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A PRIORITY AGENDA FOR ENERGY-RELATED INDOOR ENVIRONMENTAL QUALITY RESEARCH

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ABSTRACT
A multidisciplinary team of IEQ and energy researchers is working together to define a program of priority energy-related IEQ research. This paper describes the methods employed, ten high priority broad research and development (R&D) goals, and 34 high priority R&D project areas linked to these goals.

INDEX TERMS
Energy, IEQ research agenda, priorities

INTRODUCTION
Indoor environmental quality (IEQ) and building energy use are both strongly influenced by a building's design, construction, operation, and maintenance, by the activities of occupants, and by outdoor environmental conditions. Consequently, energy-efficiency measures may degrade IEQ, improve IEQ, or be IEQ neutral. Similarly, IEQ improvement measures may increase or decrease energy consumption or be energy neutral.

Given the many interactions between building energy performance and IEQ, these two issues must be addressed and researched in a coordinated manner. The U.S. Department of Energy (DOE) recognized the linkage of IEQ and energy use in the late 1970s and has since supported a modest size but important program of energy-related IEQ research. With the growing evidence that large health and productivity gains could be attained from practical improvements in IEQ, a group of state energy organizations represented by the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) has recently expressed their support for an expanded and coordinated program of energy-related IEQ research. As a first step, ASERTTI members and DOE are jointly supporting the development of an agenda for priority energy-related IEQ research. Among ASERTTI

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members, the California Energy Commission, with assistance from the California Institute for Energy Efficiency, has taken a lead role in supporting the development of this research agenda. This paper describes the draft priority R&D agenda.

METHODS

In conjunction with the sponsors, a scope for the R&D agenda was established. The agenda was to define the highest priority research needs pertaining to the interrelationships among IEQ conditions (excluding lighting and acoustics), health, occupant satisfaction, worker performance, building energy use, and the building systems and practices affecting energy use. The scope was to include residences, non-industrial commercial buildings (excluding health care buildings), and schools and to consider the design, construction, and operation phases of buildings. The agenda was to include a balanced portfolio of R&D products, ranging from new knowledge to applied products for implementation by industry.

A multidisciplinary "core team" of leading IEQ and energy professionals (see list of authors) is developing this agenda. Core team members were approved by a steering committee of the project's sponsors. An advisory team representing the buildings' industry and other stakeholders will be reviewing and commenting on the draft agenda presented in this paper.

To provide a framework for the identification of priority R&D needs, the following activities were undertaken:

1. Given the focus on *energy-related* IEQ research, the processes that link IEQ with energy use, and the IEQ conditions closely linked to energy use, were tabulated.
2. The core team reviewed several existing documents that propose IEQ research agendas (DOE, 2000; EPA, 2000; Fisk, 2000; Mendell et al., 2002; Wyon, 2000)
3. To enable the core team to identify R&D needs that are not being adequately addressed in existing programs, the existing IEQ research activities of U.S. federal agencies, ASHRAE, Air Conditioning and Refrigeration Technology Institute, and the California Air Resources Board were investigated and summarized.
4. The following criteria were identified for qualitative judging of the priority of proposed R&D activities: potential health benefits; potential comfort or odor benefits; potential productivity benefits; potential energy benefits or strength of the linkage to energy; need for expanded *public* support of R&D; potential for R&D success; expected overall benefit to R&D cost ratio; likelihood that R&D results will be used; extent to which project advances science or technology.

With this groundwork completed, the core team members developed a set of ten priority R&D goals. These broad goals reflect a consensus among the core team members and convey what the core team wants to have accomplished via this expanded program of research. For each broad goal, the core team then identified 7 to 10 priority research project areas. Via a process of discussion and voting, the core team selected the top 34 and, among them, the top 22 priority R&D project areas. Text is currently being developed to describe and justify the top 34 priorities.

RESULTS

Tables 1-3 list the 10 priority goals organized into three goal categories: 1) Advancing IEQ knowledge as needed to better address IEQ in decisions about building design, operation, and maintenance and to enable improved guidelines, standards and codes; 2) Developing tools, technologies, and practices that will facilitate the diagnosis and energy-efficient prevention or remediation of IEQ problems, and 3) Facilitating the implementation of existing knowledge

about how to maintain a high level of IEQ. The top 34 priority research project areas are listed under the most closely related goals, with the top 22 priorities labeled. Some priority goals and some priority research project areas do not fit unambiguously within a single category; thus, we have used our judgment to select the best category. In particular, some

Table 1. Priority R&D goals and project areas related to advancing IEQ knowledge.

