

# Climate Change Hits Home



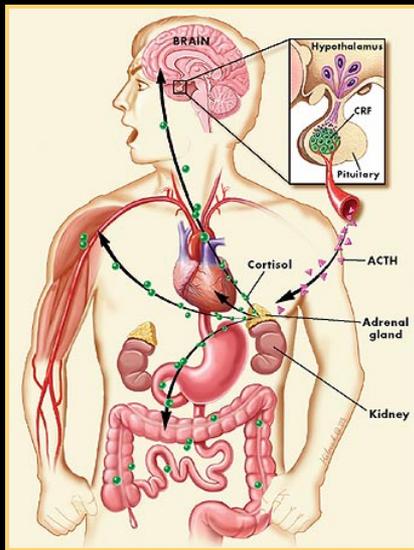
**John D. Spengler, Ph.D.**

*Akira Yamaguchi Professor of  
Health & Human Habitation*  
Harvard School of Public Health



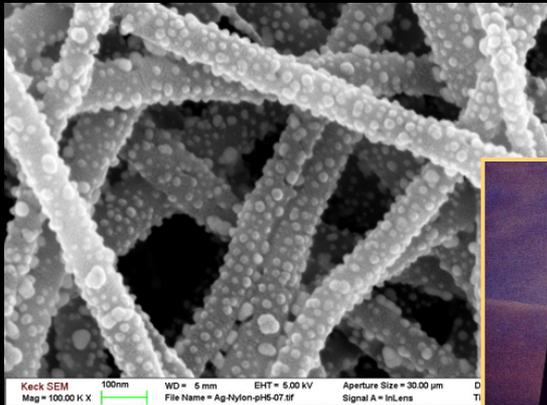
**LBNL**

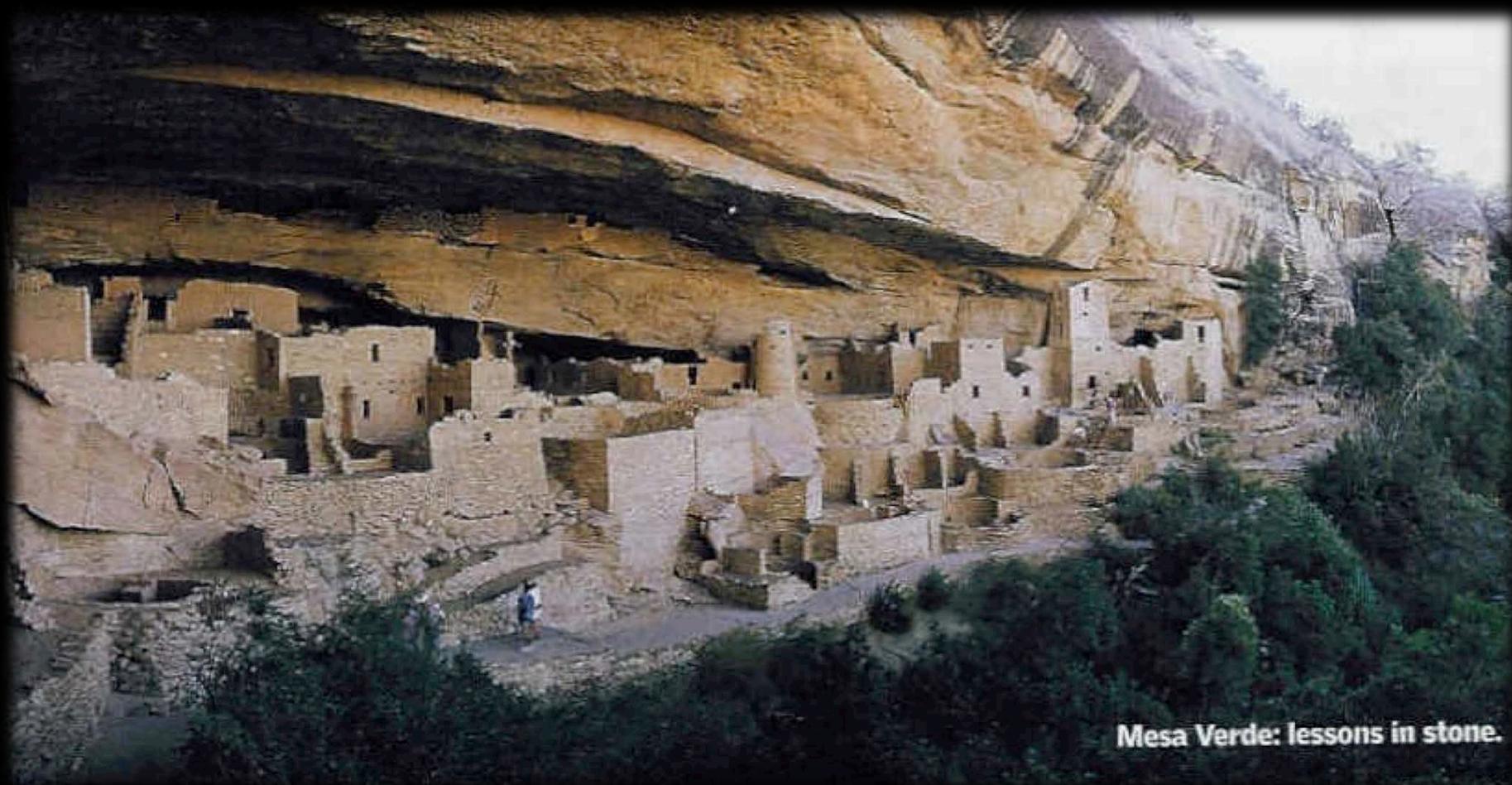
**June 18, 2012**



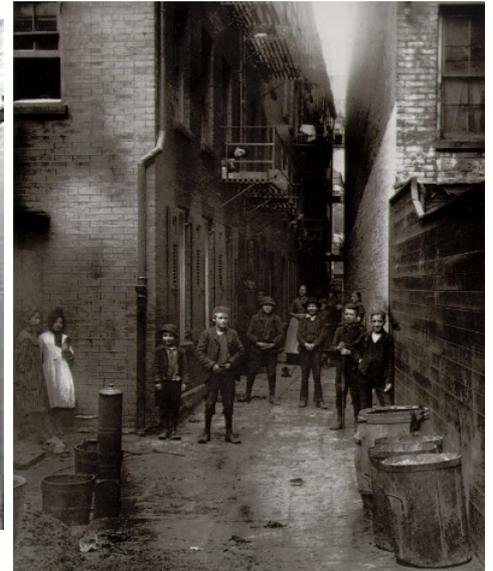
# Grand Challenges

- Infectious diseases and microbiology of us
- sVOCs--EDC
- Nano-particles-IAQ Chemistry
- Climate, buildings and health



