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Figure 1. New construction test homes each featured a two-story elevated plan built on approximately 9-ft concrete piers, as they are located in a flood zone. Homes were selected for their similar layout and square footage (2,300 ± 100 ft^2).
Photos from Southface

Smart Control Logic for Mechanical Ventilation in Humid Environments

Researchers performed field validations of a smart ventilation system to determine if it could help low-load homes in humid environments maintain acceptable indoor humidity conditions while providing adequate ventilation.

Builders have questions about mechanical ventilation in hot-humid climates. Building airtightness is crucial to lowering the energy use of homes, but tight homes also require mechanical ventilation to maintain optimal indoor air quality (IAQ). For a significant portion of the country, however, standard residential new construction has yet to embrace intentional fresh air ventilation. Builders in hot-humid climates have concerns about both the cost of mechanical ventilation as well as the risks of introducing humidity from outside. Resistance to mechanical ventilation is one of the reasons for builder push-back on increasing building enclosure airtightness requirements for state energy codes, as seen in Florida, Georgia, Louisiana, and others.

Project Information

Building Component: HVAC

Team and Partners: Southface, Emory University, UL Environment, Beazer Homes, Broan, Senseware

Application: Residential

Can smart ventilation offer a solution for cost, humidity, and IAQ? Smart ventilation solutions that minimize indoor humidity at an acceptable cost to production builders have the potential to overcome builder concerns and provide important IAQ benefits necessary for occupant health.

Field experiments and simulations performed in a previous Building America project demonstrated smart ventilation controls can be used in a hot-humid climate to meet ASHRAE 62.2-2016 relative exposure requirements while providing 5.5%–10% cooling energy savings and comfort improvements.[1] Southface researchers sought to expand on those findings by testing a market-ready smart energy recovery ventilator (ERV) in four occupied homes while monitoring IAQ and energy usage.

> Researchers sought to address builders' concerns with mechanical ventilation in humid environments and learn whether smart control logic helps with occupant comfort and indoor air quality.

Study Design

The Southface team collected field data for one year in four Charleston, South Carolina, new construction homes to identify differences in occupant comfort and comfort metrics, IAQ, and heating, ventilating, and air-conditioning (HVAC) energy consumption when toggling biweekly between an ERV operating continuously and an ERV operating with smart, time-varying humidity control logic.

The team continuously measured temperature (T); relative humidity (RH); carbon dioxide (CO_2); particulate matter

[1] Martin et al. 2018. *Field and Laboratory Testing of Approaches to Smart Whole-House Mechanical Ventilation Control*. https://doi.org/10.2172/1416954.

at 1 micron (PM_1), 2.5 microns ($PM_{2.5}$), and 10 microns (PM_{10}); and radon using "low-cost" IAQ sensors (sensors in the sub-$100 range, situated for potential future integration into smart ventilation solutions). Each of these metrics, except radon, was measured in multiple locations within each home, as well as outdoors. All of the low-cost IAQ sensor packages used in the study were tested both before and after field deployment by UL Environment in their environmental chambers and examined for sensor drift. The HVAC system energy usage and ERV performance were also continuously monitored throughout the year, and occupants were given seasonal surveys about their comfort.

Key Findings

Humidity and comfort: On an annual basis, the ERV in smart mode created a less humid indoor environment than continuous mode. However, the difference it made was inconsistent during the spring, summer, and fall months, and it was only directionally consistent during the winter months. This may be due to the long runtimes and concomitant dehumidification activity of the air-conditioning (A/C) units in response to the high sensible loads in Charleston. The effect of the smart ventilation algorithm was not discernable to the occupants in this study.

The annual averages of the comfort metrics for each house can be seen in **Table 1**. In both modes, the annual average RH is below 55% for all four homes. Although there was not a significant difference in average RH in any house, all houses have a lower RH in smart mode than continuous mode. All houses also had a lower percentage of time above 60% RH in smart mode compared to continuous mode. This trend makes intuitive sense, because the ERV control logic responds to the peaks in outdoor humidity, and thus limits the peaks in humidity that are brought indoors.

IAQ: As seen in **Figure 2**, there were small but measurable differences in both CO_2 and PM concentrations when comparing smart and continuous ERV modes, using the low-cost IAQ sensors. However, we believe that caution should be taken when making inferences regarding the role of ERV mode in either reducing or enhancing indoor pollutant levels.

Energy savings and modeling: The study also examined air-conditioning and ERV-related energy savings and how accurately the National Renewable Energy Laboratory's BEopt™ (Building Energy Optimization Tool) models predicted HVAC energy savings for test homes switching between smart and continuous operation modes. The A/C savings prediction was not very accurate in terms of raw kilowatt-hour (kWh) savings, but was reasonably accurate in terms of A/C savings percentage (5.2% savings predicted vs. 7.6% actual, on average). The ERV savings prediction

House	Comfort Metric	Continuous Mode	Smart Mode
House 1	Temperature (°F)	71.4	72.3
	RH	50.0	49.6
	% of time above 60% RH	0.40%	0.06%
House 2	Temperature (°F)	72.3	72.4
	RH	53.2	52.8
	% of time above 60% RH	13.09%	6.33%
House 3	Temperature (°F)	73.1	73.0
	RH	54.2	53.6
	% of time above 60% RH	21.42%	14.29%
House 4	Temperature (°F)	75.0	75.3
	RH	48.9	48.8
	% of time above 60% RH	0.77%	0.48%

