U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Smart Ventilation Controls Boost Energy Efficiency and Indoor Air Quality

The average American household spends more than $2,200 a year on energy, and heating, ventilating, and air conditioning (HVAC) costs comprise nearly half of the bill.[1] This is one reason why home builders focus on tightening building envelopes—to save energy. However, limiting natural building air exchange can negatively impact indoor air quality (IAQ). Mechanical ventilation systems can improve IAQ in homes with tight envelopes, but real and perceived risks relating to cost, energy consumption, and comfort have hindered market adoption in some climates.

When outdoor conditions are most extreme, there may be comfort implications from continuing high levels of ventilation. This is true even with heat recovery. The Florida Solar Energy Center (FSEC) developed and tested approaches for "smart" ventilation system controls that enable more reliable design and operation to achieve desired IAQ while also minimizing energy and comfort impacts. FSEC researchers investigated three approaches to smart ventilation control that focus on taking advantage of weather and occupancy responsiveness:

- Seasonal temperature-based
- Occupancy timer-based
- Real-time weather-based.

Key Research Findings

All three approaches demonstrated potential for heating and cooling savings while maintaining indoor comfort and air quality.

Seasonal temperature-based controls research

In a low-cost seasonal temperature-based smart ventilation control prototype implemented in an existing home in Olympia, Washington, an exhaust ventilation system with capacity more than twice the rate determined by ASHRAE 62.2-2016 for continuous ventilation was controlled based on outdoor temperature. Natural infiltration during periods of high indoor-outdoor temperature differences was modeled as sufficient to prevent unacceptable acute exposure to pollutants, allowing the fan to remain off for much of the winter. Analysis of indoor relative humidity showed that comfortable conditions were maintained.

Project Information

Building Component: Ventilation

Team and Partners: Florida Solar Energy Center, Washington State University, National Renewable Energy Laboratory

Applications: Residential, multifamily

Year Tested: 2015–2017

Smart ventilation controls enable more reliable design, installation, and operation to achieve desired indoor air quality. *Photo from FSEC*

Occupancy timer-based controls research

Researchers also tested a system that varied mechanical ventilation exhaust fan operation in response to vacancy or occupancy within the same residence in Olympia, Washington. Indoor conditions were sometimes humid during occupancy timer-based smart ventilation control (less outdoor air created less drying potential), but not so humid as to degrade comfort, IAQ, or durability.

Real-time weather-based controls research

The team developed an algorithm to interpret measurements of current and 24-hour historical outdoor temperature and moisture, and then vary ventilation to minimize sensible and latent load impacts. A supply ventilation system controlled by the algorithm was implemented in a laboratory home and tested side-by-side with an identical home operating with continuous mechanical ventilation per ASHRAE 62.2-2016. Simulations suggested that compliant annual average and acute relative exposure could be maintained with 73% sensible and 9% latent load reductions during cooling conditions. Further research demonstrated 10% average monthly cooling energy savings through monitored lab home data in Florida. A minimum of 5% space conditioning energy savings were predicted for the smart ventilation concept across differing climates in the United States.

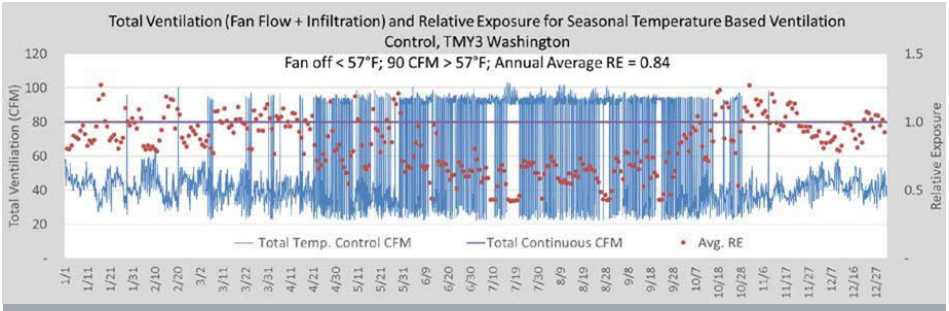
A preliminary analysis was also completed in Europe using a highly insulated, tight residential building prototype with a very efficient enthalpy recovery ventilator as the baseline. Analysis showed that the heating savings were much lower after accounting for the enthalpy recovery ventilator efficiency—typically 2%–3% in savings. However, cooling energy savings remained very significant—ranging from 12%–36%—and could potentially be larger in cooling-dominated climates.

Market Impact and Adoption

Although smart ventilation controls demonstrate potential for both energy savings and improved IAQ, only a small selection of systems are on the market. New commercially available calculators enable designers to modify a steady-state design flow using typical meteorological year

[1] U.S. EPA. 2009. "A Guide to Energy-Efficient Heating and Cooling." ENERGY STAR. www.energystar.gov/sites/default/files/asset/document/HeatingCoolingGuide%20FINAL_9-4-09_0.pdf.

data set 3 (TMY3) to implement seasonal temperature-based smart ventilation controls. However, a more concerted commercialization effort needs to be undertaken by manufacturers and other relevant industry players. During the course of this project, FSEC worked with manufacturers to increase awareness for the potential of smart ventilation controls and prime the industry for eventual device development and implementation. Key advances in residential ventilation that have already been accomplished include:



Real-time weather-based smart ventilation control research simulated total ventilation and daily average relative exposure using data from the local typical meteorological year data set 3 (TMY3). *Illustration from FSEC*

- ASHRAE 62.2 Normative Appendix C: Relative Exposure provides flexibility in the design of smart ventilation controls to save energy and enable grid interactivity without compromising occupant exposure.
- ASHRAE 62.2 now accounts for measured envelope tightness, interactions of mechanical ventilation and natural infiltration, and credit for filtration.
- Quieter ENERGY STAR®-compliant whole-house and intermittent-use low wattage fans are available on the market.
- Smart ventilation controls that use weather, occupancy, grid/price signals, HVAC run time, and/or targeted pollutant concentrations can be developed and implemented to help overcome energy use, comfort, maintenance, and operation challenges.
- Smart controls that bypass heat recovery/energy recovery ventilators can provide additional energy savings and fresh air when outdoor conditions are ideal.
- Improved ventilation switch labeling helps occupants and building owners understand system operation.
- Research leading to development of range hoods that allow for automatic operation and ratings for hood capture efficiency.

To improve widespread commercialization, energy savings from smart ventilation controls need to be considered by energy rating systems. Successful commercialization will also result from smart ventilation controls that can alert occupants when and how to take necessary actions associated with detected faults, maintenance, change in occupancy, and local outdoor air quality. This warrants further product control algorithm development and field evaluation trials in occupied homes to further quantify associated benefits. ■

This test home in Olympia, WA, was used to help demonstrate low-cost smart ventilation controls. *Photo from FSEC*

Learn More

Technical Report: www.osti.gov/biblio/1416954

Guide: basc.pnnl.gov/resource-guides/whole-house-ventilation-strategies-existing-homes

Resource: basc.pnnl.gov/information/whole-house-mechanical-ventilation-system-meets-ashrae-622

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Building America U.S. Department of Energy

Florida Solar Energy Center

For more information, visit:
energy.gov/eere/buildings/building-america

DOE/GO-102020-5260 · August 2020