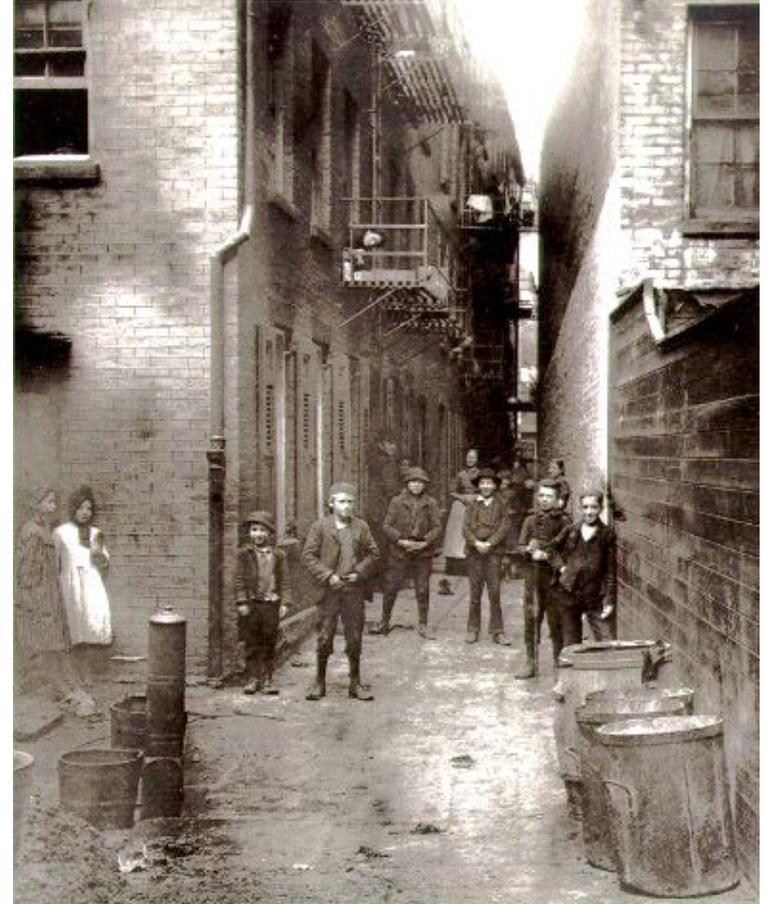


**Mesa Verde: lessons in stone.**

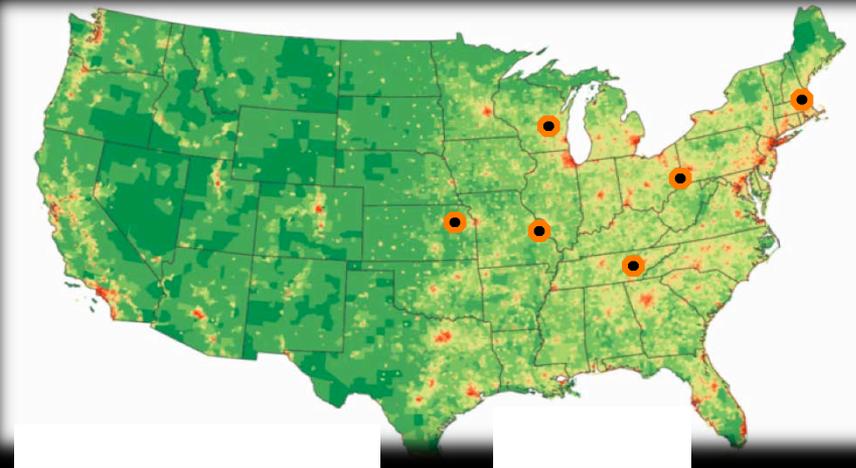


# Urban Housing – 19<sup>th</sup> Century

- Overcrowding
- High rates of infectious disease (epidemics)
  - Cholera
  - Tuberculosis
  - Typhoid fever
- Poor sanitation
- Fire hazards
- Poor lighting
- No ventilation



