Indoor Environmental Quality

Building Products Manufacturers Alliance Meeting

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Presentation Outline

- Introduction to Indoor environmental quality
- Effects on people
  - Important general findings
  - Highlighting findings of potential interest to building product manufacturers
- Opportunities for Building Products Manufacturers Alliance

Red Font

indicates (possible) links to building materials, topic of potential special interest to Building Product Manufacturers

Introduction

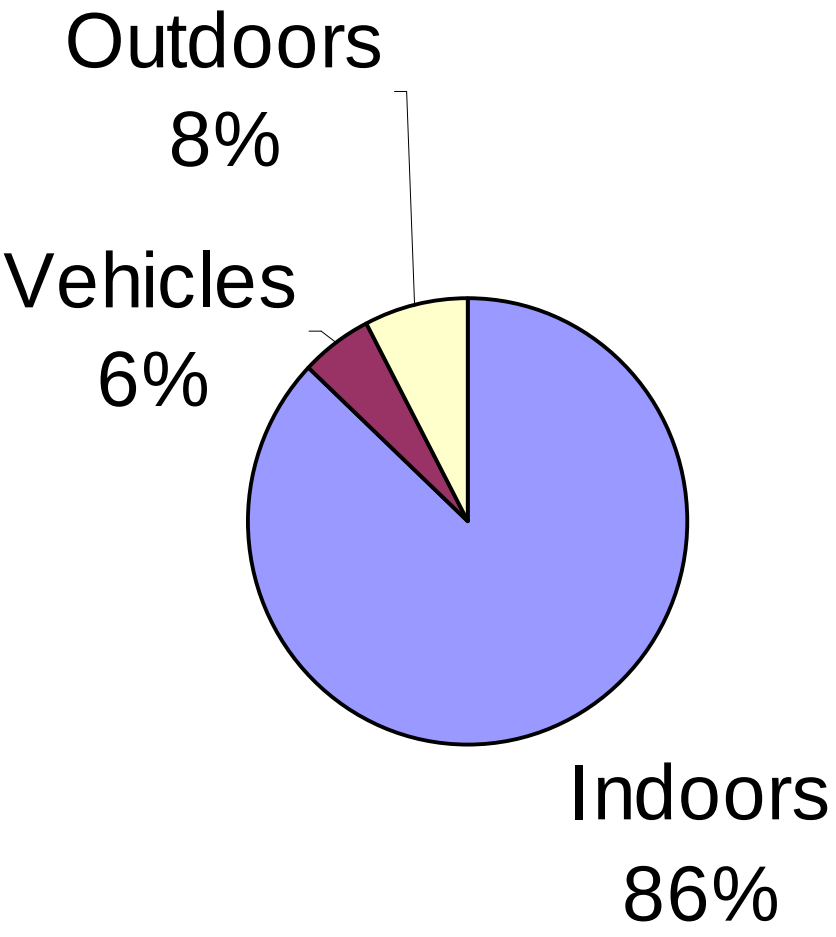
What is Indoor Environmental Quality?

- Features of indoor environment that affect peoples comfort, health, or work performance
  - Thermal conditions
  - Air pollutant concentrations
  - Acoustic environment
  - Lighting environment

Affected by building materials

Why Indoor Environments Are Important

- People indoors 90% of time
- For many pollutants, indoor concentration >> outdoor concentration
- Pollutant exposures increase 1000 fold with indoor release
- Buildings affect exposures to outdoor pollutants
- Very large population affected frequently by indoor exposures
- Large potential economic benefits of improved Indoor Environmental Quality (IEQ)



Why Indoor Environmental Quality (IEQ) and Building Energy Use Must Be Considered Together

Building features affecting both energy and IEQ

- Ventilation
- Air conditioning
- Filtration
- HVAC operation times
- Temperature setpoints
- Humidification
- Envelope materials
- Office equipment
- Window openability
- Etc.

