TECH CORNER

PHIUS+ 2018 Initial Cost Premium & Source Energy Savings

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We often get questions about the cost of passive house, meaning the initial cost. This article presents such data, from the standard-setting study for PHIUS+ 2018.

As noted elsewhere, the heating/cooling performance targets for PHIUS+ were set by cost-optimization calculations on various study buildings in a range of climates (Wright & Klingenberg 2015, Wright & White 2019). That process aims to minimize the total life-cycle cost on an annualized basis, including both the operating energy cost and the financed cost of the energy-saving upgrades. In so doing, a report was generated for each case; the reports show the energy performance but also total up the initial cost or capital cost premium for all the upgrades. The total cost premium is relative to the Building America Benchmark case - this is similar to 2009 IECC code.

Figure 1 shows a histogram of the cost premium over the 300 cases in the 2018 study. The median was $6.98/sf and the total range was $0.63 to $31.36/sf. The cost database on which these results are based was mostly the one built into NREL's BEopt 2.8, with a few extrapolations to higher-performing walls and windows for example.

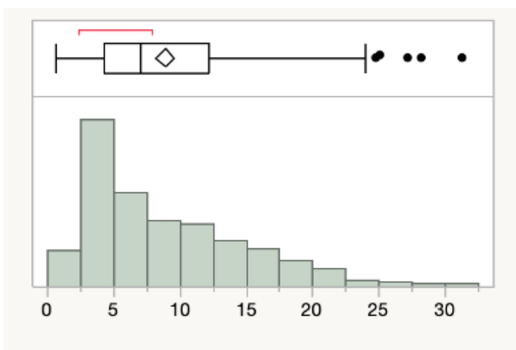

Figure 1. Histogram of capital cost premium ($ per square foot of floor area), for the 2018 study cases.

Another statistical analysis was done, looking for factors that influence the cost premium. The main factors were found to be building "size" represented by envelope-to-floor area ratio, the heating degree days (base 65F), and the price of electricity. (Most of the study buildings were all-electric.)

The prediction formula for the cost premium in $ per square foot of floor area is shown in Figure 2a. *EnvFlr* is the ratio of envelope area to floor area; *HDD65* is the heating degree days base 65°F, and *$elec* is the electricity price in $/kWh. As noted on the scatter plot of predicted vs "actual" cost premium (Figure 2b), the correlation coefficient was a reasonably good 0.84, with a root-mean-square error of $2.39/sf. As shown in the sensitivity plots (Figure 3), the cost premium increased for smaller buildings (higher Env. / Floor area) and colder climates. There was a significant interaction between those factors, that is, for larger buildings the cost was less sensitive to climate, and in warm climates it was less sensitive to size.

$$\begin{gathered} -7.390675806 + 4.7533914428 \ast EnvFlr \\ + 0.0007398753 \ast HDD65 + 17.263944797 \ast \$elec \\ + (EnvFlr - 1.7684949833) \ast ((HDD65 - 5850.4046823) \end{gathered}$$

Figure 2a

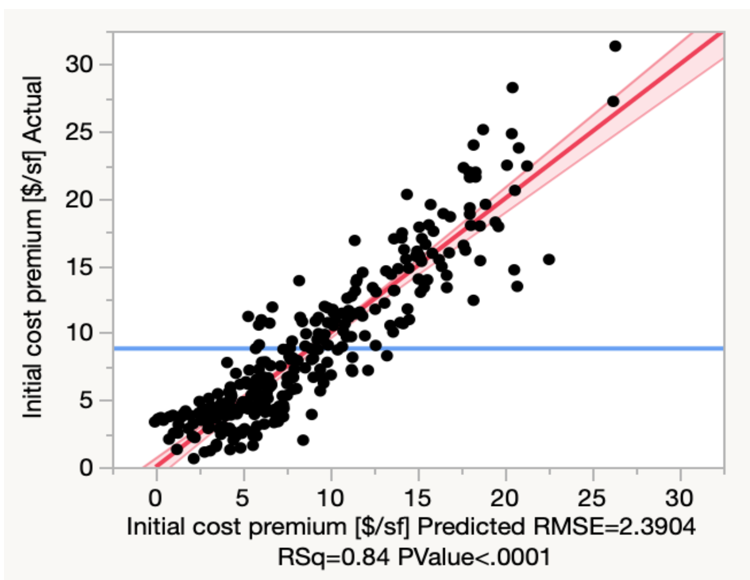

Figure 2b

Figure 2. Prediction formula for the initial cost premium, and its statistics.