Table 1. Test Home Annual Average Indoor Comfort Metrics

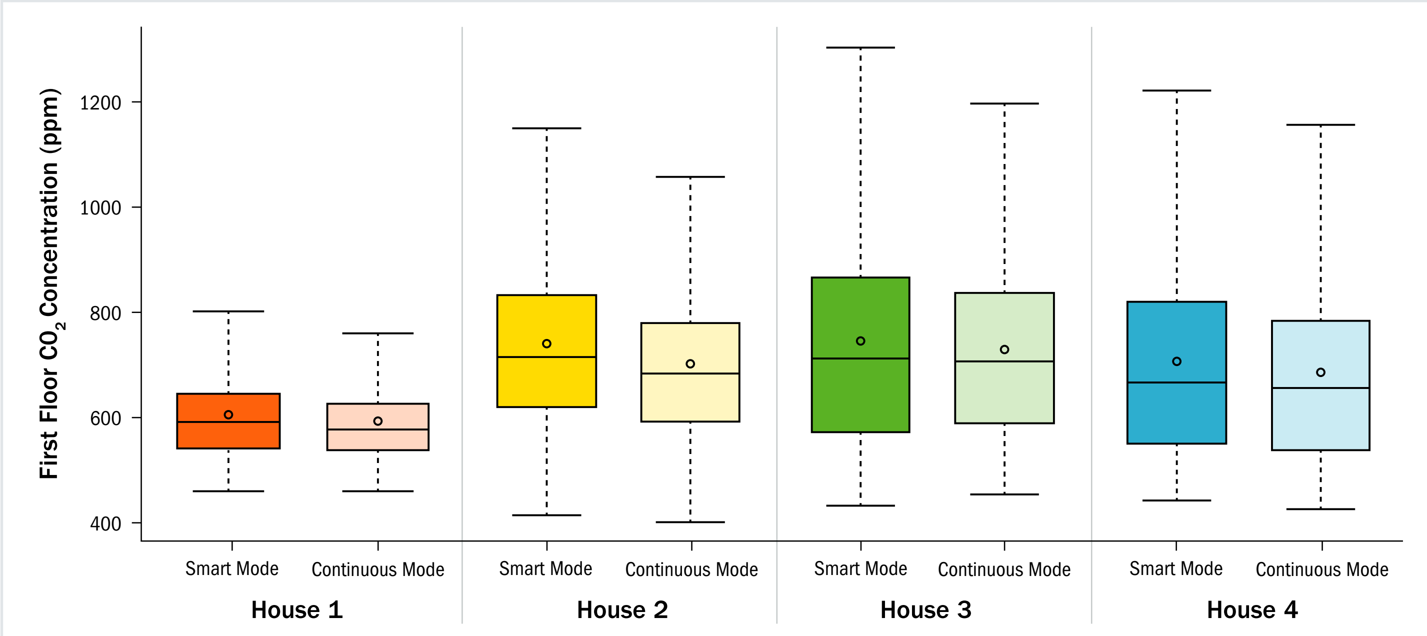

Figure 2. Smart mode showed slightly higher median and mean levels of CO_2 compared to continuous mode. *Image from Southface*

was accurate both with regard to kWh and kWh percentage savings.

Broader Market Impacts

Because the ERVs showed inconsistent effects, the results of this study instead offer broader implications and point to additional opportunities for research:

- **Proper design and commissioning of A/C equipment is critical in regions with high latent loads.** Proper design and commissioning ensure that the sensible heat ratio of the system is correct for the climate, which allows for sufficient dehumidification to occur.
- **Smart ERVs may be applicable in a wider range of climates.** A smart ERV control strategy—designed and intended initially for hot-humid climates—might be more widely applicable to other climates such as mixed humid and marine with high latent loads but not the higher sensible loads that drive A/C runtimes.
- **Negatively unbalanced (more exhaust than supply) ERVs in humid climates can draw in large amounts of unwanted moisture over the course of a year.** Positively unbalanced (more supply than exhaust) ERVs have less of this side effect.
- **Smart ventilation strategies benefit from careful design and calculation tools.** For builders seeking to implement a smart ventilation strategy, careful foresight, design, and relative exposure calculations involving house size, layout, blower door test results, and typical meteorological year weather data are necessary to achieve ASHRAE 62.2 compliance.

A simplified calculation tool would help contractors more readily adopt smart, time-varying ventilation technologies. Alternatively, an even smarter system that can compute relative exposure internally—or a "connected" system that can determine expected weather conditions from the internet and can vary its flow—can minimize upfront design requirements. ■

Learn More

Technical Report:

https://www.nrel.gov/docs/fy21osti/78662.pdf

Related 2018 Building America report (Field and Laboratory Testing of Approaches to Smart Whole-House Mechanical Ventilation Control):

https://www.osti.gov/biblio/1416954-field-laboratory-testing-approaches-smart-wholehouse-mechanical-ventilation-control

BEopt modeling software:

https://www.nrel.gov/buildings/beopt.html

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