# *Energy crisis of 1973 and air pollution*



- LBNL's indoor air research program

- Harvard's 6 cities air pollution health study

# 1978-2008 Copenhagen Conferences

## INDOOR CLIMATE

*Effects on human comfort,  
performance, and health*

Edited by P. O. Fanger and O. Valbjørn



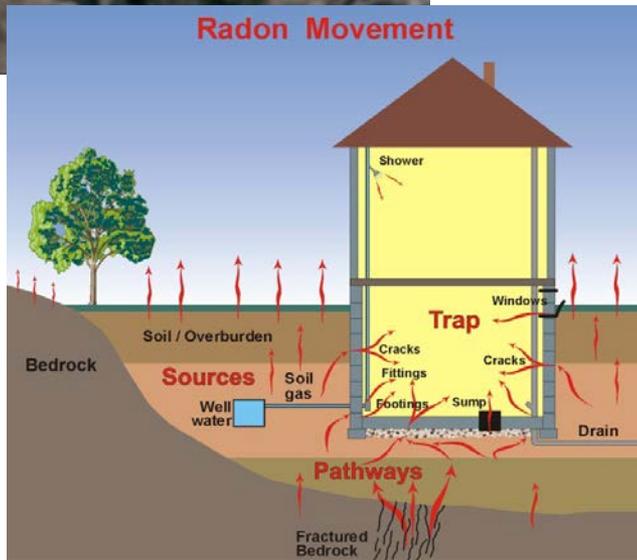
DANISH BUILDING RESEARCH INSTITUTE



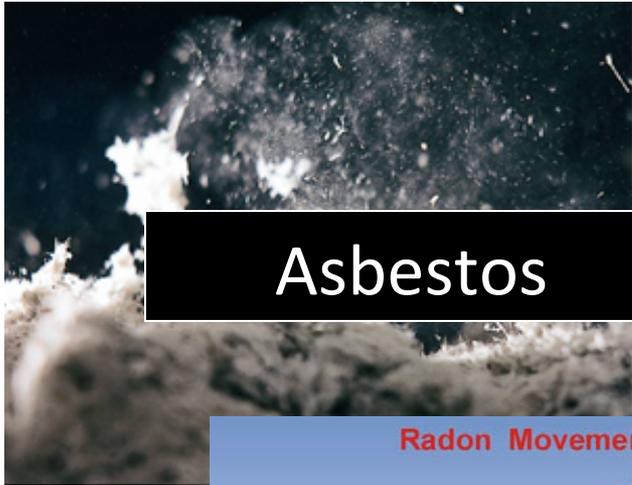
# *What did they talk about?*

- Indoor Pollutants
  - VOCs, HCHO, ETS, Radon, NO<sub>2</sub>, Allergens, Mites, Odors, Humidity
- Ventilation
  - Homes, Hospitals, ETS control
- Electric Environment
  - Ions, Static electricity, electric fields
- Thermal Comfort
  - Behavior, perceptions, sensations, discomfort, sleeping, swimming, elderly, energy, noise and heat stress effects on performance

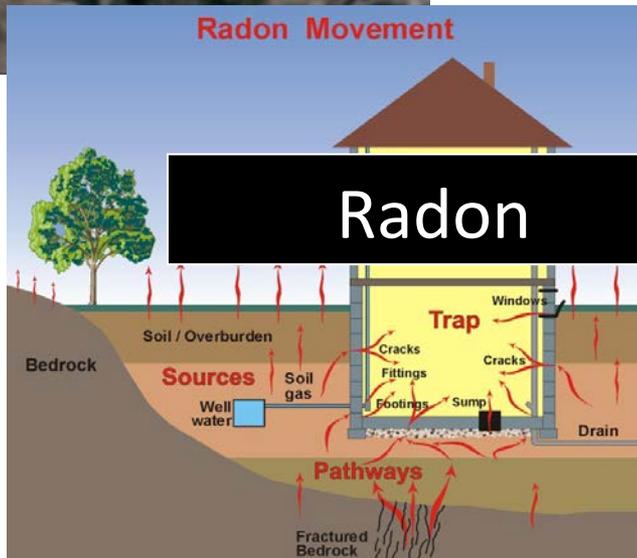
# Housing/buildings and health



# Housing/buildings and health



Asbestos



Radon



SBS



Legionnaires disease

# Household exposures: asthma, cancer, neurological, LRI

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©2001 HowStuffWorks

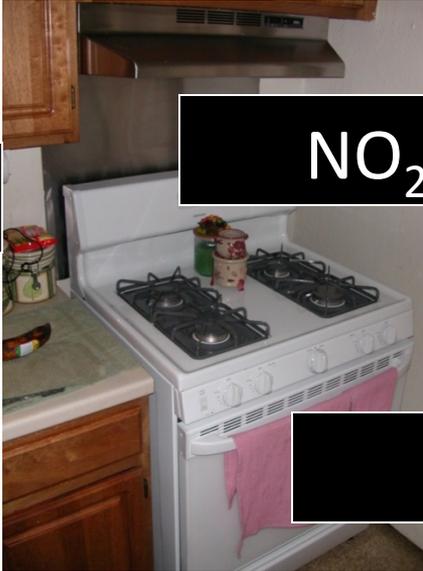


# Household exposures

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ETS



NO<sub>2</sub>, CO



Lead



VOCs



Moisture/Mold



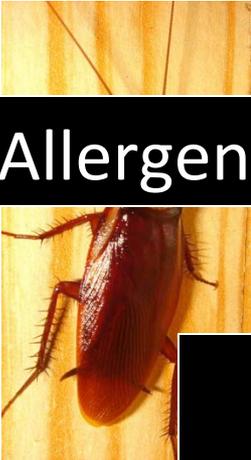
Formaldehyde



Allergens



Pesticides/  
Chemicals



Ambient  
Pollution

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# *Second Hand Smoke*



- **The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General, U.S. Department of Health and Human Services 2006**



- **The scientific evidence indicates that there is **no risk-free level of exposure to secondhand smoke.****

## Up In Smoke

# WHO

With no effective intervention, estimates are that by year 2020 the tobacco epidemic will kill **8.4 million** every year, 70% of deaths occurring in developing countries.\*

## TOBACCO still a major Health risk world wide

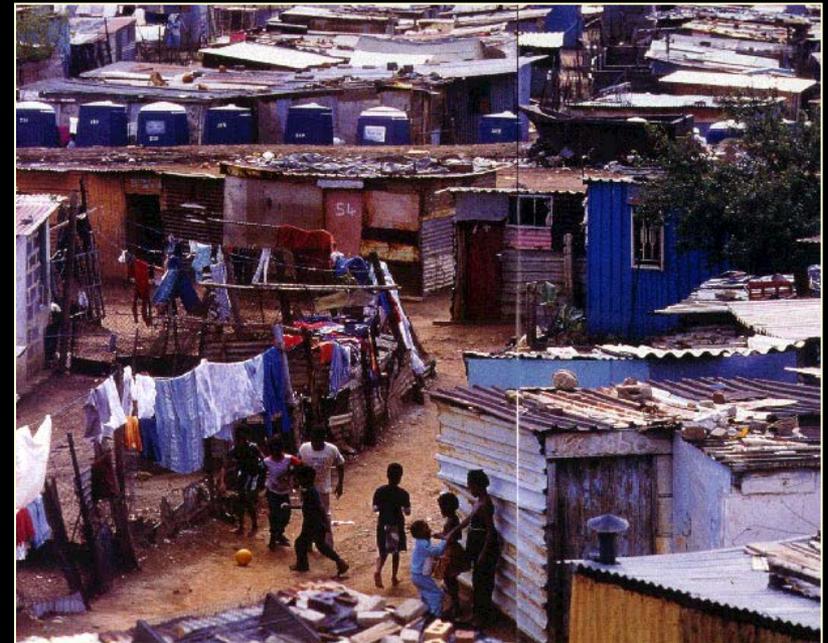
## 10 million deaths per Year by 2030



SOME PROJECTED DEATHS IN THE YEAR 2020

\* Peto, R.; Lopez, A.D.; Borehm, J., et al. (1994) *Mortality From Smoking in Developing Countries 1950-2000*. Oxford: Oxford University Press.

