A Study of Household Energy Efficiency for Space Heating in New England Region

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Abstract

Factors that could affect New England residential energy intensity (the ratio of energy consumption to some measure of demand for energy services) for space heating were examined in order to estimate energy efficiency and make suggestions for energy conservation. Residential space heating energy intensities across housing types and building age were found to be significantly different. Residential space heating energy intensities, however, do not vary significantly among households of different annual income, ownership, and ways of utility payment. The results imply that housing type has a major influence on energy intensity and efficiency for space heating. Encouraging energy efficient housing types in land use planning will be one potential effective measure for energy conservation.

Introduction

Rise of energy consumption has led to an increase in emissions of carbon, sulfur, and nitrogen oxides, which have been linked to global warming and acid rain. In the United States, residential energy use constitutes of 21% of total energy consumption, more than 50% of which is for space heating.

Rapid urban sprawl and increasing dominance of single-family houses in the last few decades gives rise to the question of energy efficiency, as single-family houses generally have low volume-to-surface ratios. My original hypothesis is that single-family houses are among the least energy efficient of all housing types.

Data and Methods

1. The 1997 Residential Energy Consumption Survey data were obtained from the Energy Information Administration website; 476 records of New England households were selected for further analysis.
2. Total annual space heating energy for each household was calculated by summing the space heating energy use by fuel type:
   E = E (electricity) + E (natural gas) + E (fuel oil) + E (kerosene) + E (propane)
3. Total annual space heating energy for each household was divided by heating degree days (HDD) of the local area in 1997 to adjust for climate variation.
   E (weather adjusted) = E / HDD
4. Two indicators of energy intensity were then developed using the following formulae:
   Indicator1 = E (weather adjusted) / Household heating space area
   Indicator2 = E (weather adjusted) / number of members in the household

In this study, "energy efficiency" is measured through the use of these surrogates of "energy intensity." Energy intensity is considered here to be inversely proportional to energy efficiency.
   Energy efficiency $\propto$ 1/energy intensity

5. Box plots, ANOVAs, and regression techniques were applied to test the hypothesis. Factors such as building age, annual household income, ownership and ways of utility payment were also examined to see if they have influence on energy intensity for space heating.

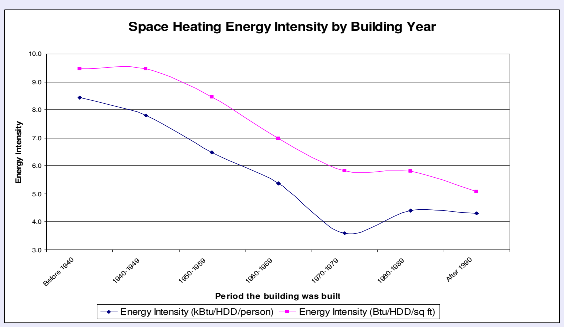

Fig.3. Household annual space heating energy intensity by building age.

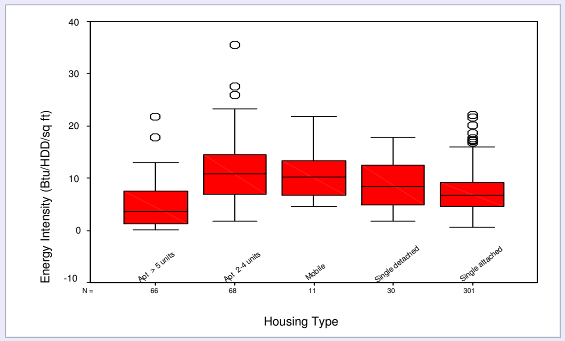

Fig.1. Boxplot of household annual space heating energy intensity (Indicator1).

