Climate Change, Energy Efficiency, and IEQ: Challenges and Opportunities for ASHRAE

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In the U.S, buildings consume approximately 39% of primary energy, including 70% of electricity [1]. Buildings are responsible for approximately 38% of U. S. carbon dioxide emissions [1]. The process of HVAC, for maintaining acceptable indoor environmental quality (IEQ), consumes 37% of the energy used in buildings [1].

Broad scale and aggressive improvements in building energy efficiency are anticipated as the U.S. strives to mitigate climate change and improve energy security. To attain the large reductions in carbon dioxide emissions considered necessary to address climate change, we will require deep energy retrofits in existing buildings plus new buildings that are nearly energy self sufficient. To meet or even approach established goals, the required pace of building energy efficiency improvement represents a dramatic change from past practice. Between 1980 and 2006, primary energy use in residential and commercial buildings increased 32%, and 69%, respectively [1]. Primary energy use per unit floor area declined on average by 1.2% per year in the residential sector but increased 0.6% per year in the commercial sector [1]. In contrast to these trends, U.S. Department of Energy, the Energy Independence and Security Act of 2007, and the American Institute of Architects call for all new buildings to consume zero net energy by 2025 or 2030. The California Air Resources Board goals are 25% and 80% reductions in carbon dioxide emissions by 2020 and 2080, respectively.

Measures taken to achieve these aggressive building energy efficiency goals will change indoor pollutant sources, heat loads, ventilation rates, HVAC equipment types, and building operating practices, all with the potential to affect indoor environmental quality (IEQ) positively or negatively. As broad-based energy-efficiency improvements are made in our buildings, ASHRAE members will need to develop and utilize HVAC technologies and practices that dramatically reduce building energy consumption while maintaining or improving IEQ. A degradation in IEQ is unlikely to acceptable in the market place given the growing evidence that ventilation rates and IEQ conditions influence health and work and school performance [2-4], each of which has important economic implications. These energy efficiency goals represent a challenge to some of the existing technologies and practices employed and marketed by ASHRAE members but also represent a very large future opportunity.

Table 1 identifies some of the expected energy efficiency strategies or measures that will be implemented, the potential impacts in IEQ, and possible associated HVAC design and practice changes and technology challenges. Many of the strategies or measures are identified within the advanced energy design guides available from the ASHRAE web site. Table 1 is not meant to be exhaustive; however, it does identify the broad range of potential changes in HVAC that will affect the practices of the ASHRAE membership. Examples include:

- increased use of mechanical ventilation systems in houses with more airtight envelopes;
- smaller capacity HVAC systems with a larger ratio of latent to sensible capacity for buildings with more thermally efficient envelopes and lower internal heat loads;

- increased use of low energy cooling systems such as those with evaporative cooling;
- more and new types of demand controlled ventilation, heat recovery, and gas phase air cleaning to reduce outdoor air (OA) ventilation energy requirements;
- more radiant heating and cooling, less air recirculation, and lower pressure drop filtration systems to reduce fan energy;
- hybrid HVAC systems, cooling systems with finer spatial and temporal control, and more mechanical ventilation without air conditioning to reduce or eliminate air conditioning energy consumption; and
- increased resources dedicated to HVAC maintenance and correction of control system problems.

Table 1 does not mention the better integration of HVAC components, and better integration of HVAC with other building systems, which are other necessary responses to the energy efficiency challenge. The IEQ implications of integration practices are uncertain and are likely to be varied. Also omitted from Table 1 are the numerous challenges outside of the purview of the ASHRAE membership, such as development of building materials and products with very low emissions of harmful or odorous pollutants.

Many HVAC technologies and practices exist to address the challenges listed in Table 1 above and increases in their utilization are anticipated. However, improvements in technology performance, reductions in cost, and new innovations are still necessary if energy use is to be reduced dramatically while maintaining good IEQ. The pace of change in the HVAC field will need to be much faster than in recent decades if the aforementioned goals are to be met. In the opinion of the author, meeting these HVAC-related challenges should be one of the highest priorities for ASHRAE and the ASHRAE membership in the coming decades.

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Table 1. Energy efficiency responses to climate change and consequences for IEQ and HVAC.

Energy Efficiency Measures	Potential IEQ Consequences	Potential HVAC Design and Operation Responses and Technology Challenges
More air tight building envelopes	Less uncontrolled OA ventilation Less rapid drying within the building envelope posing microbial contamination risks Increased sheltering from OAr particles and ozone	Mechanical OA ventilation for houses Commercial OA ventilation systems that better assure minimum ventilation rates
More thermally efficient building envelopes More energy efficient lighting and equipment	New pollutants and increased or decreased pollutant emission rates from envelope materials Reduced sensible cooling loads Reduced filtration rates as supply air flow rates diminish	Reduced capacity HVAC systems with greater latent to sensible capacity ratio Separate HVAC for OA ventilation Flexible exhaust air systems for removing heat and pollutants from point sources
Reduced OA ventilation rate	Higher indoor concentrations of indoor-generated pollutants if no compensating measures Increased sheltering from outdoor particles and ozone	Effective and low cost gas phase air cleaning that consume less energy than OA ventilation More and new types of demand controlled ventilation Air supply and removal technologies that increase ventilation efficiencies
Reduced HVAC air flows, pressure drops, and fan energy consumption	Reduced filtration rates as supply air flow rates diminish Reduced noise from HVAC systems	Low pressure drop filtration systems Auxiliary filtration systems independent of the HVAC supply air streams Use of liquids in place of air to transport energy Radiant cooling and heating technologies Ultraviolet germicidal irradiation of cooling coils
Low energy cooling systems	Changes in OA ventilation rates Changes in indoor temperatures and humidity values Microbial risks from evaporative cooling Condensation on chilled surfaces and associated microbial risks	Direct and indirect evaporative cooling systems Systems to reduce microbial risks with evaporative cooling Cooling systems with finer spatial and temporal control Ventilation heat recovery Increased use of ventilation economizer controls. e.g., retrofits, in smaller HVAC systems
Less use of air conditioning or no air conditioning	Changes in ventilation rates, indoor temperatures and humidity values Greater exposure to outdoor noise with open windows Greater exposure to OA pollutants with open windows Less interior masking of noise by HVAC systems	Hybrid HVAC systems that employ cooling only during peak weather periods Mechanical ventilation without air conditioning Night time ventilative cooling systems integrated with thermal storage Workstation or chair based cooling systems Auxiliary filtration systems independent of the HVAC supply air streams
Building energy standards based on measured energy consumption, with associated minimum IEQ maintenance requirements	Failure to meet energy standards may increase pressures to relax temperature, humidity, and ventilation conditions Simultaneous requirements to demonstrate the maintenance of minimum IEQ conditions will drive new technology adoption.	Real time monitoring systems for energy use and IEQ conditions integrated with HVAC controls. Improved HVAC control systems Increased HVAC maintenance Adoption of various HVAC energy technology advances.