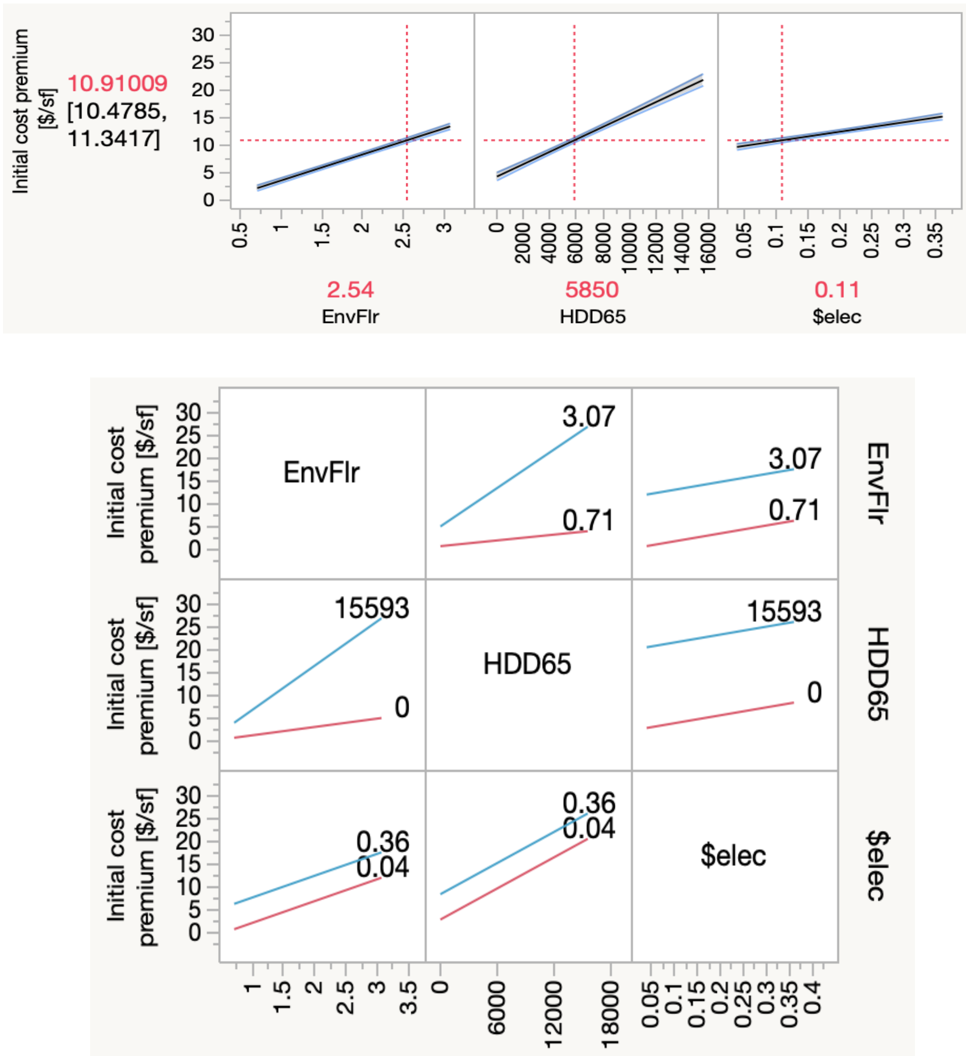

Figure 3. Visualization of the sensitivity of the cost premium to the predictive factors, including interaction between the Envelope-to-Floor area ratio (EnvFlr) and the base–65°F heating degree days (HDD65). Electricity price is in $/kWh.

A similar analysis was done on the overall annual energy savings, in terms of percent reduction from the BA Benchmark (see Figures 4, 5, 6.) This turned out to be predictable from the same factors as the initial cost premium, but with different sensitivities.

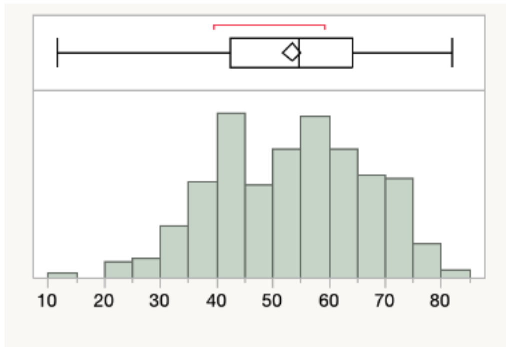

Figure 4. Histogram of annual source energy savings, percentage reduction, for the 2018 study cases.

