Appendix G

EnergyPlus Model

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G.1 EnergyPlus Modeling Inputs

Building energy models are created for Lab homes A and B, to using EnergyPlus[1]. These models are used to generate annual savings estimates for the highly insulating windows as compared to baseline windows. Building geometry is created in OpenStudio and internal gains and mechanical systems are added through EnergyPlus's interface. Figure G.1 is an image of the model exported from OpenStudio.

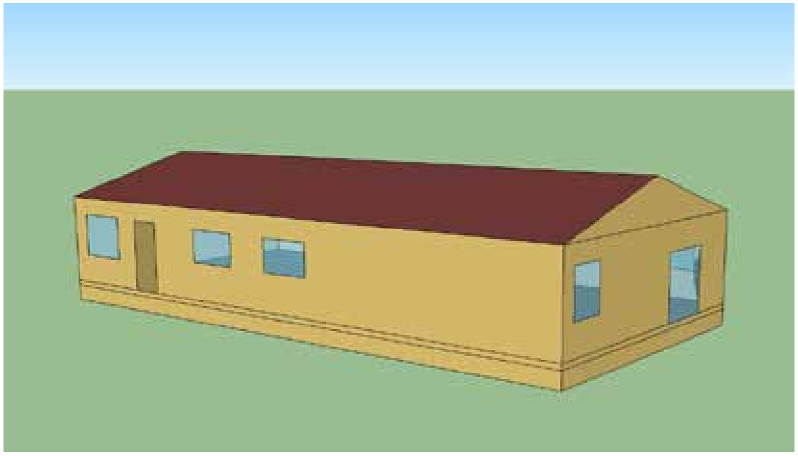

Figure G.1. Building Geometry Exported from OpenStudio

The mechanical equipment, internal gains, and ceiling, wall, and floor insulation levels are the same for the two homes. Lab Home B is fitted with highly insulating windows. Table G.1 below summarizes envelope properties for Lab Homes A and B.

Table G.1. Envelope Insulation Levels

	Lab Home A	Lab Home B
Ceiling Insulation	R-22	R-22
Wall Insulation	R-11	R-11
Floor insulation	R-22	R-22
Window U-factor	0.68	0.20
Window SHGC	0.70	0.19
Window VT	0.73	0.36

Infiltration is modeled through a model based on the Sherman-Grimsrud equations. The model requires effective leakage area (ELA) specified for the whole house and calculates the impact of infiltration based on wind and stack coefficients. Like any empirical relationship, this model is representative of an average home and the actual measured impact of infiltration may be different from the impact estimated by the model.

[1] http://apps1.eere.energy.gov/buildings/energyplus/

The ELA can be derived from the results of the blower door tests. The values used in the model are representative of the measured building leakage after the windows installation. Blower door test results are converted to EnergyPlus inputs using the equations below. Table G.1 summarizes the total house ELA for the baseline and the experimental home.

Conversion equations:[2]

$$C_{ela} = \frac{cfm50}{50 ** 0.65} \quad (1)$$

$$ELA = 0.2833 * C_{ela} * (4 ** 0.65) \quad (2)$$

Table G.2. ELA Input to EnergyPlus

	Baseline Home (Lab Home A)	Experimental Home (Lab Home B)
C_ela	55.66	51.51
ELA (in.2)	38.83	35.93

The heating, ventilation, and air conditioning (HVAC) system is modeled as a single-speed heat pump with a Seasonal Energy Efficiency Ratio (SEER) of 13 and electric resistance backup heat.

The measured data between February and August consists of various periods where internal gains, heat pump operation mode and zone thermostat set-points are varied. Two sets of EnergyPlus models, one for Lab Home A and one for Lab Home B, are created to match the temperature set-points, heat pump operating modes and internal gains for each test period resulting in an expanded set of 14 models.

Figure G.2 through Figure G.5 show various daily schedules used in the model. Table G.2 summarizes the peak power value associated with each schedule. Appliance loads are only simulated for the relevant period of time in the summer season to match the measured data.