Goa1 1. Identify IEQ problem areas and opportunities to improve IEQ by filling critical gaps in information about IEQ and about IEQ-influencing characteristics within existing buildings.

Project Areas:

- Characterize ventilation rates and IEQ conditions in energy efficient and conventional new housing. **Top22**
- Characterize ventilation and air-flow performance in existing buildings as a function of region, building type, HVAC system type. **Top22**
- Characterize IEQ in small (< 2500 m^2) commercial buildings. **Top 22**

Goal 2. Advance knowledge of how to improve IEQ, health, comfort and productivity by improving our understanding of the relationship of these outcomes with building ventilation, infiltration, and uncontrolled airflows.

Project Areas:

- Compare health outcomes among students in schools with very high and very low ventilation rates. Top22
- Investigate the influence of ventilation (natural and mechanical) on concentrations of contaminants from a diverse range of contaminant sources. Top22
- Relate ventilation rates in residences to health symptoms and to satisfaction with IAQ.
- Quantify the influence of outside air ventilation rates on prevalences of communicable respiratory diseases.

Goal 3. Advance knowledge of how to improve health, comfort and productivity by improving our understanding of the relationship of these outcomes with IEQ conditions and associated building characteristics (other than ventilation, infiltration, and uncontrolled airflows which are addressed in goal 2).

Project areas:

- Quantify the relationships between indoor chemical and biologic contaminants of greatest current concern and health effects on occupants. Top22
- Identify the health, energy, comfort, and productivity impacts of access to fixed and operable windows. Top22
- Characterize the effects of thermal comfort parameters on health and comfort in commercial and institutional buildings, including comparisons between air-conditioned and naturally ventilated buildings. Top22

Goal 4. Advance knowledge and models of how important IEQ conditions depend on characteristics and operation of buildings, providing as basis for improvements in building design, operation and maintenance and associated guidelines, standards, and codes.

Project areas:

- Characterize the impact of air flows, pressure differentials, ventilation rates, and HVAC system performance on contaminant transport and indoor humidity, and on related IEQ problems in small commercial buildings located in humid climates, and develop associated remediation measures. Top22
- Based on health and comfort effects, determine, as a function of climate, if the use of economizer cycles can enable a reduction of minimum ventilation rates.
- Quantify the IEQ and energy impacts of building/HVAC maintenance and space cleaning.

priority "*R&D*" areas call for facilitating the implementation of existing knowledge, when the existing knowledge about an issue is incomplete. Consequently, facilitating existing knowledge and development of related new knowledge should proceed in parallel.

Table 2. Priority R&D goals and project areas related to developing IEQ tools, technologies, and practices.

Goal 5. To enable energy-efficient improvements in IEQ, characterize indoor pollutant sources and develop pollutant source reduction measures.
Project areas:
- For various climates, develop best ventilation and insulation practices for crawl spaces and attics to minimize moisture problems and energy waste. Top22
- Characterize the dependence of microbiologic growth on surfaces within buildings and HVAC systems upon the materials used, airflows, humidities, moisture contents, condensation, and soiling; and develop scientifically-documented strategies for material selection, design, and construction of building envelopes and HVAC systems that minimize risk of microbiologic contamination, while maintaining energy efficiency. Top22
- Determine the pollutants, with their source strengths, emitted from common energy consuming office equipment such as copiers, printers, computers, etc.

Goal 6. Improve the IEQ performance of environmental control technologies and systems and develop new innovative technologies and systems for environmental control, including technologies and systems controlled by the building's occupants.
Project areas:
- Develop new and innovative HVAC system designs that provide improved IEQ at minimum life cycle cost. Top22
- Identify the components and features of current HVAC technologies posing risks, in actual use, of microbiologic contamination and dissemination. Top22
- Develop and evaluate strategies for micro-zoning while providing individual control, with a focus on spatial and temporal variability in IEQ conditions, on occupant interactions with the building [including its systems and environment] and on the resulting effects on health, comfort, productivity, and building energy use.

