IMPACT OF ENVELOPE EFFICIENCY, HEATING SYSTEM TYPE AND DOMESTIC HOT WATER SYSTEM TYPE

Mary Fagerson, Jane Ubbelohde, and Jessica Shaten
Minnesota Cold Climate Building Research Center
University of Minnesota, and
David Robinson, Robinson Technical Services

INTRODUCTION

In 1987 the Energy Division of the Minnesota Department of Public Service initiated a data collection project to fill gaps in existing data on energy consumption in Minnesota multifamily buildings. Existing data, collected by the Minneapolis Energy Office and the Energy Resource Center in St.Paul, was limited primarily to buildings within the city limits of Minneapolis and St. Paul. The goal of this project was to collect data on buildings representing the suburban Twin Cities and greater Minnesota areas and representing a range of heating system types.

Initial one page questionnaires were mailed to building owners who were on mailing lists provided by the Minnesota MultiHousing Association, the Department of Housing and Urban Development, the Minnesota Housing Finance Agency, and the Farmers Home Administration. The questionnaires were intended to identify owners willing to participate in the study and the basic characteristics of their buildings. A second 7-page questionnaire was then mailed to those responding to the first questionnaire. This questionnaire sought more detailed data on general building characteristics, the building envelope, the mechanical system, auxiliary energy consuming equipment or building features, building occupancy, fuel sources and end uses as well as signed releases for utility records. Utility records were then requested from the utilities supplying these buildings.

This study looks at both gas and electricity accounts which provide space heating in the buildings. Buildings which had all or part of the space heating provided by propane or oil were rejected due to the difficulty in analyzing the consumption of these fuels.

The compilation and analysis of these data are being carried out by the Minnesota Cold Climate Building Research Center at the University of Minnesota. One hundred and fifty-nine first questionnaires and 95 second questionnaires were returned. Complete utility records for space heating fuels fulfilling the analysis requirements were received for 103 buildings. The utility records were analyzed using the Princeton ScoreKeeping Model (PRISM) (Fels, et.a., 1986).

This paper reviews the results from the preliminary analysis of the relationship between the Normalized Annual Consumption (NAC), provided by the PRISM analysis, and variables which describe portions of the envelope and mechanical systems. These variables include:

1) envelope conductive heat loss rate(BTU/DD),
2) heating system type, and
3) domestic hot water type.

SUMMARY OF DATA

Preliminary analysis was carried out on 99 Buildings. Seventy of these buildings are located within the Minneapolis - St. Paul greater metropolitan area. Sixteen of the buildings are located in the southern one-third of the state, while the remainder are located in the central and north central regions. Fifty-three percent of these buildings are subsidized.

There is a wide variation in the size of the buildings in the sample. The number of rental units per building ranges from 4 to 264 with 80% of the buildings having between 12 and 50 units and 8% of the buildings having 100 or more units. For the majority of the sample the unit of analysis is a building. However, there are two complexes included in the sample which had only one gas and one electric account so that consumption on a per building level was not possible. One complex has 3 buildings and 306 units while the other has 2 buildings and 104 units.

The majority of the buildings are heated with natural gas. Three of the 99 buildings in the preliminary anaylsis use electricity in the form of baseboard heating systems. The 96 buildings heated with natural gas have boilers, 3 of these with steam distribution systems. The remaining 93 have hot water distribution systems. The proportion of steam heated buildings in this sample of suburban Twin City and greater Minnesota buildings is markedly different from that found within the city of Minneapolis where between 57% and 59% of multifamily buildings included in the "Preliminary Baseline Data" (Hewett et. al.) are assumed to be heated with steam distribution systems. Figure 1 compares the numbers of buildings in this study utilizing these two distribution systems and the presence or absence of cutout and reset controls on the boilers.

Fifty-three percent of the buildings have mechanically driven hallway ventilation and 89% have individually controlled thermostats in each unit.

