Study Design of the Healthy Zero Energy Buildings (HZEB) Program in California

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1 Introduction

The Healthy Zero Energy Buildings (HZEB) Program# is studying the relationships of commercial building ventilation rates (VRs) with occupant health, satisfaction, work performance, and building energy consumption. HZEB aims to assist the California Energy Commission in developing VR standards.

Current VR standards in the U.S. (e.g. ASHRAE 62.1 and CA Title 24) are close to 10 Ls^{-1} per person. This VR is based on laboratory experiments on the acceptability of odor generated by occupants. This method of setting VR standards is inadequate because it considers building occupants as the only pollutant sources, and ignores emissions from other indoor and outdoor sources (e.g., building materials and equipment, pollutants in outdoor air). The current VR standard also does not consider other important human outcomes besides acceptability, such as symptoms, illnesses, absenteeism, and work performance.

Scientific literature on the relationship between VRs and human outcomes in offices generally shows worsening of one or more outcomes below about 20 or 25 Ls^{-1} per person (Seppanen et al. 1999; Wargocki et al. 2002; Sundell et al. 2011). There are many challenges in considering such findings in VR standards. It is the goal of HZEB to develop an approach to standard setting that utilizes scientific data from multidisciplinary studies on several effects of VR. HZEB will conduct new studies in areas where literature reviews have identified knowledge gaps. Study approaches will likely include cross-sectional and intervention studies, controlled laboratory experiments, risk assessment, and energy modelling and analysis. An overview of HZEB study objectives and approaches to address knowledge gaps on VR effects is described here.

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2 Materials/Methods

HZEB will expand the criteria that should be considered in setting VR standards, including:

- Perceived air quality and comfort
- Acute and chronic health effects
- Illness-related absenteeism
- Work Performance
- Energy efficiency goals

The types of human outcomes studied will vary depending on building types and their occupants. For example, while health and work performance of employees are important in offices, perceived air quality for customers may be a more critical determinant of VRs in retail stores.

Studies have found the quality of VR measurements to vary considerably (Seppanen et al. 1999). HZEB will investigate novel techniques to measure outdoor air supply rates continuously. These techniques will allow more accurate characterization of time-varying VR (as a result of economizer cycles, for example), and of VR effects on fast processes such as indoor air chemistry. In addition, whole-building VRs will be measured using tracer gas methods that include the contribution from air infiltration.

To assess VR effects on occupant health, HZEB will collect data on short-term outcomes, and perform risk assessment for chronic health outcomes. Sundell et al. (2011) concluded that no available studies had assessed how VRs affects chronic outcomes, although serious chronic health effects such as cancer have been associated with indoor air pollutants. Measurements of airborne carcinogens, e.g. formaldehyde, will be performed in buildings at sufficient temporal and spatial resolution to quantify potential changes in occupant exposure as VR varies. Wargocki et al. (2002) recommend collecting data on health outcomes other than self-reported SBS symptoms. HZEB will assess other health effects, possibly including respiratory illnesses and related sick leave. HZEB will estimate the response relationships of human health outcomes with VR, which are less prone to chance findings (Seppanen et al. 1999).

Design and operation of HVAC systems are important factors that can affect study outcomes. For example, buildings with air-conditioning systems, or with mechanical as opposed to natural ventilation, seem to be associated with higher prevalence of SBS symptoms (Sundell et al. 2011). These and other HVAC factors such as air distribution, recirculation, and humidification will be considered during recruitment of study buildings. By considering these and other aspects of HVAC operations, HZEB study findings can be more generally applied for commercial buildings in California.

HZEB will monitor outdoor air quality, such as ambient PM and ozone, that are associated with morbidity and mortality. In areas with polluted outdoor air, increased ventilation without adequate air cleaning may result in adverse health impacts. For example, laboratory experiments will be conducted to study the effect of ozone on used air filters in potentially generating secondary pollutants.

Synthesizing data for setting VR standards will require common metrics to combine the effects on different human outcomes. This may involve cost analysis, determination of acceptable human outcomes in relation to baseline levels, and/or estimating aversion to specific adverse health effects. HZEB will assess the energy implications of changes in outside air VR on a range of typical commercial buildings in California using EnergyPlus simulations. While HZEB will not set VR standards, recommendations will be made to advise standard setting bodies on how to utilize diverse data collected from multidisciplinary studies in this process.

3 Discussion

Most studies imply that VR standards for offices should be increased from the current 8–10 Ls^{-1} per person. This would increase energy use in new buildings. Therefore, VR standards may need to allow energy-efficient alternatives to increased VR such as air cleaning (Beko et al. 2008). Pollutant source reduction, by using low-emission building materials for example, may be another energy-efficient alternative to increased VR for improving indoor air quality, but this requires knowing the health impacts of specific indoor air pollutants. Consideration of pollutant sources is a feature of the tiered VR standards by the European Directive (Olesen 2007), which categorize VR requirements by commercial building type, source strength, and targeted indoor air quality levels.

In summary, HZEB will study the associations between VR and various health-related human outcomes, as well as energy consumptions in commercial buildings. HZEB will consider the mixture of indoor air pollutants present and their source strengths, and the potential for air cleaning and source control, which are important for VR standards.

4 References

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