Goal 7. To facilitate more efficient prevention or diagnosis of IEQ problems, develop practical measurement tools and diagnostic procedures for IEQ conditions of particular concern.
Project areas:
- Develop inexpensive instruments for rapid and sensitive identification and measurement of indoor pollutants of concern. Top22
- Develop diagnostic protocols and tools for failures of HVAC that deteriorate IEQ and energy efficiency. Top22

DISCUSSION

The identified R&D priorities reflect a strong need to better characterize IEQ conditions and to better understand how people are affected by IEQ conditions and by the related building characteristics or practices. Studying the effects of building characteristics and practices on IEQ conditions, which provides the basis for energy efficient and effective IEQ control measures, was also considered a priority. Advancements in IEQ-related tools, technologies, and practices, primarily those related to indoor pollutant sources and to HVAC, were identified as priorities. Despite the gaps in existing knowledge, the core team believes that existing knowledge about how to improve IEQ is underutilized; thus, many of the priority

"research" project areas identified (Table 3) focus on facilitating the increased use of existing knowledge. Some readers may not characterize these activities as true scientific research, but the message from the core team is that these activities deserve a high priority.

Table 3. Priority R&D goals and project areas related to facilitating the use of existing IEQ knowledge.

Goal 8. Develop IEQ performance metrics, guidelines, and standards that guide building design, construction, operation, and maintenance.

Project areas:

- Based on a cost/benefit analysis, determine the appropriate minimum ventilation rates in building codes. Top22
- Combine current scientific and practical knowledge on health effects of building design operations and maintenance, including ventilation, into guidelines for best building practices. Top22
- Use existing knowledge to develop recommended maximum pollutant concentrations for pollutants and pollutant mixtures of particular concern. Top 22
- Integrate materials, IAQ, IEQ knowledge and appropriate weighting factors into the LEEDS Rating System for Green Buildings. Top22

Goal 9. Develop and evaluate strategies and instruments to disseminate critical IEQ information, and decision-making tools that enable building professionals to improve IEQ in an energy efficient manner.

Project areas:

Identify key decision makers for IEQ and energy efficiency in buildings through the building life cycle, and develop effective information dissemination and decision-making tools for IEQ and energy efficiency specifically targeted to these individuals.

Create a consumer-report style document that ranks the performance IEQ related building products in use.

Develop a database of costs and economic benefits of energy efficient practices and technologies for improving IEQ.

For design professionals and code officials, develop and deliver education programs in HVAC and building science related to best practice for IEQ.

Goal 10. To stimulate improvements in IEQ, develop financial incentives and remove barriers.

Project areas:

Develop life cycle cost analysis methods that include human and energy effects of IEQ. **Top22**

Develop financial incentive tools to stimulate energy-efficient or energy-neutral improvements in IEQ in commercial and institutional buildings, such as: model lease language; marketing strategies a la the LEEDS rating system; model IEQ insurance policies; and model IEQ/energy efficiency disclosure requirements linked to sales. **Top22**

Document the full human and environmental cost of least-cost decision-making including health cost, energy consequences, productivity losses, and waste produced. **Top22**

Better quantify the productivity costs and investigation and remediation costs of SBS problems.

Develop financial incentives for the design and construction team that reward high IEQ and energy performance.

Consistent with the focus on "energy-related" research priorities, building ventilation and HVAC are prominent in the agenda. The agenda also specifically calls for research on residences, *small* commercial buildings, and schools because these types of buildings have

been underrepresented in prior research. Research related to moisture and microbiological problems, particularly within hot and humid climates, are also prominent within the agenda. Many of the priority needs identified apply for both existing buildings and new construction.

It is important to recognize that this agenda has been tailored to match the missions and R&D capabilities of the sponsors; hence, many important research needs may be omitted from the agenda, e.g., studies of the mechanisms underlying IEQ-related health effects. Additionally, very important areas of research currently being addressed by sponsors may not have ended up within the list of highest priorities, solely because our goal was to identify R&D needs that are not being adequately addressed in existing R&D programs.

How should sponsors and researchers use this agenda? We recommend that they use the final version of this agenda, as it will reflect the comments of an advisory team. This final agenda will be made available at the following address < http://eetd.lbl.gov/ied/ied.html> after approximately July 15, 2002. We believe that many meritorious research efforts will be consistent with the priorities in this agenda. Specific research efforts may contribute to multiple goals and research project areas, or be more narrowly focused. Multidisciplinary research approaches are strongly encouraged. Finally, because it is likely that the core team has overlooked some critical research needs, we caution that sponsors should not exclude projects simply because they do not align with the priorities in this agenda.

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