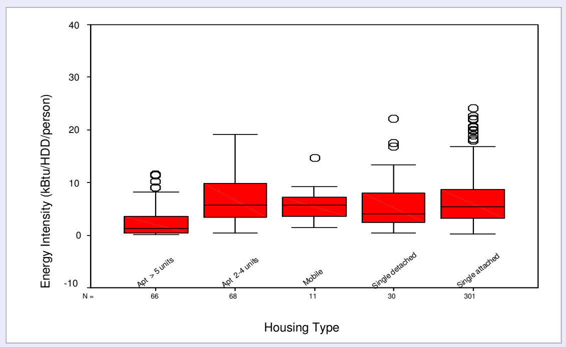

Fig.2. Boxplot of household annual space heating energy intensity (Indicator2).

Tab.1. Mean household annual space heating energy intensity and mean heating space area by housing type.

	Apt >5 units	Apt 2-4 units	Mobile homes	Single Attached	Single Dettached	ANOVA test significance Value
Mean Energy Intensity (Btu/HDD/sq ft)	5.03	11.69	10.86	9.05	7.38	0.00
Mean Energy Intensity (kBtu/HDD/person)	2.66	7.04	6.05	6.45	7.05	0.00
Mean Heating Space (sq ft/person)	456	588	594	635	982	0.00

Literature Cited

Energy Information Administration. "Measuring Energy Efficiency in the United States' Economy: A Beginning". [HTTP://www.eia.doe.gov/emeu/efficiency/ee_report_html.htm] (Jan 23, 2003).

Results

The means of energy intensity for space heating are statistically different across housing types using both energy intensity indicators (See figure 1, figure 2, and table 1). In the regression model, housing type and building age explain 21.4% of the total variation of household space heating energy per square foot (See figure 4).

ANOVA tests (not all shown here) also suggest that space heating energy intensities are not statistically different by household income, ownership, and ways of utility payment at a significance level of 5%.

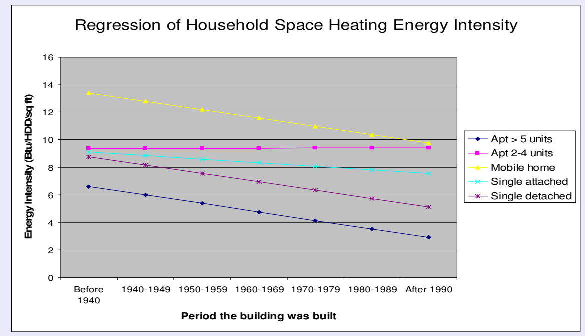

Fig.4. Regression of household annual space heating energy intensity (Indicator1) against building age (R square = 0.214).

Discussion and Conclusions

Buildings with more than five units are the most energy efficient of all housing types. One reason for this may be that they have lower volume-to-surface ratios. Buildings with 2-4 units, on another hand, are relative inefficient. This may suggest that some buildings with 2-4 units are not well insulated or their heating system efficiency can be improved. Counter-intuitively, single-family houses, mostly built within the past 20 years, turn out to be the second most efficient in terms of Indicator1, energy consumption per square foot. This is probably due to better insulation building materials and more efficient heating systems. Single-family houses, however, are the least efficient in terms of Indicator2, per capita energy consumption due to high per capita heating space. An interesting phenomenon is the variation within a same housing type or buildings constructed within the same period. A reason for this variation may be the effects of different human behavior, such as the duration of time spent at home, preference for room temperature and so on. Future studies can have a closer look at building structure and human behavior.

Results from this study may be considered by policy makers, developers, and consumers with regard to options that encourage energy efficient housing development. For cities such as Worcester where 4000 or so old apartments with 2-4 units exist and growth of single-family houses continues, this study suggest the need to explore possibilities for upgrading old houses and heating facilities and changing human behavior in order to improve energy efficiency and conservation potential.

Acknowledgments

This research was made possible through the support of the Center for Integrated Study of the Human Dimensions of Global Change, National Science Foundation and HERO network.

I would like to thank Professor Samuel J. Ratick for guidance. I would also like to thank Professor Robert J.Pontius, Post Doctor Researcher Ke Chen for additional support .