THE ENERGY USE IMPLICATIONS OF DESIGN CHOICES IN COMMERCIAL BUILDINGS

by

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{ TC "ABSTRACT" \l 1 }

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The process of designing a heating and cooling system for a commercial building usually proceeds from building design to design of an HVAC system that can meet the loads in the building. The purpose of this thesis is to focus instead on what can be done to minimize buildings loads, by making the best design choices.

Wisconsin and other states are currently in the process of adopting their building energy codes to conform to ASHRAE/EIS standard 90.1-1989. The Energy Policy Act of 1992 requires that each state develop a commercial building code that is at least as stringent as this standard. This thesis investigates the effect of these revised codes on the energy use of new buildings. A case study of two common building types is used to quantify the effect of the codes on building loads.

The thesis is a case study of two commercial buildings; using an office building and a retail building. These types of buildings were chosen because, together, they make up a large portion of the energy consumption and peak demand in the commercial building stock. For each of the buildings, TRNSYS computer simulations were used to estimate the energy use in the building. TRNSYS decks were created from data gathered from building plans and site visits. The computer simulations were validated using monthly energy bills from the two buildings.

Computer simulations were used to estimate the effect of compliance to the ASHRAE standard on the energy use of the buildings. The building models were modified to include the addition of insulation to roofs, walls and building perimeters that would be required by the code. A life-cycle

savings method was used in conjunction with the building models to determine what level of insulation would be the most cost effective design for the buildings. These optimal levels were compared to the ASHRAE required amount of insulation for five cities in the U.S.

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.

Two daylighting strategies were also evaluated using the retail building model. The TRNSYS deck and building input description were modified to simulate the addition of skylights and sawtooth roof monitors to the building. The building models included both the direct effects of lighting energy savings, and the indirect effects on heating and cooling loads in the building. A life-cycle cost analysis was conducted to determine the optimal area of skylights or monitors to add, and the energy and cost savings associated with each.

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 the installation of more daylighting in commercial buildings.

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{ TC "NOMENCLATURE" \l 1 }NOMENCLATURE

A_i	Area in zone corresponding to segment i
A_s	Gross projected horizontal area of all the skylights
A_w	Area of the workplane
C	Boolean variable for commercial business; 1 if business, 0 if residence
c	Specific heat
COP_{EFF}	Effective COP duel to part load correction
COP	Nominal COP
CU	coefficient of utilization
D	Ratio of down payment to initial investment
d	Discount rate
E	First costs of option to be considered (equipment)
E_i	average incident illuminance on the workplane from skylights
E_0	First costs (equipment) of base case building
E_{xh}	horizontal exterior illuminance on the skylights
F_{ANN}	Annual fuel costs of option to be considered
$F_{ANN,0}$	Annual fuel costs of base case building
F_2	Heat loss per unit length of building perimeter
$h_{a,in}$	Enthalpy of the air entering the cooling tower
$h_{a,out}$	Enthalpy of the air leaving the cooling tower
$h_{w,in}$	Enthalpy of the air/water mixture corresponding to the temperature of the water entering the cooling tower
$h_{w,out}$	Enthalpy of the air/water mixture corresponding to the temperature of the water leaving the cooling tower

i	General inflation rate
i_F	Fuel inflation rate
k	Thermal conductivity
LCS	Life cycle savings, relative to base case building
M_s	Ratio of first year miscellaneous costs to initial investment
m	Annual mortgage interest rate
$\dot{m}_w$	Mass flow rate of the water in cooling tower [kg/s]
N	Total number of segments in slab
N_D	Depreciation lifetime in years
N_e	Period of economic analysis
N_L	Term of Loan
N_{min}	Years over which mortgage payments contribute to the analysis
N'_{min}	Years over which depreciation contributes to the analysis
P	Length of perimeter of building
p	Property tax rate based on assessed value
PLR	Part load ratio
$\dot{Q}_{CT}$	Heat removed from the water in cooling tower
$\dot{Q}_{conv,i}$	Internal convective gains
$\dot{Q}_{coupling,i}$	Gains from adjacent zones
$\dot{Q}_{inf,i}$	Infiltration gains
$\dot{Q}_{surf,i}$	Net heat transfer by convection from all inside surfaces
$\dot{Q}_{vent,i}$	Ventilation gains
q	Local internal heat generation rate per unit volume

$\dot{q}_{slab}$	Total heat loss through slab in zone
$\dot{q}_{slab,i}$	Heat loss through slab segment i
R_v	Ratio of resale value at end of period of analysis to initial investment
T	Temperature
T_{amp}	Amplitude of surface temperature variation
T_{mean}	Mean value of ground surface temperature over year
t	time
ti	Temperature inside building
t_o	Temperature outside building
t_{shift}	Time lag between beginning of year and time of minimum surface temperature
$\bar{t}$	Effective income tax rate
V	Ratio of assessed valuation in first year to the initial investment
α_{soil}	Thermal diffusivity of soil
ε	Effectiveness of cooling tower
ρ	local density
τ	net transmittance of the skylights