{ TC "'CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS'" \l 1 }CHAPTER

SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary{ TC "6.1 Summary" \l 2 }

The thesis examined energy savings from two general types of energy saving measures in commercial buildings. The first of these was the addition insulation to roof, walls and building perimeter required by ASHRAE Standard 90.1 The second was the addition of daylighting to a retail building. Computer simulations were developed to provide estimates of the energy savings of each of these types of changes to building envelopes.

Detailed models of losses through slab-on-grade foundations were developed to assess the energy savings associated with adding perimeter insulation to the commercial buildings. A two-dimensional finite-element model was used to predict the heat transfer through different insulation configurations in five climates. The slab losses agreed well with the results from BASECALC™, a computer program designed by CANMET, Natural Resources Canada. They differed significantly, however, from results given by simplified methods in ASHRAE Fundamentals.

Computer simulations were developed based on construction data from two commercial buildings in Madison, Wisconsin. These models included very detailed information on the construction and thermal characteristics of each zone in the building, scheduling of internal loads, external shading of building elements, and interactions between lighting and HVAC equipment. Equipment models were also developed to model the performance of heating and cooling equipment as a function of equipment loads and outdoor conditions.

A new TRNSYS component was developed to model the performance of a water-loop heat pump system in the office building. The model used sub-components to individually simulate the performance of heat pumps, boilers and a cooling tower that made up the system.

The two computer models were validated using monthly utility data from 1994. Energy use estimates from the models showed good agreement with actual billing data from the two buildings.

A life-cycle savings method was used to evaluate the cost effectiveness of building envelope changes required by ASHRAE Standard 90.1. The method was also used to determine what levels of roof, wall and perimeter insulation would offer the greatest cost savings to building owners.

Daylighting models were developed for the retail building to assess the energy savings from skylights and roof monitors. The primary energy savings from these measures result from dimming or turning off electric lights when daylight is able to provide enough light. Energy savings also result from lower cooling loads in the building due to decreased internal gains from lighting. The building models were able to estimate the energy savings from both of these effects.

6.2 Conclusions{ TC "6.2 Conclusions" \l 2 }

The energy and cost savings resulting from meeting the prescriptive version of the ASHRAE Standard 90.1 were found to be significant. In both of the buildings studied, building owners would have saved money had the buildings been built to comply with the standard. The simple payback period for individual measures required by the code varied over a wide range. Some measures would have paid for themselves instantly, in cooling equipment cost savings. Other measures had payback periods up to 24 years. Taking all the required measures together yielded payback periods of 6 to 8 years.

The energy savings resulting from complying with Standard 90.1 were primarily due to decreased heating loads in the buildings. Both buildings used natural gas as the primary source for heating energy. Because natural gas is cheaper than electricity on a unit energy basis, the energy savings from complying to the code had lower cost savings for building owners than would have resulted from cooling load savings.

The results of the insulation optimization indicated that levels of wall insulation greater than those required by ASHRAE Standard 90.1 would be beneficial to building owners. In eight of the ten cases tested, the life-cycle savings were maximized by a level of wall insulation greater than that required by the standard. The difference between the optimal and the required amounts were most striking in the cases of the retail building in Phoenix and Miami. In those cases the standard had no requirement for wall insulation, but the optimum level was found to be over six inches of batt insulation.

The level of insulation required by the ASHRAE standard for roofs and building perimeters is close to the optimal level found by maximizing life-cycle savings. The results for roof insulation were inconclusive, with the level recommended by ASHRAE being sometimes greater than, and sometimes less than the optimum. For perimeter insulation, the thickness required by ASHRAE was usually the same as the optimum found by maximizing life-cycle savings. In cases where the required insulation was different from the optimum, the difference in life-cycle savings was small.

Sensitivity analyses were conducted to determine which economic assumptions were the most influential in determining the optimal level of roof and wall insulation. Variations in the assumptions for roof and wall insulation cost were found to cause the greatest change in the optimal level of insulation. The period of the analysis was the least influential variable in the analysis.

Skylights were found to be an economic way to add daylighting to retail buildings. In each of the five locations studied, skylights were found to pay for themselves in 2 to 3 years. In Madison, Seattle, and Washington DC, adding skylights and dimmable lighting reduced peak cooling loads in the building. In Phoenix and Miami, skylights added to peak cooling loads but in each of the locations, the skylights led to an overall decrease in electricity consumption. The optimal size of skylights was found to be from 2 to 2.5% of the gross ceiling area of the building.

Sawtooth roof monitors were found to be a cost effective method for daylighting in four of the five locations tested. The life-cycle savings of roof monitors were, however, less than the life-cycle savings from skylights.

Like skylights, roof monitors reduced peak cooling loads in Madison and Washington DC, but increased them in Phoenix and Miami. However, in each of the locations where monitors were cost effective, they led to an overall decrease in electricity consumption. The optimal glazing area for roof monitors in the three climates where they were most cost effective was from 3.5 to 4% of the gross ceiling area of the building.

The daylighting measures offered payback periods equal to or less than the insulation measures required by ASHRAE Standard 90.1. Daylighting measures yielded cooling energy savings, and decreased electricity bills, while ASHRAE code compliance mainly provided energy savings from heating loads met with natural gas. Should energy planners want to focus more on electricity savings rather than natural gas, one way to do it would be to facilitate or regulate the installation of more daylighting in commercial buildings.

6.3 Recommendations{ TC "6.3 Recommendations" \l 2 }

ASHRAE Standard 90.1 provides a daylighting credit for skylights and perimeter daylighting. However, it does not offer a daylighting credit for roof monitors or clerestories. The standard should include a similar credit for these options that can provide cost effective ways of saving energy in commercial buildings.

ASHRAE Fundamentals currently offers a simple method for calculating the heat loss through slab-on-grade foundations. The method only includes a few different configurations and climates. The results of these methods differed substantially from the results of the finite element models used in this thesis. As building shells become tighter, the heat losses from slabs and foundations become more important. It may be time to update the methods used for simple calculations of slab and below grade heat losses. A wider array of correlations for different climates, slab configurations, and insulation levels seems warranted.

The office building studied in this thesis includes a water-loop heat pump system. This system has a number of components that are interdependent. The performance of each component depends on the output from other components and may be effected by the size of loads and outdoor air conditions. The optimal method for controlling such a system is not an obvious choice. The models developed in this thesis would provide a good basis for further research to determine the best way to control a water-loop heat pump system.

TRNSYS Type 56 could be improved to facilitate the parametric study of building designs. Currently, some inputs to Type 56 must be constants, and cannot be input from the TRNSYS Deck. Window areas, for example, must be constants in the building input description file. If these could be inputs, it would make it much easier to examine how heating and cooling loads are effected by changes in building design. To make this change possible, BID, the Building Input Description preprocessor, would have to be run by the TRNSYS deck at the start of each building simulation.

The models used in this analysis have shown that TRNSYS can be used to study daylighting and its effects on heating and cooling loads in commercial buildings. The flexibility of TRNSYS would allow it to accommodate a more detailed method for daylighting analysis. A potential area for further research would be to investigate adding a detailed lighting analysis tool, like Superlite, to TRNSYS.