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THE ROLE OF THE U.S. DEPARTMENT OF ENERGY IN INDOOR AIR QUALITY AND BUILDING VENTILATION POLICY DEVELOPMENT

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ABSTRACT

Building ventilation consumes about 5.8 exajoules of energy each year in the U.S. The annual cost of this energy, used for commercial building fans (1.6 exajoules) and the heating and cooling of outside air (4.2 exajoules), is about $US 33 billion per year. Energy conservation measures that reduce heating and cooling season ventilation rates 15 to 35% in commercial and residential buildings can result in a national savings of about 0.6 to 1.5 exajoules ($US 3-8 billion) per year assuming no reduction of commercial building fan energy use. The most significant adverse environmental impact of reduced ventilation and infiltration is the potential degradation of the building's indoor air quality.

Potential benefits to the U.S from the implementation of sound indoor air quality and building ventilation reduction policies include reduced building-sector energy consumption; reduced indoor, outdoor, and global air pollution; reduced product costs; reduced worker absenteeism; reduced health care costs; reduced litigation; increased worker well-being and productivity; and increased product quality and competitiveness.

INTRODUCTION

"To ensure that improved energy efficiency enhances, rather than harms, indoor air quality, the Federal Government will continue its support of research and other activities in this area... Energy-efficiency measures need not interfere with achieving a high-quality, healthy, safe, and pleasant home environment. Buildings-related research and development by the Department of Energy, the Environmental Protection Agency, and other agencies, as well as industry- and utility-sponsored research, will continue to emphasize indoor air quality." (1)

"The (U.S.) Congress ... declares that the establishment of a Department of Energy is in the public interest and will promote the general welfare by assuring coordinated and effective administration of Federal energy policy and programs. It is the purpose of this Act ... to create and implement a comprehensive energy conservation strategy that will receive the highest priority in the national energy program ..., to assure incorporation of national environmental protection goals in the formulation and implementation of energy programs, and to advance the goals of restoring, protecting, and enhancing environmental quality, and assuring public health and safety ..." (2)

The above two citations are indicative of why the U.S. Department of Energy (USDOE) should be heavily involved in indoor air quality and building ventilation research and policy development. Building ventilation consumes about 5.8 exajoules of energy each year. The annual cost of this energy is about $US 33 billion per year. Energy conservation measures that reduce ventilation rates in commercial and residential buildings can result in significant energy savings. The primary adverse environmental impact of reduced ventilation and infiltration rates is the potential degradation of the building's indoor air quality. However, intelligent implementation of energy conservation measures that reduce ventilation rates can be accomplished without compromising the quality of indoor air and can sometimes improve indoor air quality.

Occupants of office buildings are responsible for "producing" one-half of the U.S. Gross National Product, $US 2.5 trillion/yr (3). A 1% increase in building-occupant productivity, perceived to be obtainable through improved indoor air quality, can result in an increase of $US 25 billion in productivity (3).

Acceptable indoor air quality and reduced building sector energy consumption can be achieved through the development of appropriate policies and strategies. The development of advanced indoor air quality models that explicitly include building energy consumption parameters is one tool that can assist the USDOE in the development of policies to reduce wasted ventilation energy without a detrimental environmental impact of this "new source" of energy.

BACKGROUND

Ventilation Energy Consumption in the U.S.

Building ventilation consumes 5.8 exajoules of energy ($US 33 billion) each year in the U.S. Direct ventilation of commercial buildings (i.e., fan power) consumes 1.6 exajoules; residential and commercial building heating and cooling consume about 13 exajoules (4), about one-third of which, 4.2 exajoules, is used to heat or cool outside air (5).

Energy is currently being wasted in both the commercial and residential sectors by the over-ventilation of buildings. Average commercial building ventilation rates are three-fold higher than the rates recommended by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) and average residential building ventilation rates are twice the ASHRAE recommendation (6-8). Although the building ventilation rate data is limited, the potential for saving 15 to 35% or more of the energy used to heat or cool outside air appears to exist. This would result in an energy savings of about 0.6 to 1.5 exajoules/yr ($US 3-8 billion/yr).

The Relationship between Ventilation and Indoor Air Quality

Ventilation is the primary mechanism for removing indoor-generated pollutants from a building and for supplying fresh air to the building and its occupants. Indoor-generated pollutants include traditionally-benign pollutants such as carbon dioxide, perfumes, and body odors as well as more toxic pollutants such as carbon monoxide, radon, legionella, and volatile organic compounds -- some of which are carcinogenic. The adverse health effects of high indoor air pollutant concentrations include mild headaches, nausea, eye and nose irritation, chest tightness, increased risk to various cancers, and, in very rare situations, death. Additional

adverse impacts of high indoor air pollution include increased absenteeism, increased medical costs, reduced productivity, reduced product quality, and reduced product competitiveness. Improved indoor air quality can help reverse these impacts.

If the building ventilation rate is too low for the amount of pollutants generated indoors, then the concentration of indoor pollutants will rise above an "acceptable" level. If the building ventilation rate is higher than needed for the removal of indoor-generated pollutants, then valuable energy is wasted. Most U.S. buildings fall into the latter category based on limited data (7,8).

DISCUSSION

The USDOE's Goal of Minimizing Ventilation Rates while Maintaining Acceptable Indoor Air Quality

An important goal of the USDOE is to develop energy conservation technologies and strategies that reduce the energy consumption of building ventilation, while maintaining healthful, productive and comfortable indoor environments (9,10).

