)) and SHGC of 0.10–0.35 technologies can use as little or less energy than a home with no windows. In particular, dynamic windows, with solar heat gain properties that vary with the season, are

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doi:10.1016/j.enpol.2011.08.046


**Fig. 1.** Climate zones in South Korea.

found to offer significant potential in reducing peak demands in northern and central US climates, while static windows with very low solar heat gain properties offer the most potential in southern climates. Another study by Arasteh et al. (2007) found that in heating-dominated climates such as Minneapolis, Salt Lake City, and Washington D.C., windows with a *U*-factor of 0.10 Btu/h ft$^2$ $^o$F (0.57 W/m$^2$ K) can be energy neutral with solar heat gains offsetting conductive losses during the winter. It is also found that dynamic windows, with the ability to modulate solar heat gain coefficient from a high value during the heating season to a low value during the cooling season, can be net energy producers in mixed climates with both heating and cooling seasons. A life cycle assessment analysis of an advanced window system found that an electro-chromic glazing can be suitable for cooling dominated climates with a potential of providing 55% of energy savings (Papaefthimiou et al., 2009). Singh and Garg (2009) carried out a detailed energy analysis to develop an energy rating model to select window glazing for buildings in India. Ten different window systems, including single clear glazing and double low-e, absorbing film coated and reflective film coated glazing, were considered in the analysis. The results of the energy analysis indicated that a double reflective film coated glazing achieved 17–22% energy savings in cooling dominated regions but 13–27% energy increases in heating dominated regions. Double low-e coated glazing was recommended to reduce building energy use in cold climates. The effect of solar energy transmittance through the rooms in residential buildings in Iran has been investigated for selected combinations of glazing systems and overhang configurations (Ebrahimpour and Maerefat, 2011). The results of the study indicated that single clear pane glazing with overhangs or side fins lead to the reduction of building energy use equivalent to high performance glazing. However, double low-e glazing window was found to be the most energy efficient option. Gasparella et al. (2011) have evaluated the impact of glazing systems and window sizes on thermal performance of well insulated residential buildings in central and southern European climates. They concluded that triple glazing provides the best energy performance. Moreover, they found that windows with low thermal transmittance would reduce building energy use in wintertime but would increase energy consumption during summertime.

For South Korean residential buildings, Leigh and Won (2004) found that the impact of the glazing type on cooling loads is rather small, but significant on heating loads. For instance, the heating load of a south-oriented house with double low-e glazing is half that of a south-oriented house with single glazing. Based on the results of their analysis, Leigh et al. suggest using low-e glazing to achieve both heating and cooling energy savings. Similar studies were conducted by Kim et al. (2004) and Mun et al. (2007) to evaluate thermal performance of low-e glazing for office buildings. In particular, Kim et al. have suggested the use of clear low-e glazing in mixed heating and cooling climates and tinted low-e glazing in cooling dominated climates.

In this paper, the results of a detailed analysis are described to evaluate the impact of thermal properties of glazing on both heating and cooling of prototypical residential unit in various South Korean climates and window distributions. General guidelines are then developed to help designers select the proper glazing for residential buildings in order to minimize the energy impact of windows. First, the energy analysis approach is described. Then, a summary of the analysis results is provided.

## 2. Analysis approach

To analyze energy performance of various window glazing types, features of a prototypical housing unit such as floor area, orientation, window-to-wall ratio (WWR), and aspect ratio were defined using results from previously published surveys and studies. According to a survey of residential buildings in South Korea, the average housing unit have an area of 1076 ft$^2$ (100 m$^2$), an aspect ratio of 1:1.2, and 1-story south-ward orientation (Jang et al., 2004). The average WWRs for each orientation are 45% in the South, 15% in the North, 10% in the East, and 10% in the West (Kim et al., 2001) while the lighting power density (LPD) is 1.21 W/ft$^2$ (13 W/m$^2$) (Leigh and Won, 2004). Tables 1 and 2 summarize the basic features of the prototypical housing unit used in the energy analysis. As indicated in Table 1, a gas furnace is used for heating (efficiency=80.6%) and DX coil (COP 2.86) is used for cooling. The thermostat set-point for heating is 68 $^o$F (20 $^o$C) and for cooling is 82.4 $^o$F (28 $^o$C). Table 2 lists the thermal characteristics of the building envelope and the values in parenthesis presents the guidelines based on the Korea energy efficiency code.

The housing unit features outlined in Tables 1 and 2 are used to model the prototypical unit using DOE-2 (Winkelmann et al., 1993), a detailed hourly building energy simulation tool. In the simulation analysis, the size and the glazing properties are varied to model various potential window configurations for the prototypical housing unit. In particular, WWR is varied from 10 to 30% with 10% increment. The glazing thermal properties including SHGC and *U*-factor are varied from 0 to 1 with 0.1 increments so a total of 300 window configurations are considered for each climate. Two cities Inchon and Ulsan are selected to represent