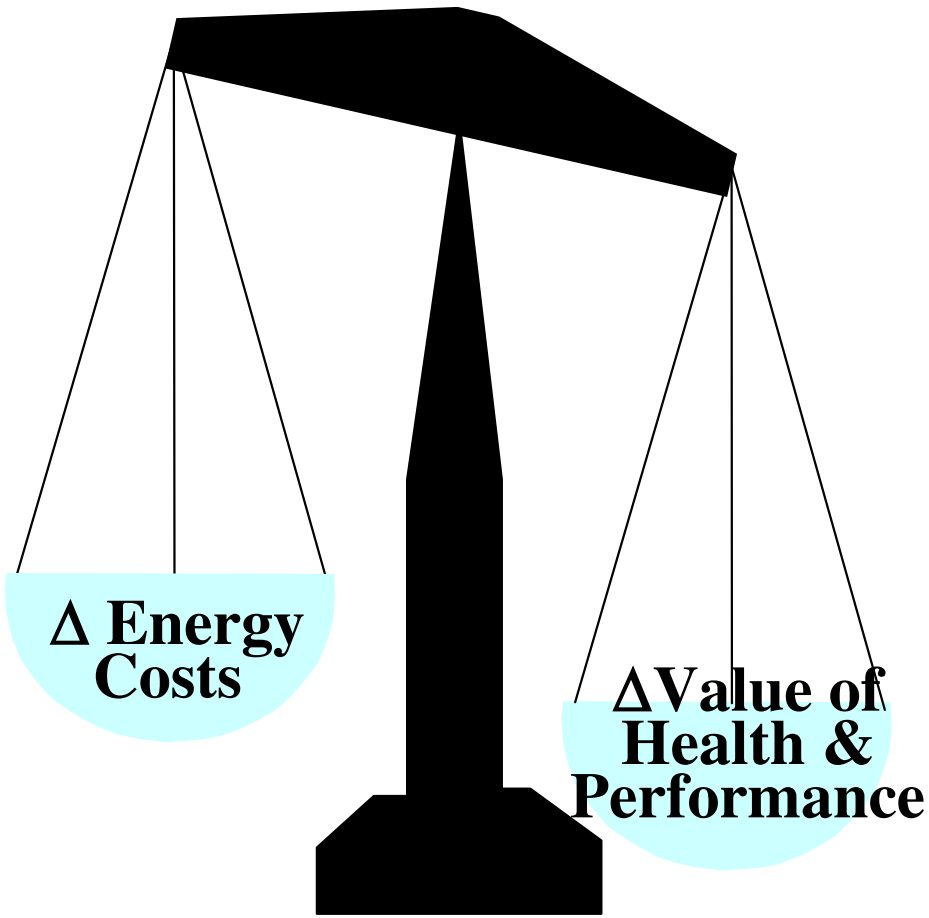
Building energy use*

- $1 - $2 per ft^2

People*

- $150 - $300 per ft^2

The Challenge



*example annual costs for U.S. office buildings

Indoor Pollutant Sources and Pollutants

Sources	Pollutants
Building materials and furnishings and consumer products	Volatile and semi-volatile organic compounds, some particles
Tobacco smoking & other unvented combustion	Complex mixture of particles and gases
Molds, bacteria colonizing wet building surfaces	Inflammatory agents, allergens, some infectious agents (mostly particles)
People	Odorous gases, infectious particles
Ozone-initiated chemical reactions	Aldehydes, ultrafine particles
Soil gas	Radon, volatile organic compounds

Effects of IEQ on People

Indoor Comfort

- Thermal comfort
  - Depends on air temperature, surface temperature, humidity, air velocity
- Perceived air quality (e.g., odors, satisfaction)
  - Depends on indoor pollutant sources including building products, outdoor air ventilation rates, air cleaning, air temperature
- Acoustic comfort (noise levels, speech privacy, etc.)
  - Depends on occupants, building equipment, building materials, building design, outdoor noise
- Lighting comfort (lighting levels, glare, etc)
  - Depends on lighting system, envelope design