$$23.67705123 + 11.602634398 * \text{EnvFlr} + (EnvFlr - 1.766) * ((EnvFlr - 1.766) * -9.99087292) + 36.066257194 * \$elec + 0.0017000388 * HDD65$$

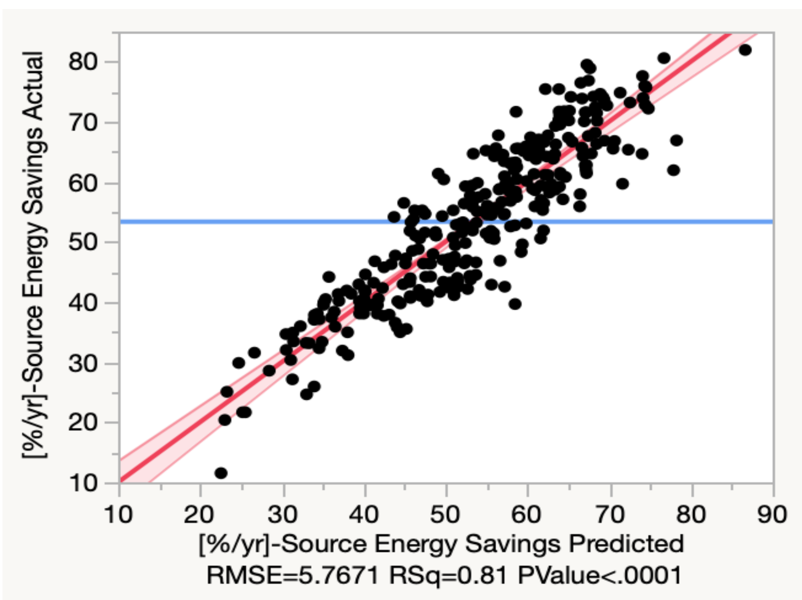

Figure 5. Prediction formula for the annual source energy savings, and its statistics.

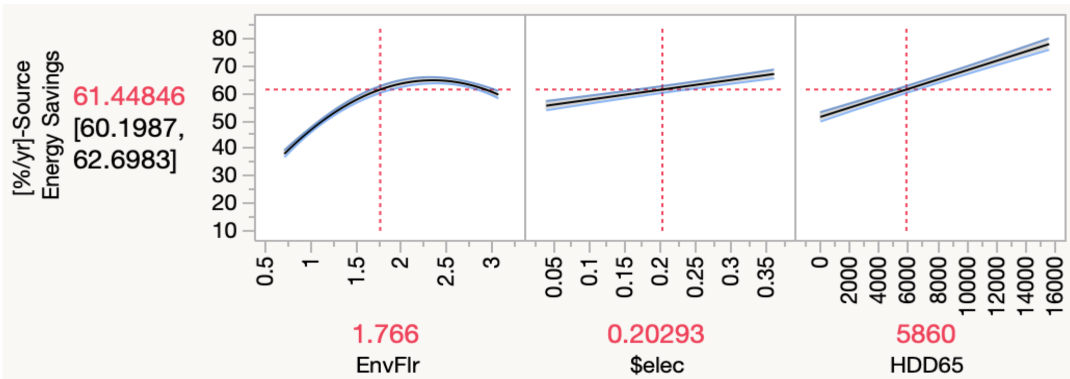

Figure 6. Visualization of the sensitivity of the percent source energy savings to the predictive factors. The effects were additive (no interactions), but the dependence on EnvFlr was nonlinear, fading for smaller buildings.

The prediction formulas for the capital cost premium and source energy savings have been built into a handy online estimator. It gives a low-to-high range of plus or minus one RMS error. The inputs are automatically limited to the ranges studied. It has a mode that estimates the EnvFlr ratio from the floor area alone, as EnvFlr ~ 26.3 $FA^{-0.283}$.

Although these data are all from modeling rather than built projects, they do cover quite a wide range of cases. The estimator worksheet may be useful for initial/general project program discussions or policy work.

Try out the estimator here: Cost Estimator

References

Wright GS, Klingenberg K. 2015. Climate-Specific Passive Building Standards. Golden, CO: U.S. Dept. of Energy. [accessed 2019 Sep 20]. https://www.nrel.gov/docs/fy15osti/64278.pdf

Wright G, White L. 2019. Setting the heating/cooling performance criteria for the PHIUS+ 2018 passive building standard. Thermal Buildings XIV 2019, Conference Proceeding by ASHRAE.