Four types of domestic hot water systems are represented in the study: tank type, heat exchanger in a primary space heating boiler, heat exchanger in a secondary space heating boiler and a separate DHW boiler with storage tank. Figure 2 compares the numbers of each of these and the presence or absence of recirculation loops in the sample buildings.

A conductive heat loss rate(BTU/DD) was calculated for each building and used as a variable in the analysis. For visual comparison of the relative efficiencies of the sample buildings, this value was divided by the floor area of the building to yield a Thermal Integrity Factor (TIF in BTU/ft2.DD). Figure 3 shows the distribution of the TIFs in the sample. This provides an indication of the relative efficiencies of the building envelopes in the sample.

DERIVATION OF THE ENVELOPE CONDUCTIVE HEAT LOSS RATE

The conductive heat loss rate for each building was estimated using a simple rectangular building model, and self-reported building envelope data. This included information on the type and thickness of insulation in the walls, roof and foundation, the number and type of windows, the floor area and the number of stories in the building. A fixed building width of 52 feet (two 24 foot apartments, plus a four foot hallway between

them) was assumed. Building length and height were calculated from the total number of floors (assuming nine feet between floors) and the total floor area reported. The glazing area was estimated from the number of regular and picture windows and the number of patio doors. The calculation was completed by summing the "UA" values for each above and below grade surface of the building envelope (except below grade floors). Losses for slab on grade floors were based on ASHRAE perimeter loss rates.

ANALYSIS

Multiple regression was carried out using the Normalized Annual Consumption (NAC), expressed in BTUs, as the dependent variable. The initial analysis explored the impact of the following variables on the NAC: heating system type, domestic hot water type and envelope conductive heat loss rate.

A total of 90 cases were included in the initial analysis. Nine cases were deleted from the analysis. Some of these were deleted due to lack of or questionnable data. Also the 4 buildings with over 10 stories and those with extremely high energy consumption were dropped from this analysis. Since only one steam heated building remained it was also dropped.

The analysis indicated that the envelope conductive heat loss rate explains almost 60% of the variation in the NAC. Figure 4 shows a scatterplot of the NAC versus the heat loss rate. The strong relationship between these variables is evident. Both the type of heating system and the type of domestic hot water system also have a significant impact on the predicted NAC accounting for 4% and 11% of the variability.

DISCUSSION

Envelope Conductive Heat Loss Rate

It is somewhat reassuring to find that the calculated envelope heat loss rate is so significant. It is not clear whether this is due primarily to its ability to account for the size of the building instead of the insulating value of the envelope. A fortuitous error in the early stage of the analysis suggests that the glazing heat loss rate may be a significant predictor of the NAC. Further analysis will explore this.

Heating Systems

This analysis includes 87 hot water heated buildings and only 3 electrically heated buildings. A larger sample of electrically heated buildings is desireable. Records for electrically heated buildings are difficult to obtain. We will attempt to collect records for more electrically and steam heated buildings to increase these segments of the sample.

Domestic Hot Water Systems

The type of domestic hot water system appears to have a significant impact on the total energy consumption of the building. Typically DHW consumption is one third of total energy consumption. The type of DHW system is only one factor in hot water consumption. The number of occupants in the building is also known to be strongly related to hot water consumption. This variable will be considered in future analysis.

Further exploration will also attempt to rank the four systems in order of relative efficiency.

Deleted Cases

Buildings with more than 10 stories, high energy consumption and heated with steam distribution systems will be included in future analyses.

CONCLUSIONS

The calculated variable, conductive heat loss rate of multifamily buildings in this study, is a very significant determinant of their space heating fuel consumption, accounting for almost 60% of the variability in the NAC. The type of heating system and domestic hot water system account for 4% and 11% of the variability respectively.

Further analysis of this data set will explore the impact of insulation levels, glazing areas, number of stories, number of occupants, occupant age, relative effectiveness of the DHW systems, heating system controls such as outdoor reset and cutout and thermostats, and hallway ventilation.

