ABSTRACT

Author: Jiang, Jinglin. MSCE
Institution: Purdue University
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Title: Investigating How Energy Use Patterns Shape Indoor Nanoaerosol Dynamics in a Net-Zero Energy House
Committee Chair: Dr. Brandon E. Boor

Research on net-zero energy buildings (NZEBs) has been largely centered around improving building energy performance, while little attention has been given to indoor air quality. A critically important class of indoor air pollutants are nanoaerosols – airborne particulate matter smaller than 100 nm in size. Nanoaerosols penetrate deep into the human respiratory system and are associated with deleterious toxicological and human health outcomes. An important step towards improving indoor air quality in NZEBs is understanding how occupants, their activities, and building systems affect the emissions and fate of nanoaerosols. New developments in smart energy monitoring systems and smart thermostats offer a unique opportunity to track occupant activity patterns and the operational status of residential HVAC systems. In this study, we conducted a one-month field campaign in an occupied residential NZEB, the Purdue ReNEWW House, to explore how energy use profiles and smart thermostat data can be used to characterize indoor nanoaerosol dynamics. A Scanning Mobility Particle Sizer and Optical Particle Sizer were used to measure indoor aerosol concentrations and size distributions from 10 to 10,000 nm. AC current sensors were used to monitor electricity consumption of kitchen appliances (cooktop, oven, toaster, microwave, kitchen hood), the air handling unit (AHU), and the energy recovery ventilator (ERV). Two ecobee smart thermostats informed the fractional amount of supply airflow directed to the basement and main floor. The nanoaerosol concentrations and energy use profiles were integrated with an aerosol physics-based material balance model to quantify nanoaerosol source and loss processes. Cooking activities were found to dominate the emissions of indoor nanoaerosols, often elevating indoor nanoaerosol concentrations beyond 10^4 cm^{-3}. The emission rates for different cooking appliances varied from 10^{11} h^{-1} to 10^{14} h^{-1}. Loss rates were found to be significantly different between AHU/ERV off and on conditions, with median loss rates of 1.43 h^{-1} to 3.68 h^{-1}, respectively. Probability density functions of the source and loss rates for different scenarios will be used in Monte Carlo simulations to predict indoor nanoaerosol concentrations in NZEBs using only energy consumption and smart thermostat data.