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SUMMARY

An energy model of the as-built Farnsworth House was developed to include the dominant envelope characteristics including an open floor space, cubicles located north-east of the open floor space, outdoor exposed floors, an estimated Window to Wall Ratio (WWR) of 95.0%, and overhang on the west fenestration. A baseline retrofit model was developed to include a 39.9m^2 expansion located north of the east elevation to accommodate 2 extra bed spaces, 1 cubicle adjoined to the existing cubicles to serve as a bathroom and a 43.8m^2 2-car garage located south of the west elevation while maintaining the WWR of the as-built model. Default construction and schedules were taken from ASHRAE 189.1 Standard for midrise apartment building while energy performance simulations of both models were run using Chicago-Midway AP TMY weather file [1]. Compared to the as-built model, the retrofit model had 9.23% less Energy Use Intensity (EUI) but 42.8% higher site energy. The dominant annual energy end uses in the retrofit model were heating and cooling loads at 67% and 20% respectively hence analysis of the building's heat energy transportation phenomenon could result in improved energy efficiency.

Table 1. Baseline retrofit model parametric analysis

Measure	Energy Use Intensity Reduction (%)	Electricity Savings (%)	District Cooling Savings (%)	District Heating Savings (%)
Adiabatic exterior floor	34.0	0.0	-11.0	55.0
No infiltration	22.0	0.0	10.0	29.0
1% WWR	18.0	0.0	41.0	15.0
R-99 windows	17.0	0.0	-22.0	32.0
Adiabatic exterior roof	10.0	0.0	4.0	13.0
No lighting	6.0	64.0	12.0	-7.0

Using Open Studio's Parametric Analysis Tool (PAT) an approach similar to that in [2] was adopted to investigate the impact of removing each thermal energy path or source. Table 1 lists the applied parametric measures in descending order of EUI reduction with respect to the baseline retrofit model. Given the high WWR, parametric analysis was carried out on windows but not exterior walls. EUI and district heating reduction showed direct correlation. The greatest heating savings occurred through adiabatic floors and windows as well as eliminated infiltration. The maximum EUI reduction of 34% came from the adiabatic exterior floor. Although the elimination of infiltration reduced the EUI by 22%, natural ventilation in the space may be needed to meet the PHIUS standards [3] for the simulation location. With the WWR reduced to a negligible amount, maximum district cooling savings of 41% was achieved which is attributed to the reduction in solar heat gains. The R-99 window measure increased district cooling by 22% as a result of the counteractive reduced heat losses during warmer periods. All measures resulted in heating energy savings except the exclusion of lighting as a result of the loss of passive heating provided by the lighting fixtures. Despite the 64% reduction in electricity savings from the excluded lighting loads only 6% EUI reduction was achieved.

The parametric analysis shows that the building's energy consumption is weather driven and internal loads have negligible effect on annual consumption. Reduction of window surface area or inclusion of shading systems could reduce solar gains. Also, improved envelope insulation could drive up the cooling load in warmer periods. Manually or automatically controlled windows could be opened to offset the cooling and ventilation loads when the outside air temperature is conducive for such application.

REFERENCES

[1] https://www.energyplus.net/weather-location/north_and_central_america_wmo_region_4/USA/IL/USA_IL_Chicago-Midway.AP.725340_TMY3

[2] Deru, M., P. Torcellini, and S. Pless. 2005a. Energy design and performance analysis of the BigHorn Home Improvement Center. NREL Report No. TP-550-34930. National Renewable Energy Laboratory, Golden, CO. www.nrel.gov/docs/fy05osti/34930.pdf.

[3] https://www.phius.org/phius-2015-new-passive-building-standard-summary