REFERENCE

Hewett, Martha, Timothy Dunsworth, Carla Holmen, "Preliminary Baseline Data For Multifamily Buildings in Minneapolis," Minneapolis Energy Office.

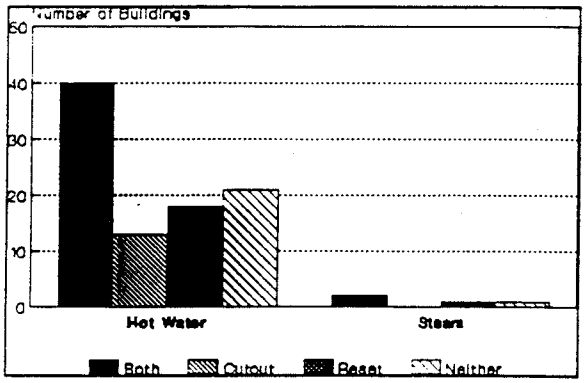

Figure 1. Distribution of Hydronic Heating Systems: Over 90% of the buildings are heated with hot water systems. Two thirds have either outdoor reset or cutout controls or both.

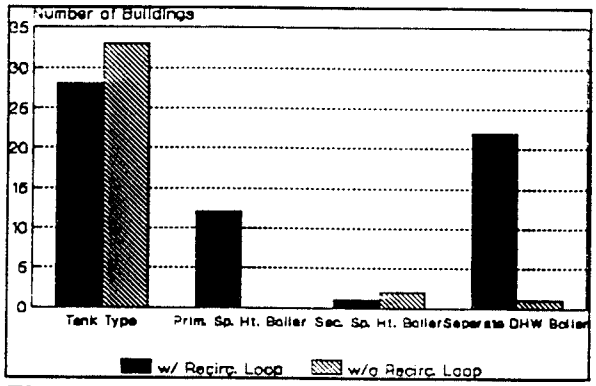

Figure 2. Distribution of Domestic Hot Water Systems. Sixty percent of the buildings have tank type heaters. Almost 2/3 of the buildings have recirculation loops.

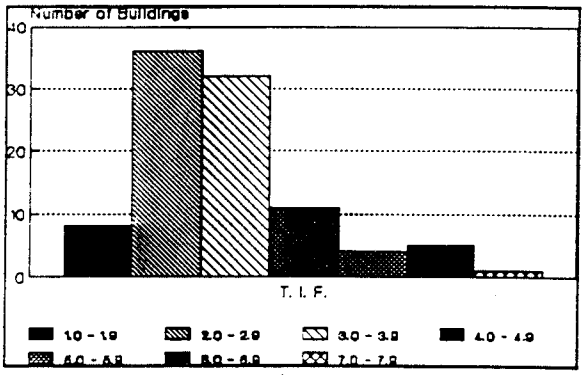

Figure 3. Distribution of Calculated Thermal Integrity Factors (BTU/FT2.DD) (conductive loss only). Two thirds of the buildings have envelope conductive heat loss rates between two and four BTU/FT2.DD.

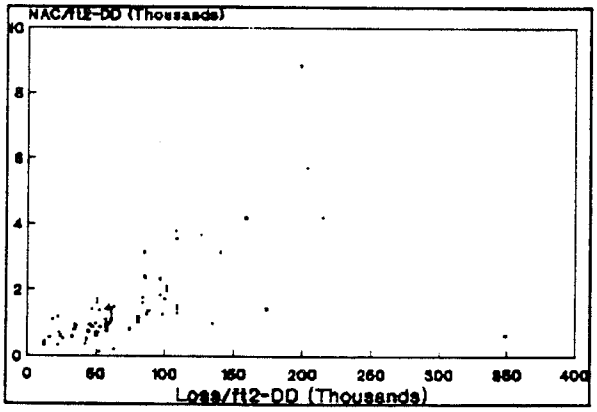

Figure 4. Envelope Conduction Heat Loss Rate (BTU/DD) vs NAC. The calculated heat loss rate explains almost 60% of the variability in the NAC.