# *Asbestos*



*Soweto Slums, South Africa*

**Product bans**

**Guidance for management  
In buildings**

**Property transfer**

# *What's happening now?*



- Indoor Air vs. Outdoor Air Policy Void
- Smoke free indoor policies taking hold
- Surgeon Generals call for Health Homes
- Globalization of products: Chinese Wallboard
- Always new chemicals in the market
- Rapid urbanization and disparities

“The United States EPA ranks indoor air pollution among the top five environmental risks to public health.

Unhealthy indoor air is found in up to **30%** of new and renovated buildings”.

(Sustainable Building Technical Manual, Washington, D.C.: Public Technology, Inc. | Architects & Consultants / AVA Agnes Vorbrodt & Associates)



IAQ **can affect** people's comfort, health, and work and schoolwork performance.

(Source: Lawrence Berkley National Laboratory. <http://www.iaqscience.lbl.gov/overview.html>)

A **broad range** of health effects may result from indoor pollutant exposures.

(Source: Lawrence Berkley National Laboratory. <http://www.iaqscience.lbl.gov/overview.html>)

*LEED Platinum Bank of America  
building at 1 Bryant Park NYC*



*Yet, IAQ problems persist!  
And , may get worse!*

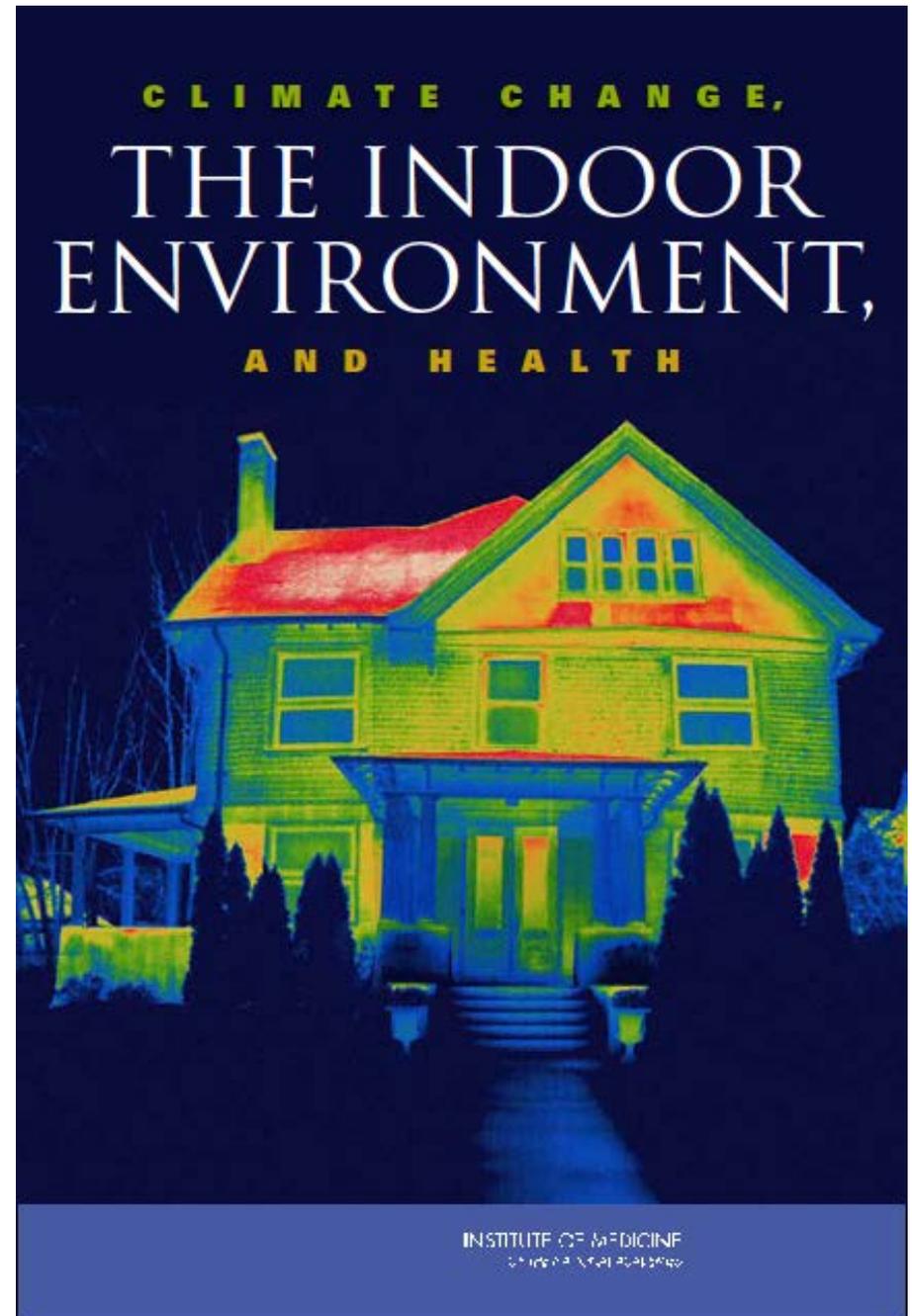
# Climate Change and Indoor Environments and Health

*Institute of Medicine  
National Academy of Science*

*Released June 7<sup>th</sup>, 2011*

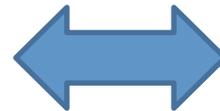
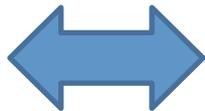
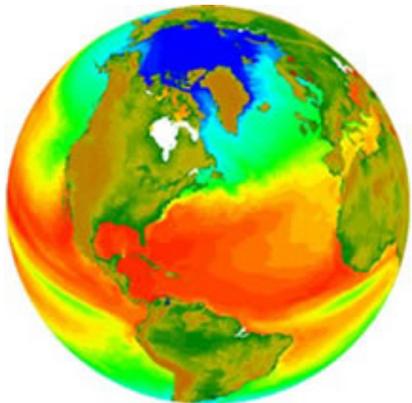
[http://www.nap.edu/  
climatechangehealth](http://www.nap.edu/climatechangehealth)

