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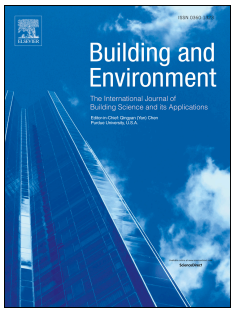

Alternative ventilation strategies in U.S. offices: Saving energy while enhancing work performance, reducing absenteeism, and considering outdoor pollutant exposure tradeoffs

Tom Ben-David, Adams Rackes, Michael S. Waring

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Alternative ventilation strategies in U.S. offices: Saving energy while enhancing work performance, reducing absenteeism, and considering outdoor pollutant exposure tradeoffs

Tom Ben-David, Adams Rackes, Michael S. Waring

Keywords: Indoor air quality (IAQ), healthy buildings, energy efficiency, multi-criteria decision-making, building energy simulation, economizer controls

ABSTRACT. Mechanical ventilation can improve occupant productivity, use or save energy, and increase outdoor-to-indoor pollutant transport. This work explores those impacts for eight ventilation strategies, relative to a baseline constant mechanical ventilation rate (VR) of 9.4 L/s/occ, in two representative offices. Strategies were unique combinations of airside economizing, demand-controlled ventilation, and supply air temperature reset, along with doubling the baseline VR. These were evaluated within a Monte Carlo analysis that varied climate and outdoor pollution, along with 19 building parameters. Energy modeling, empirical correlations, and indoor air quality (IAQ) modeling were used to quantify outcomes of: (*i*) energy use; (*ii*) profitable IAQ impacts, e.g. work performance; and (*iii*) negative IAQ health impacts due to indoor particle and ozone exposure. 'Win-win' strategies were defined as those that saved energy *and* increased work performance, and these always included an economizer. Relative to the baseline, the win-win strategies: increased annual geometric mean VRs by 5–10 L/s/occ; reduced mechanical system energy consumption by 12–27% (saving \$1–1.75/m^2/year); increased work performance by 0.5%; eliminated 5 hours of absenteeism per year; and increased indoor $PM_{2.5}$ by 0.5 μg/m^3 and ozone by 3 ppb. A sensitivity analysis identified infiltration and climate as the largest outcome drivers. Median annual benefits for small-to-medium-large offices in the U.S. (~75% of office floorspace) were \$28 billion for implementing the win-win strategy with the greatest energy savings, and \$55 billion for implementing the win-win strategy with the greatest work performance increase. Particle exposure tradeoffs were mitigated by use of efficient filters.

1 Introduction

Mechanical ventilation is the intentional supply of outdoor air (OA) inside buildings by heating, ventilation, and air conditioning (HVAC) systems. Minimum mechanical ventilation rates are prescribed throughout the developed world by standard-setting organizations like ASHRAE, as a crucial part of providing "acceptable indoor air quality (IAQ)" [1]. Ventilation dilutes indoor-emitted pollutants, reducing potentially unhealthy or irritating exposures and advancing occupant olfactory comfort and perceived IAQ satisfaction [2]. Low ventilation rates (VR) have been correlated with increased illness absence and sick building syndrome (SBS) symptoms, negative odor perceptions, and reduced task performance [3–8]. Conversely, significant cognitive and task performance increases and sick leave reductions have been associated with VRs that well exceed ASHRAE Standard 62.1 recommendations [9–12]. From an energy

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