Health Effects of Indoor Environments

- Building related (sick building) symptoms
- Allergies and asthma & related respiratory effects

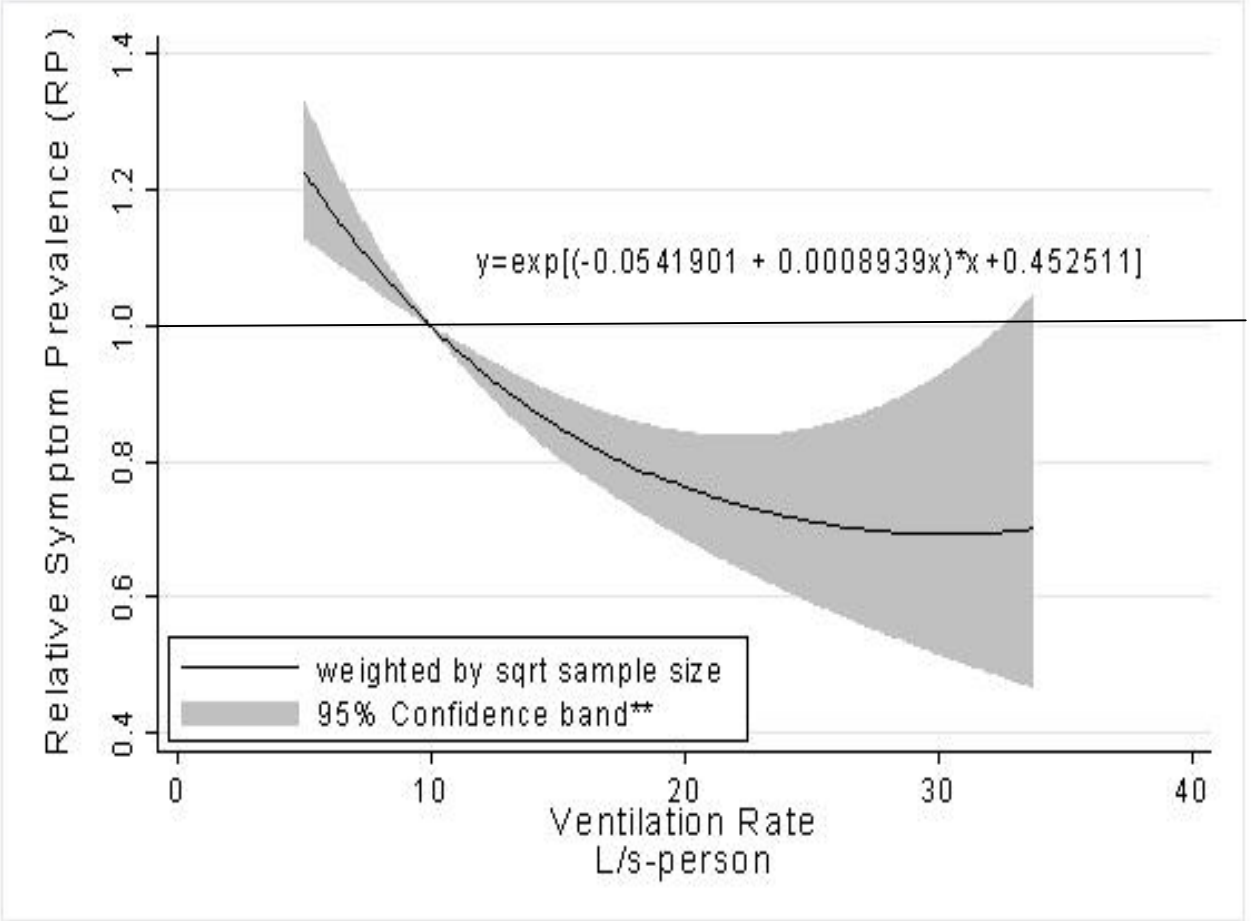
Link to building materials

- Rates of communicable respiratory disease (e.g., common colds, influenza)
- Infectious diseases with building as source (e.g., fungal infection in immune compromised)
- Cancer
- Reproductive effects?