*Sponsor: US EPA*



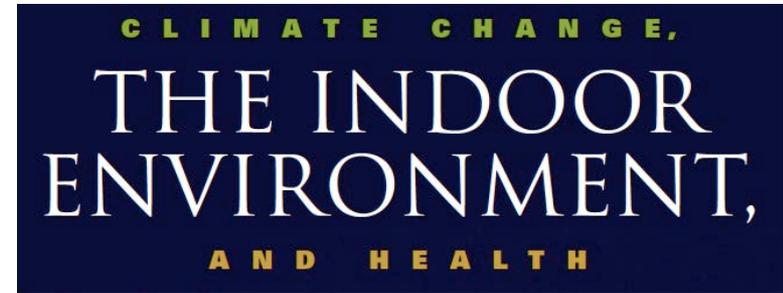
# Key questions

- What are the likely impacts of climate change in the U.S. on human exposure to chemical and biological contaminants inside buildings, and what are the likely public health consequences?
- What are the likely impacts of climate change on moisture and dampness conditions in buildings, and what are the likely public health consequences?
- What are priority issues for action?



# IOM NAS Committee

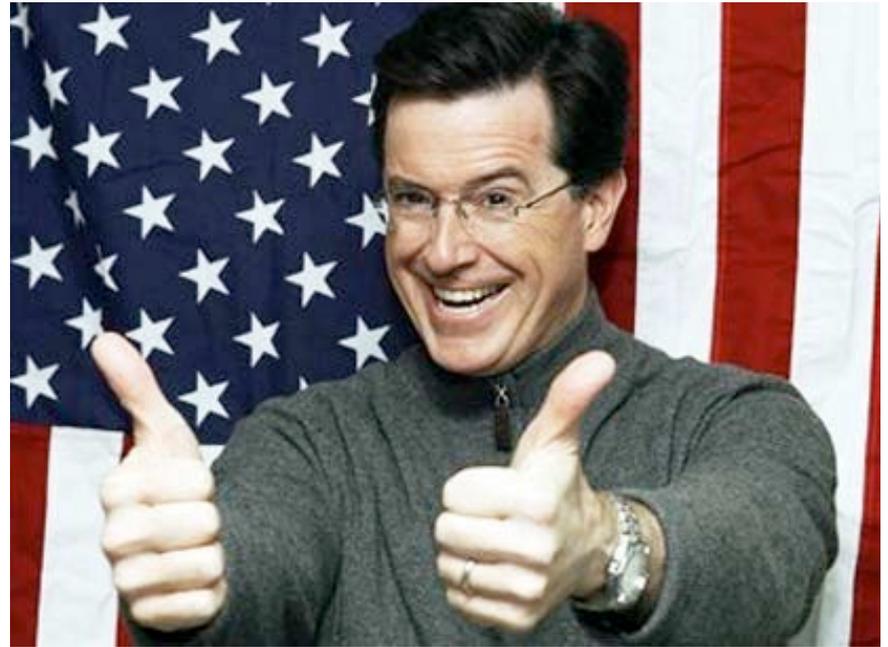
- **John D Spengler**, Harvard University (chair)
- John L Adgate, University of Colorado
- Antonio J Busalacchi, University of Maryland
- Ginger L Chew, Centers for Disease Control
- Andrew Haines, London School of Hygiene and Tropical Medicine
- Steven M Holland, National Institutes of Health
- Vivian E Loftness, Carnegie Mellon University
- Linda A. McCauley, Emory University
- William W Nazaroff, University of California, Berkeley
- Eileen Storey, National Institute for Occupational Safety and Health



Study Director: David A Butler    Research Associate: Lauren Savaglio

Why study the effect of climate change on the indoor environment and health?

*“What's the best way to deal with climate change?”*



*“Staying inside works fine for me.”*

**Stephen Colbert**  
*The Colbert Report*  
28 February 2011



**1°C  
increase in  
global  
temperature**

**=**

**5% increase in  
moisture in the  
atmosphere**

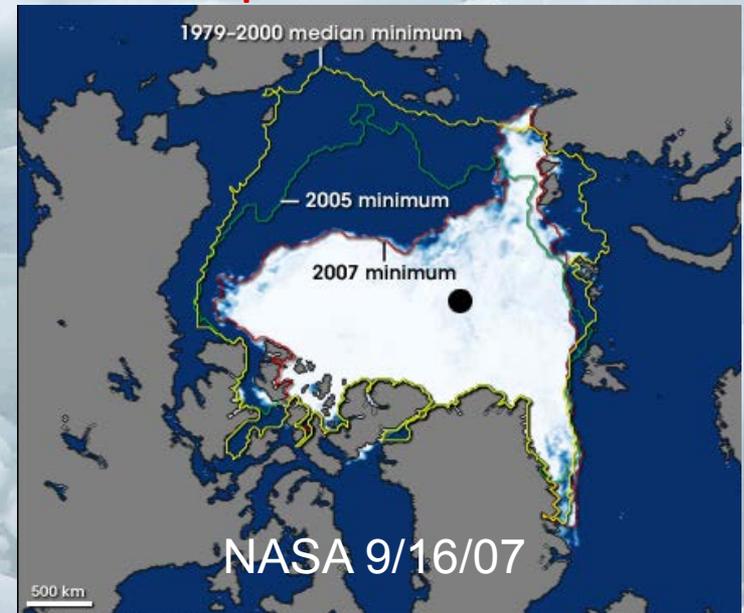
# Evidence for global warming is unequivocal

## Since 1970, Rise in:

- Global surface temperatures
- Tropospheric temperatures
- Global SSTs, ocean Ts
- Global sea level
- Water vapor
- Rainfall intensity
- Precipitation extratropics
- Hurricane intensity
- Drought
- Extreme high temperatures
- Heat waves
- Ocean acidity