The USDOE is interested in accomplishing several indoor air quality objectives. One, identify major indoor air pollution sources that can be removed or separately ventilated and develop policies that encourage such action. Removing (or minimizing) indoor air pollution sources allows the building ventilation rate to be reduced while simultaneously improving the quality of indoor air. Two, develop cost-effective, energy-efficient methods for reducing occupant health risks when an indoor air pollution problem is identified (e.g., radon in residences). And three, identify buildings that are over-ventilated and develop policies to encourage ventilation rate reductions in those buildings.

The ideal strategy for achieving the goal of minimizing ventilation energy is to:

* First, minimize the number or severity of indoor air pollution sources.

* Second, design a cost-effective ventilation strategy that maximizes pollutant removal and minimizes ventilation energy consumption.

* Third, adjust the ventilation rate to the minimum rate needed for the indoor air pollution sources still present and for the ventilation scheme/efficiency of the building.

This greatly-simplified example of a potential national strategy essentially applies to new and existing residential and commercial buildings. Policy tools, including models, must be developed to effectively implement such a strategy.

Models are needed to determine which buildings are likely candidates for implementing the above procedure and thus reduce ventilation energy consumption. It is virtually impossible, and certainly not cost-effective, to measure ventilation rates, indoor pollutant concentrations, and indoor pollutant generation rates for all unhealthy pollutants in all U.S. residences and commercial buildings. Policies must be developed, based on modeling and research results, to encourage the optimal use of ventilation energy and to target buildings that waste the most ventilation energy.

USDOE's Traditional Role in Indoor Air Quality

The predecessor of the USDOE, the U.S. Energy Research and Development Agency, started an on-going and continuous research program addressing building ventilation and indoor air quality in 1975. This research program was started, in part, because of the energy crisis during the 1970s and the knowledge that building ventilation rates could be reduced only if acceptable and healthy indoor environments were maintained. Early research was sponsored by the USDOE's Office of Health and Environmental Research (OHER) and by the predecessor of the USDOE's Office of Building Technology (OBT). Both Offices supported research to "characterize" the indoor air quality situation in the U.S. OHER concentrated on the health and human exposure aspects of indoor air pollution and OBT concentrated on the building and energy aspects, although many projects overlapped.

In the mid-1980's, the USDOE's Office of Environmental Analysis (OEA) entered the picture, filling research and other gaps that were not being addressed by OHER or OBT. OEA reaffirmed and strengthened USDOE's growing interest and expertise in indoor air quality research and policy development (9).

OEA, with co-funding from OBT and the U.S. Consumer Product Safety Commission, funded the development of an indoor air quality model that explicitly linked building energy consumption parameters to indoor air pollution concentrations (11). This model, the first to go beyond the modeling of a single indoor environment, simulated the indoor air quality and ventilation energy consumption distributions of large groups of similar single-family residences. This type of model can be used as a tool for evaluating the indoor air quality impact of ventilation- and infiltration-reducing policies. When combined with policy or program costs, models will help develop cost-effective approaches to minimizing building ventilation energy consumption while maintaining or improving indoor air quality.

The Role of Other Federal Agencies in Indoor Air Quality

The primary U.S. Federal agency, other than the USDOE, conducting research on indoor air quality is the U.S. Environmental Protection Agency (USEPA). One key goal of the USEPA is to reduce human exposures to harmful pollutants, including those pollutants found indoors. Two other agencies involved in indoor air quality issues are the U.S Consumer Product Safety Commission (USCPSC) and the U.S. Department of Health and Human Services (USDHHS). The USCPSC conducts research on products that may pollute the indoor environment and cause a health hazard to the building occupants. The USDHHS conducts a wide variety of indoor air quality research through the numerous entities under its umbrella. For example, the National Institute for Occupational Safety and Health and the Surgeon General, both under the USDHHS umbrella, have conducted research and some policy development in the areas of occupational indoor air quality and passive (involuntary) smoking, respectively.

SUMMARY

The USDOE must take an active role in developing policy tools and policies if the goal of reducing building energy consumption while maintaining or improving indoor air quality is to be met. No other agency, federal or other, has the USDOE's perspective on indoor air quality and ventilation issues. No other agency has a mandate to develop sound policies that minimize building energy consumption while maintaining acceptable indoor air quality.

The USDOE needs to maintain a strong indoor air quality research program that characterizes indoor air pollution sources, investigates existing and novel ventilation strategies, develops energy/indoor air quality trade-off models, and develops appropriate policy tools and policies. The USDOE also needs to work closely with other U.S agencies. Sound policies, based on sound scientific research, can potentially save 0.6 to 1.5 exajoules of energy ($US 3-8 billion) per year in the U.S. while maintaining, sometimes improving, the quality of indoor air.

The U.S. Congress and other U.S. government bodies have recognized the USDOE's interest and need for involvement in indoor air quality issues. Potential benefits to the U.S. from the implementation of sound indoor air quality and ventilation-reduction policies include reduced building-sector energy consumption; reduced indoor, outdoor, and global air pollution; reduced product costs; reduced worker absenteeism; reduced health care costs; reduced litigation; increased worker happiness and productivity; and increased product quality and competitiveness.

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