Possible link to building materials

Building Related (Sick Building Syndrome) Symptoms

- Irritation (eyes, nose), headache, fatigue, etc.
- Associated with occupancy in building
- Common (e.g., 5-30% of office workers)



Hypothesis:

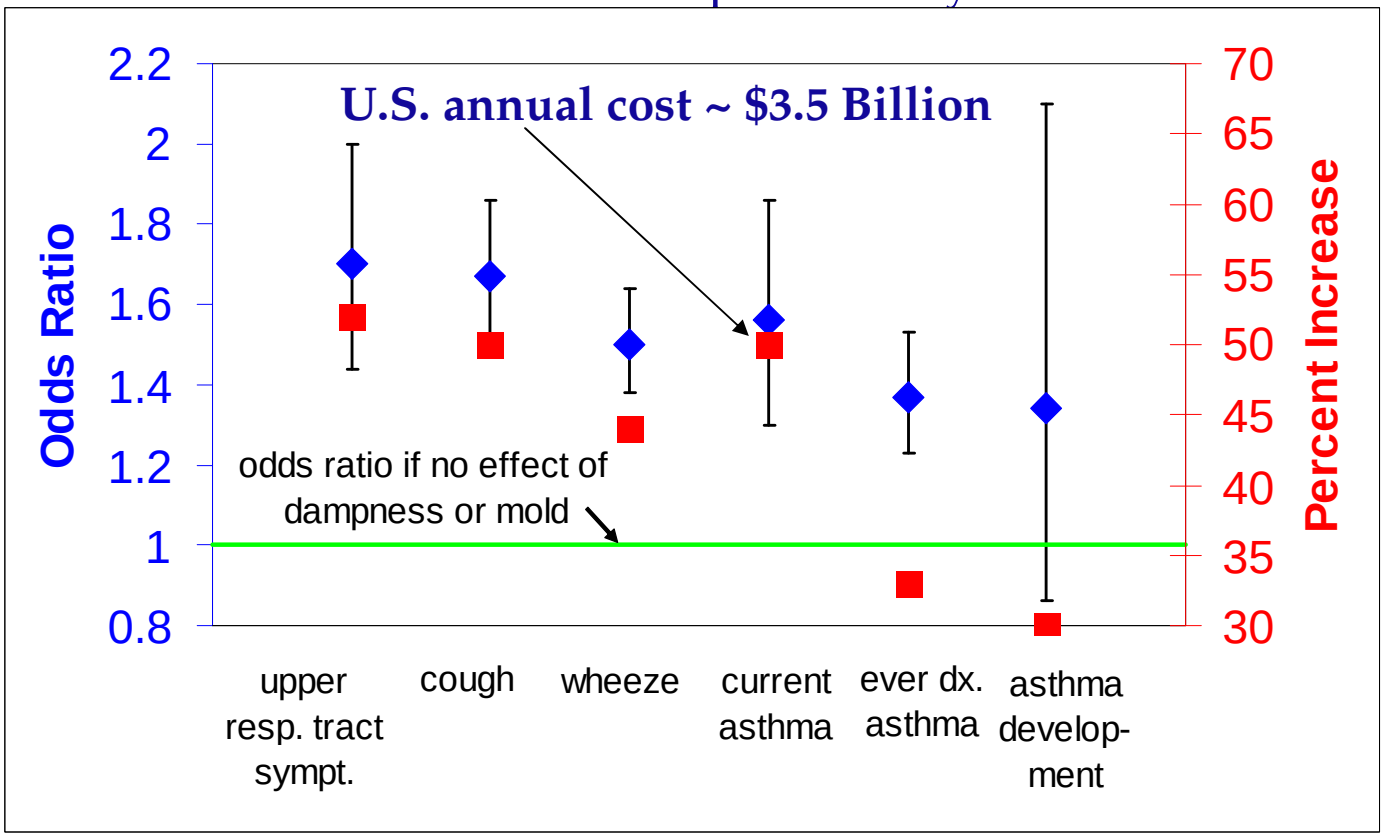
Symptoms are caused primarily by organic gaseous pollutants from building materials, furnishings, and consumer products

