ComEd
Energy Efficiency Program

THE TIERRA LINDA PASSIVE HOUSE: A COMPARATIVE CASE STUDY EXECUTIVE SUMMARY

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Cover Photo Tierra Linda, Chicago, IL, a LUCHA property. Landon Bone Baker Architects. © 2018 balloggphoto.com

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I. EXECUTIVE SUMMARY

This study described in this report examines differences in energy consumption, operating costs and indoor air quality for two new 6-unit multi-family properties in ComEd's service area. One property was constructed to federal ENERGY STAR® standards, while the other was certified under the Passive Institute US PHIUS+ 2015 program. Both properties participated in ComEd's Affordable Housing New Construction (AHNC) offering. The PHIUS+ property has a considerably tighter envelope, higher R-value walls and higher-performance windows compared to the ENERGY STAR property. It also uses air-source heat pumps and energy-recovery ventilators for space conditioning, versus conventional condensing gas furnaces, split-system air conditioners and bath fans at the ENERGY STAR property.

In other respects, the two properties are nearly identical: they have the same footprint and floor plans, are oriented the same and are located within a block of one another on Chicago's near northwest side. This creates a nearly ideal test case for comparing the two new-construction efficiency standards side by side. Both properties are intensively instrumented for energy consumption and indoor air quality. This final report covers the monitoring period from completion of construction in late November 2018 through early October 2020.

Key findings from the field monitoring are as follows:

- **The high-performance shell for the PHIUS+ property translates into substantially lower seasonal heating energy requirements.** On a weather-normalized seasonal basis, the PHIUS+ property requires 65±2% less delivered heating energy. Modeling suggests that most of these savings come from the extremely tight shell combined with heat recovery ventilation and high-performance, triple-pane windows. The high-performance windows appear to make an outsize contribution to delivered heating-energy savings: they provide almost 30% of the savings for the property but less than 10% of the incremental cost.
- **Space-cooling impacts are difficult to assess.** The monitoring data suggest slightly lower cooling energy requirements for the PHIUS+ property, but the difference between the two properties is not statistically significant at a 95% confidence interval, and the PHIUS+ property may benefit from somewhat more shading from its neighbor to the south. Energy modeling suggests that the PHIUS+ property should have higher cooling energy needs in the summer owing to its high-solar-gain windows and the presence of unvented clothes dryers. However, both the monitoring and the modeling analyses are subject to uncertainty from untracked occupant behavior regarding opening windows and use of interior shading.
- **Input energy for space conditioning is even lower for the PHIUS+ property.** In addition to the reduced delivered-energy requirements from the higher-performance building shell, the air-source heat pumps at the PHIUS+ property are more efficient than the gas furnaces and split-system air conditioners at the ENERGY STAR property on a site-energy basis. The PHIUS+ property requires 76±1% less site energy for space conditioning. However, the measured heating-season efficiency of the PHIUS+ heat pumps is lower than expected for this type of equipment, suggesting that there is potential for even greater energy savings.
- **Total site energy use is about a third less for the PHIUS+ property.** When water heating, lighting and other appliances are added to the mix, the PHIUS+ property

has an overall site energy use intensity (EUI) of about 33.4 kBtu/ft2, which is 37% less than that of the ENERGY STAR property.

- **Annual energy costs for the PHIUS+ property are about 19% less than the ENERGY STAR property, mainly due to differences in utility rates.** In particular, the results are sensitive to differences in monthly natural-gas customer charges: in other parts of ComEd's service territory, a PHIUS+ property like that tested here could be slightly more expensive to operate. An all-electric building with better-performing heat pumps and high-performance water heating and cooking equipment would help ensure lower operating costs, but this case study also illustrates that it can be difficult for electric heating to compete against gas at current prices.
- **Greenhouse gas emissions for the PHIUS+ property are a quarter to a third less than those of the ENERGY STAR property, depending on the perspective one takes regarding emissions factors for electricity.** An all-electric version of the PHIUS+ property with high-efficiency appliances could achieve 60-70% lower emissions.
- **Modeling based on detailed air-leakage and ventilation flow measurements suggest that the PHIUS+ property has an average annual air-change rate that is about 40% higher than that of the ENERGY STAR property, with substantially lower air-change-related space conditioning delivered-energy requirements, owing to the use of energy-recovery ventilators (ERVs) providing balanced ventilation.** The ERVs at the PHIUS+ property were observed to freeze up on the exhaust side on a number of occasions in very cold weather: this could be eliminated through the use of in-line heaters set to trigger only under extreme conditions to minimize their energy penalty.
- **Heating-season indoor humidity in the PHIUS+ property is better than at the ENERGY STAR property.** At 20-30% relative humidity, the ENERGY STAR property is undesirably dry during the winter; the PHIUS+ property has indoor relative humidity in a preferable range of 30-40%. The two properties exhibit similar humidity levels during the summer.
- Other indoor air quality (IAQ) markers tracked for the study (carbon dioxide, particulates and volatile organic compounds) are highly dependent on occupant behavior, making comparison between the two properties more difficult given the small number of units in each property. **Nonetheless, there are no indications that IAQ in the PHIUS+ property is any worse than in the ENERGY STAR property.**

The substantial space-conditioning energy savings demonstrated here—without compromises to indoor air quality—demonstrates that there is significant remaining energy-efficiency potential related to shell and ventilation improvements in the market. While entry barriers for PHIUS+ level remain, evidence elsewhere suggests that these are not insurmountable. Adding a PHIUS+ track to the current AHNC offering would enhance its effectiveness, though some changes to the program would be needed to appropriately capture the additional energy savings.