## Decrease in:

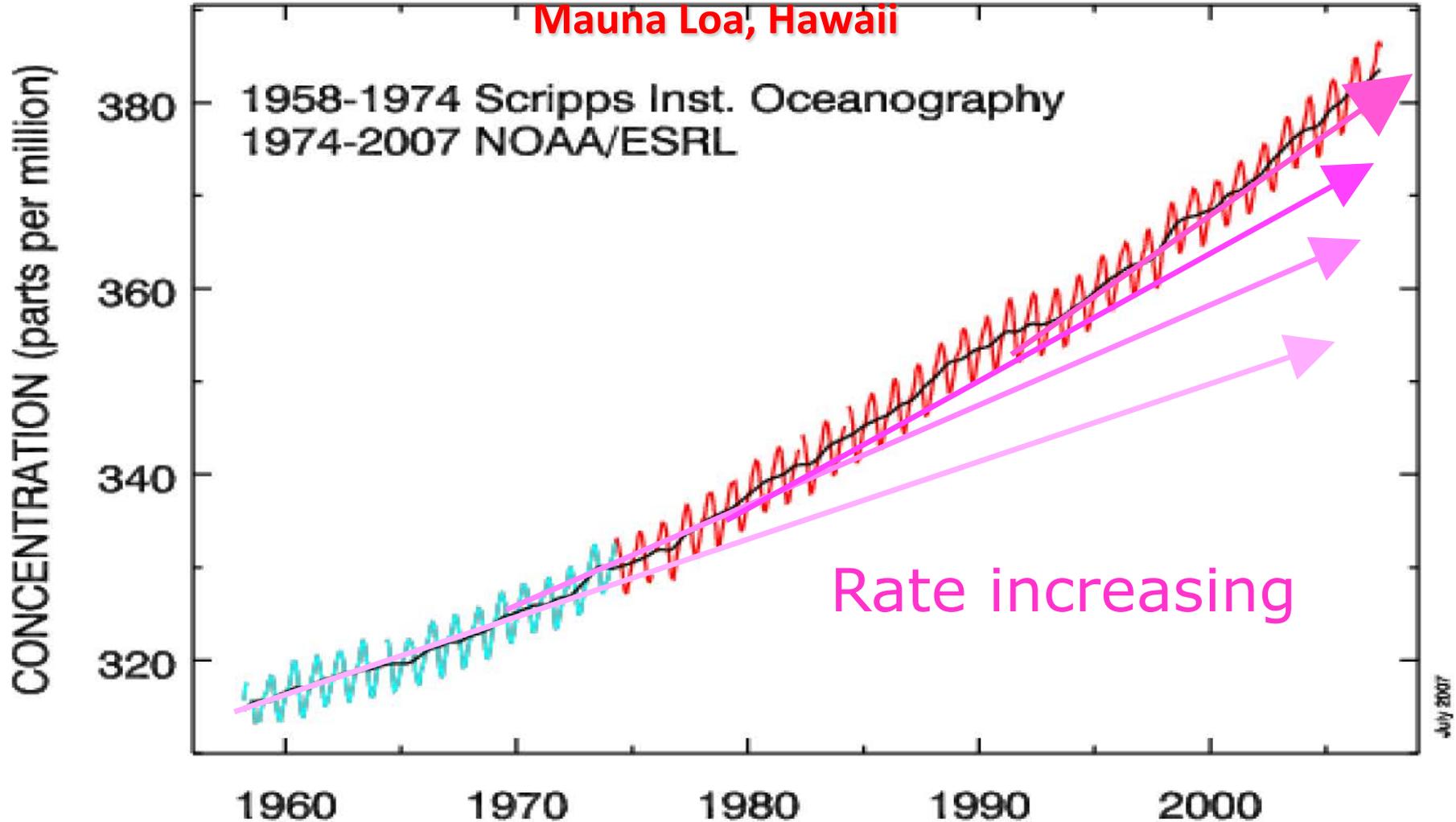
- NH Snow extent
- Arctic sea ice
- Glaciers
- Cold temperatures