Asthma & Respiratory Effects of Dampness & Mold

Indoor Allergen or Inflammatory Agent Sources

- Dust mites
- Cock roach
- Pets
- Molds and bacteria from damp buildings
  - Affected by building material types

Health Risks in Damp or Moldy Homes



Possible Health Risks of Formaldehyde emitted from Building Materials

Formaldehyde

- Many indoor sources especially manufactured wood products
- Potent irritant
- Listed as a human carcinogen by World Health Organization
- Higher concentrations correlated with increases in asthma, allergy, respiratory symptoms*
- Indoor concentrations in homes often exceed guidelines
  - In 108 home survey, 59% of new CA homes had formaldehyde > CA ARB guideline of 33 $\mu g/m^3$ to prevent respiratory effects

* causal link not established

Indoor Plasticizers: Possible Health Risks

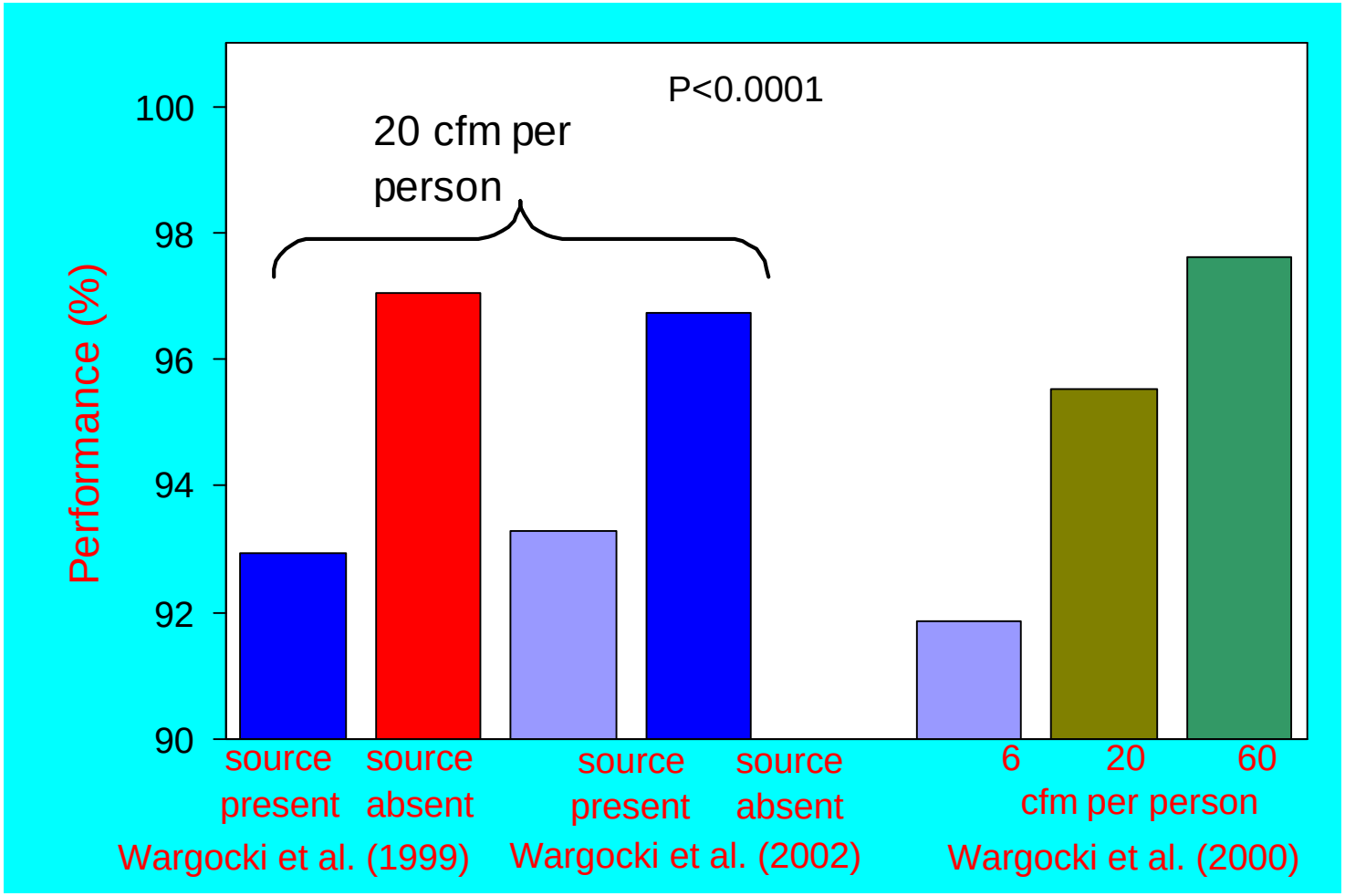
- Used to soften plastics
- Plastics, especially PVC, are used widely for flooring, wall covering, cabinets, etc
- Higher concentrations of some plasticizers* in indoor dust have been correlated with asthma and allergy outcomes
  - diagnosed asthma (ns, 2 studies), bronchial obstruction (1 study)
  - wheeze (2 studies; not in 1), cough (1 study)
  - phlegm (1 study), allergy (2 studies)
  - rhinitis (1 study), eczema (1 study)
- Higher quantity of PVC materials in homes also has been correlated with allergy & asthma outcomes**
- Some plasticizers may act as synthetic hormones
  - possible reproductive effects, etc.
- Food is also a source of plasticizer exposure