[2] EnergyGauge Technical Reference Manual

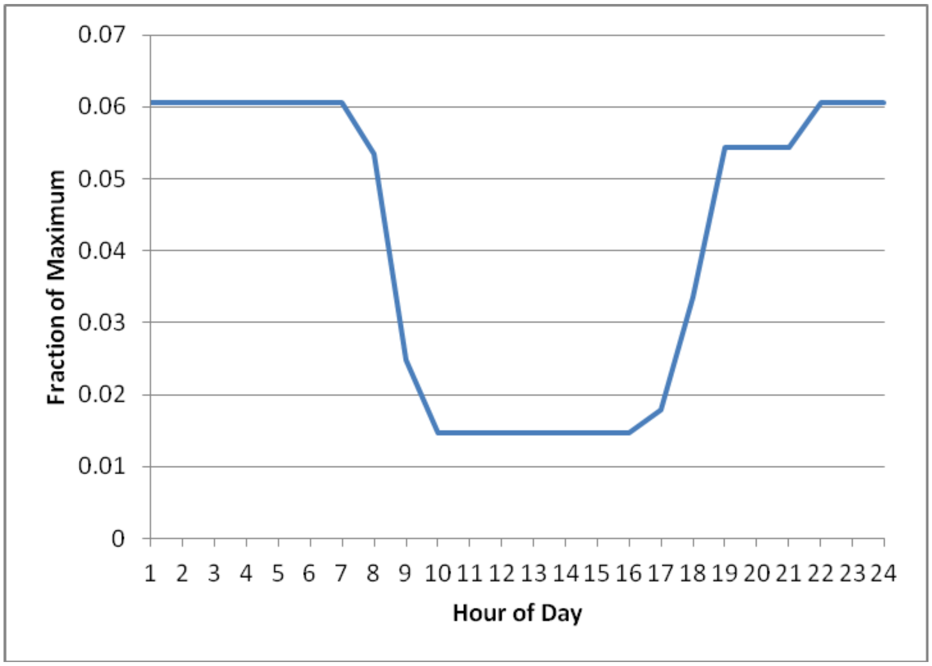

Figure G.2. Occupancy Schedule

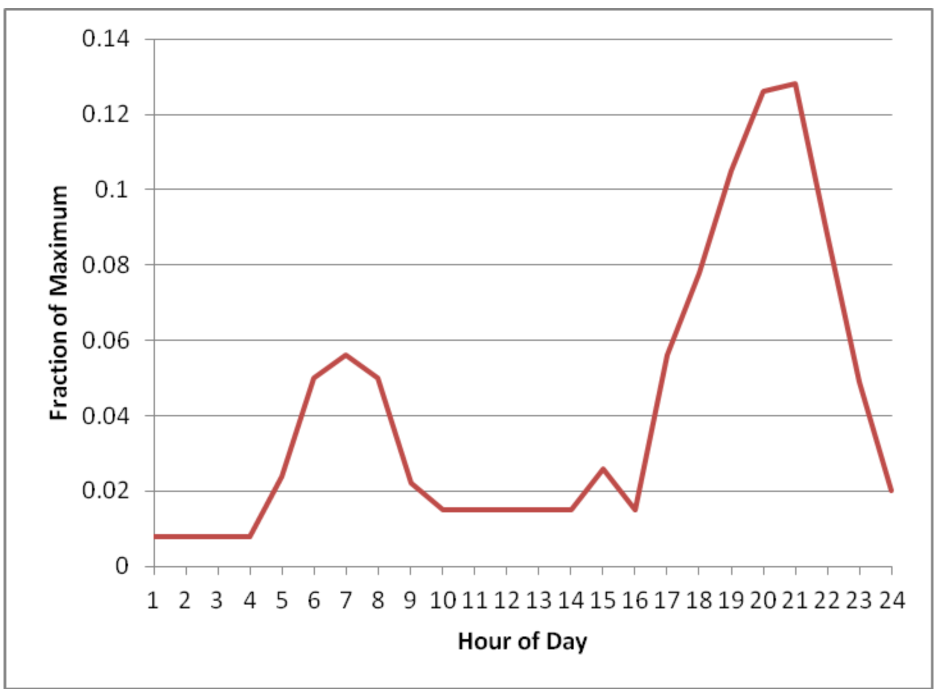

Figure G.3. Lighting Schedule

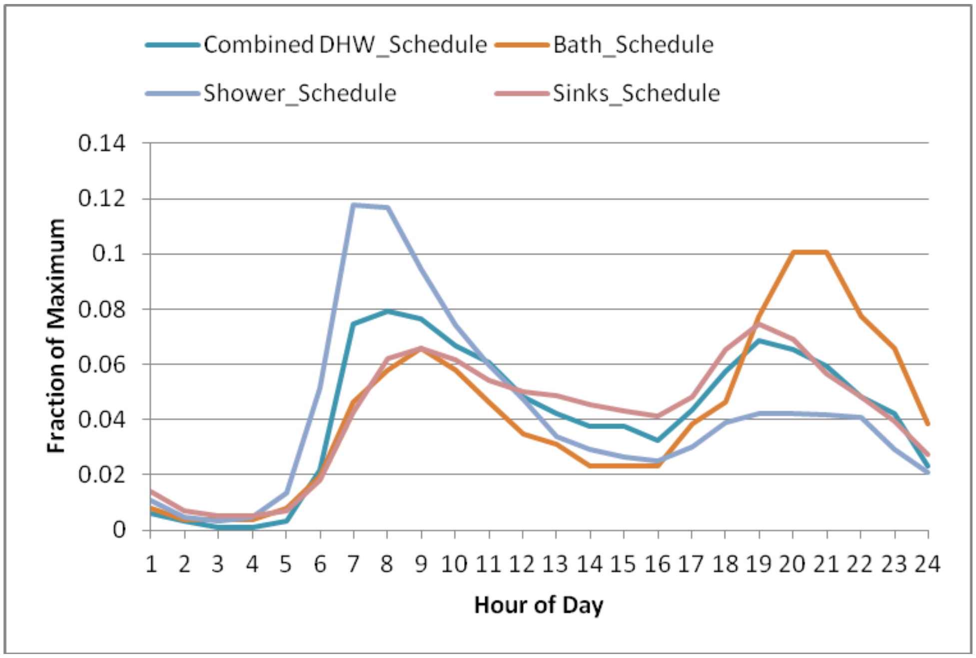

Figure G.4. Domestic Hot Water Use Schedules

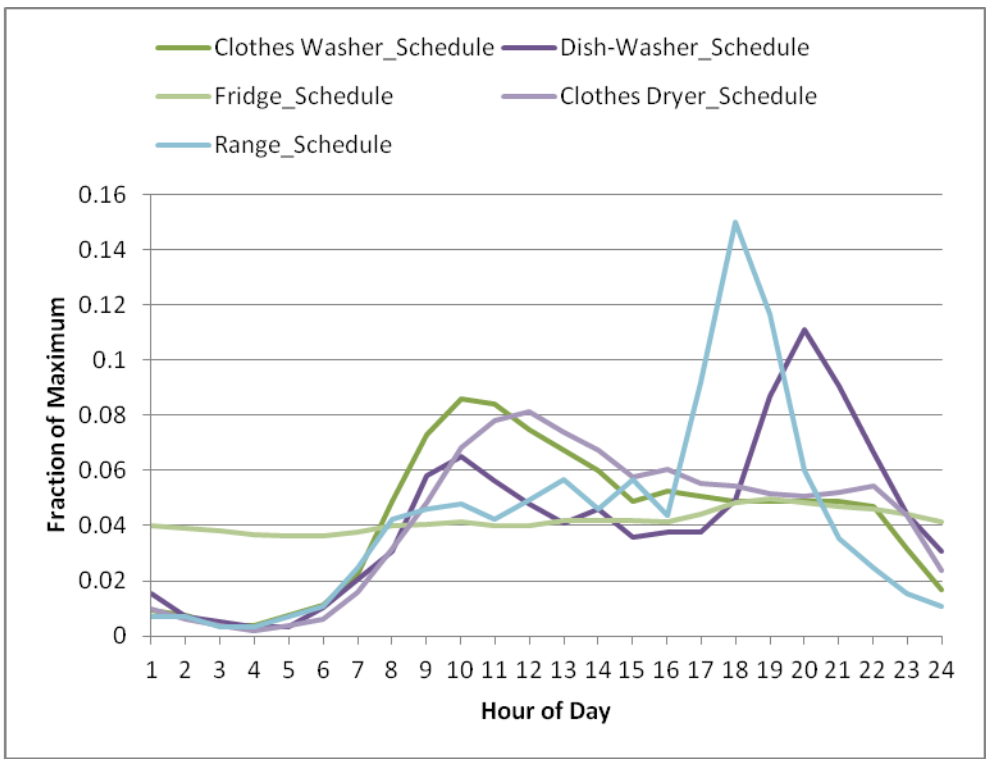

Figure G.5. Appliance Use Schedules

Table G.3. Peak Power Value for Each Internal Gains Component

Appliance	Sensible (Btu/day)	Latent (Btu/day)	Total
Clothes Washer	614	0	614
Dishwasher	848	212	1,060
Combined Domestic Hot Water	3,113	0	3,113
Bath	371	0	371
Shower	1,482	1,408	2,890
Sinks	619	281	900
Refrigerator	6,272	0	6,272
Clothes Dryer	1,447	482	1,930
Range	3,508	2,631	6,139

Table G.4 below lists the relevant inputs used to model the differences between Lab Homes A and B.

Table G.4. Input Parameters Used to Model the Differences Between Lab Homes A and B

	Lab Home A	**Lab Home B**
Window U-factor	0.68	0.2
Window SHGC	0.7	0.19
Window VT	0.73	0.36
Envelope Leakage (sq.in)	38.83	35.93