Fr: K Trenbreth, Climate Analysis Section, NCAR IPCC Lead Author

Photo Credit/Crédit photographique: Dan Crossie

# Changing atmospheric composition: CO<sub>2</sub>

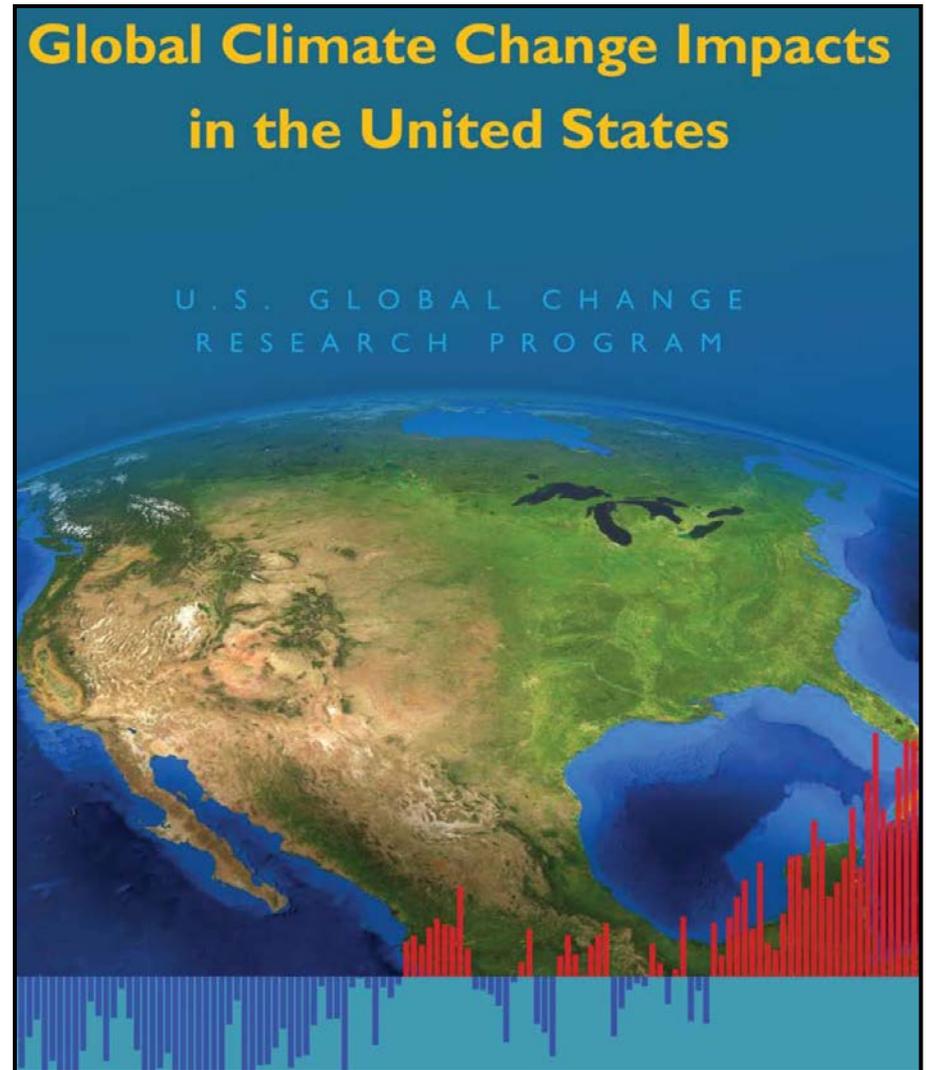


Data from Climate Monitoring and Diagnostics Lab., NOAA. Data prior to 1974 from C. Keeling, Scripps Inst. Oceanogr.

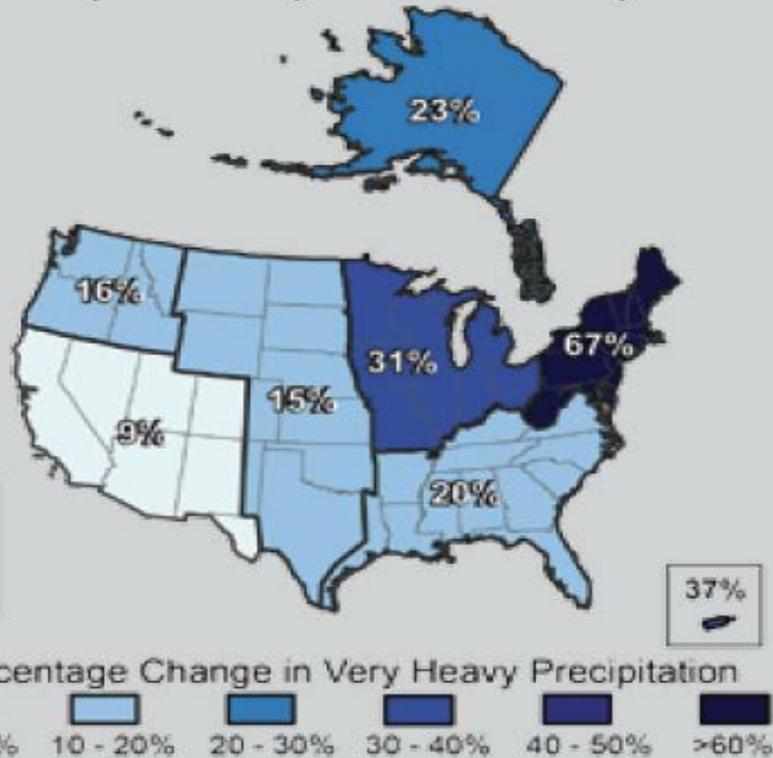
Fr: K Trenbreth, Climate Analysis Section, NCAR IPCC Lead Author

# White House Assessment of Climate Change Impacts in the US

- **Northeast**
  - Warmer
  - Heat waves
  - Wetter
  - Extreme precipitation

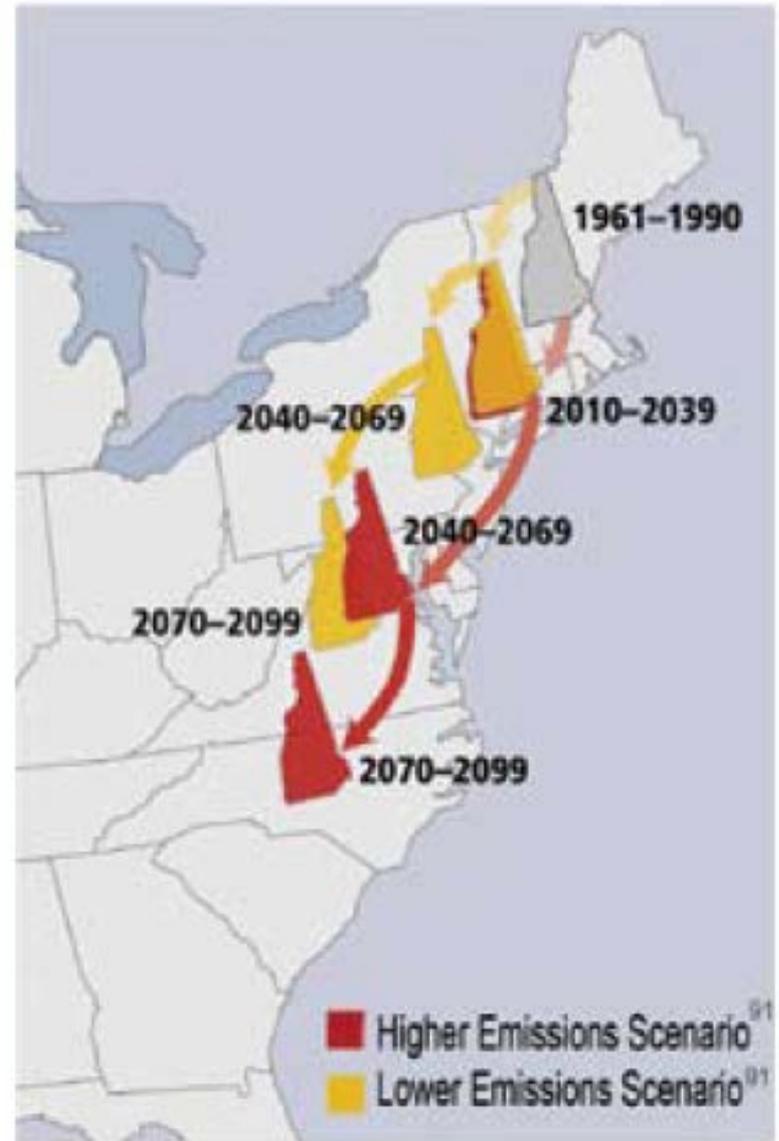


## Increases in Amounts of Very Heavy Precipitation (1958 to 2007)



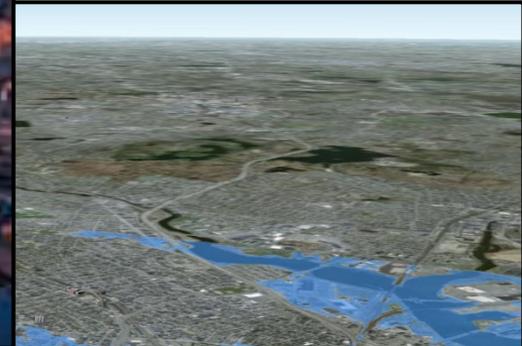
Updated from Groisman et al.<sup>113</sup>