***BBzP**= n-butyl benzyl phthalate
***DEHP=** diethyl hexyl phthalate

** causal links not established

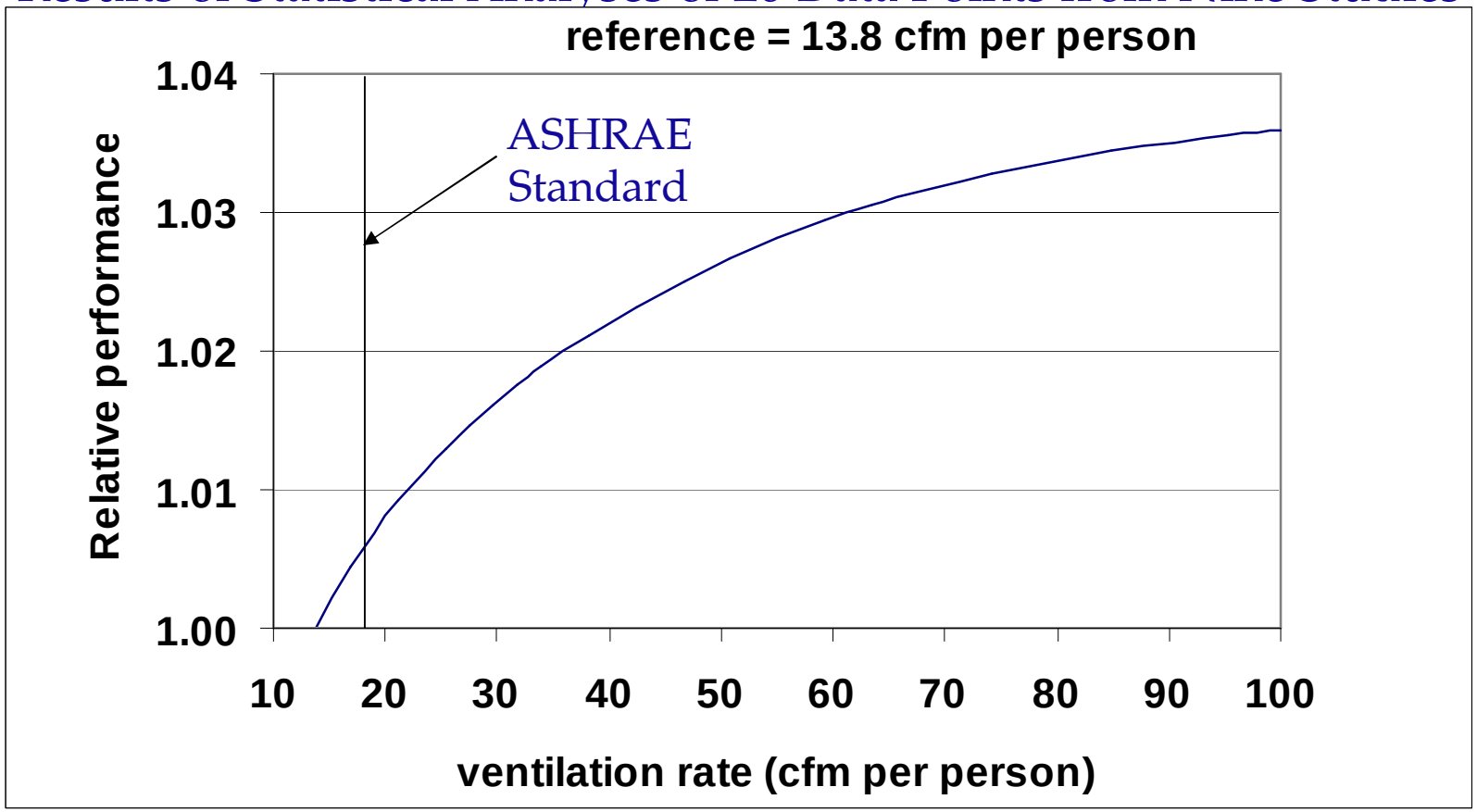
Work Performance Affected By Building Materials & Ventilation Rates

Results of Controlled Laboratory Studies in Denmark



Effects of Ventilation Rates on Work Performance

Results of Statistical Analyses of 26 Data Points from Nine Studies



Underlying mechanism/exposure is unknown

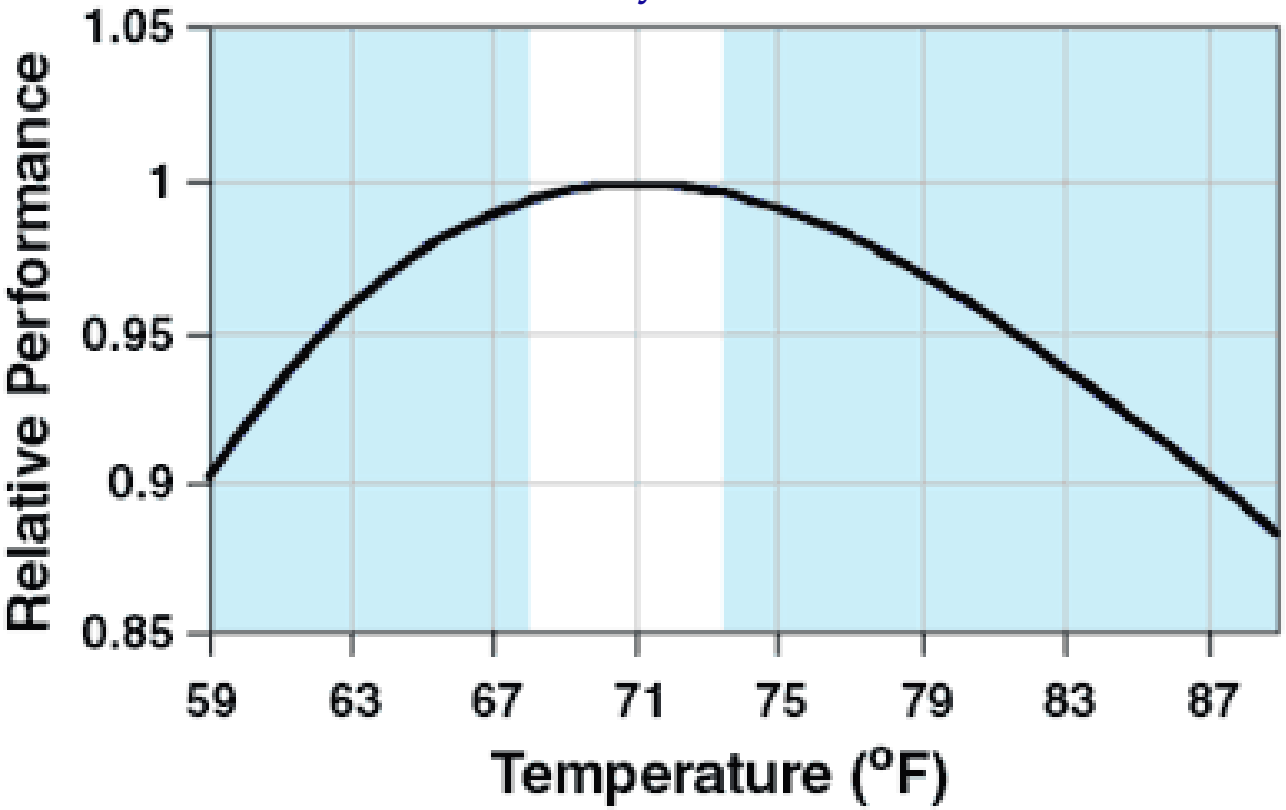
Estimated Benefits of Work Performance Improvements from Increased Ventilation

Change in Ventilation Rate (rates in cfm per person)	Estimated Increase in Performance (%)	Annual Economic Benefit per Worker @ $100K per Worker
15 to 20	0.6	$600
15 to 25	1.1	$1100
15 to 30	1.4	$1400
20 to 25	0.4	$400
20 to 30	0.8	$800
20 to 40*	1.4	$1400
30 to 40	0.6	$600
30 to 50	1.0	$1000
30 to 60	1.4	$1400

*approximate increase in annual average ventilation rate from use of economizer controls in Washington D.C. office building which saves $26 in energy per year per person

Effects of Temperature on Office Work Performance

From Statistical Analyses of Results of 24 Studies



Estimated Economic Value of Work Performance Changes from 1 °F Shift in Temperature Toward Optimum

Temperature Change		Estimated Increase in Performance (%)	Annual Economic Benefit per Worker @ $100K per Worker
increasing temperatures	67 to 68 °F	0.43	430
	68 to 69 °F	0.30	300
	69 to 70 °F	0.17	170
	70 to 71 °F	0.05	55
decreasing temperatures	76 to 75 °F	0.43	430
	75 to 74 °F	0.35	350
	74 to 73 °F	0.26	260
	73 to 72 °F	0.16	160

*Assuming $100K cost per worker for salaries and benefits

Opportunities for Building Product Manufacturers

- Building materials with low pollutant emissions
  - Green building credits → established market
  - Needed for very energy efficient buildings with reduced outdoor air ventilation
  - A challenge is to identify the key pollutants to control, other than formaldehyde
- Building materials resistant to microbial colonization
  - Some products in the market (wallboards, filters)
- Building materials that remove key indoor pollutants (e.g., formaldehyde, ozone)
  - Scavengers, room temperature catalysts → some products entering market in Japan and Europe
  - Helpful for very energy efficient buildings with reduced outdoor air ventilation

For More Information

- Many related papers downloadable at http://eetd.lbl.gov/IED/
- Concise summaries and downloadable papers at www.iaqscience.lbl.gov