## Climate on the Move: Changing Summers in New Hampshire



Hayhoe et al.<sup>359</sup> Fig. from Frumhoff et al.<sup>234</sup>

# Some implications of climate change

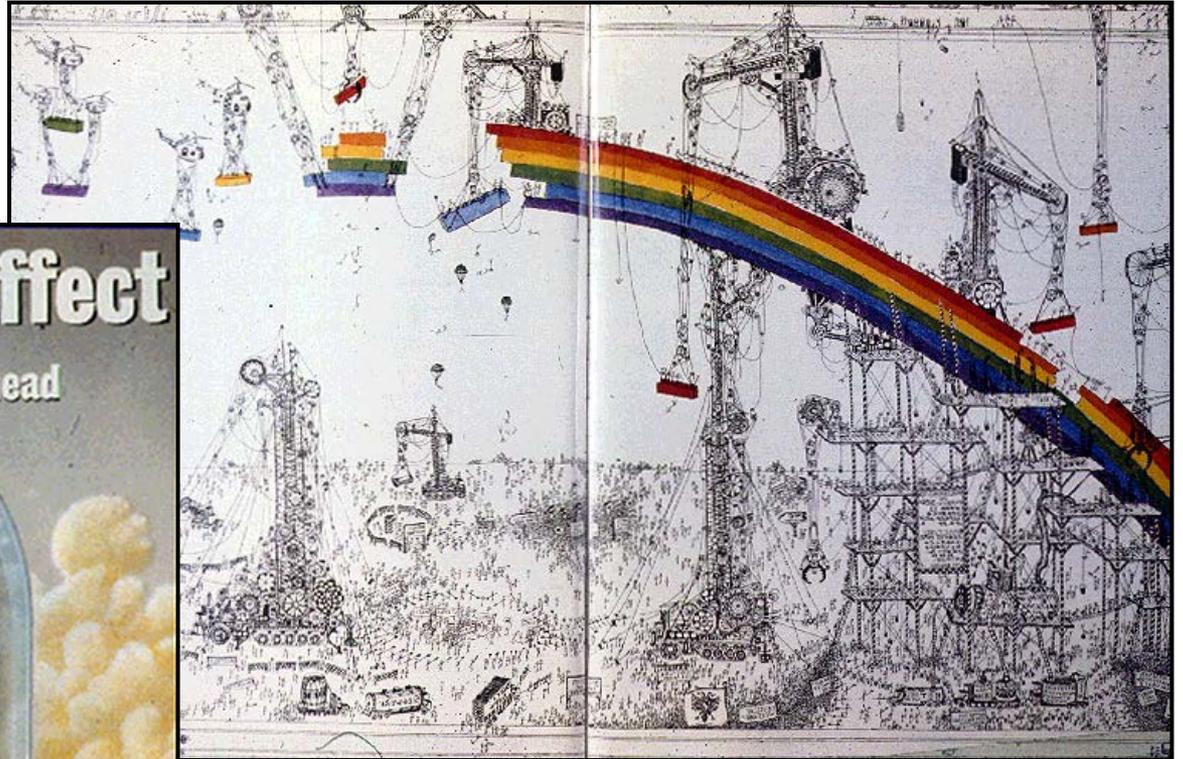
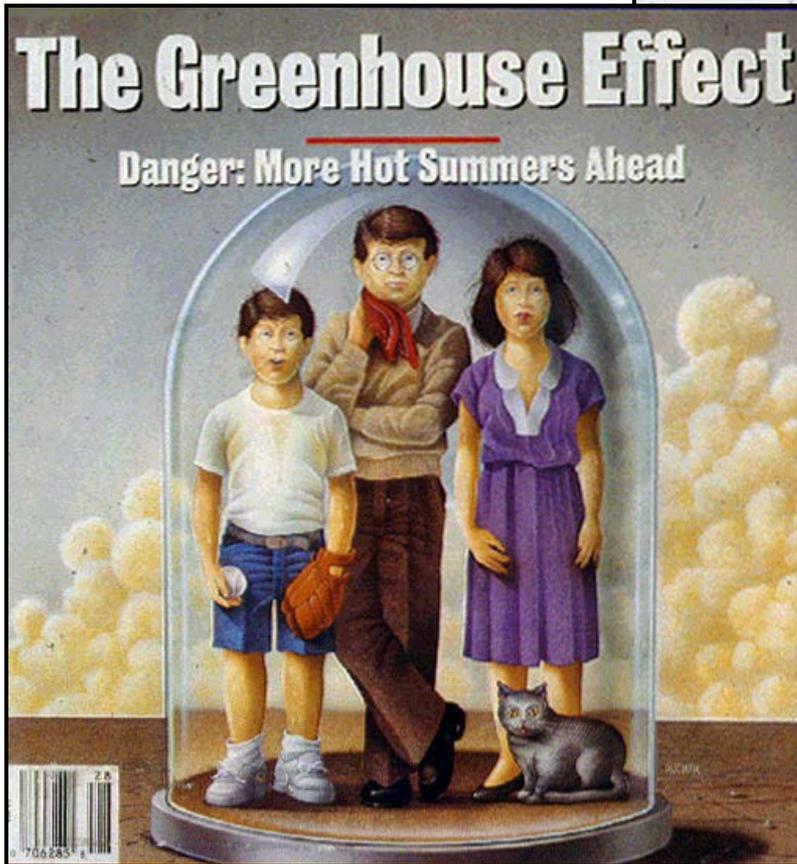


**End of century  
rise in sea level**



# Which is Our Future?

Life  
indoors



Technological  
development

# Responses to Climate Challenge

- **Mitigation**

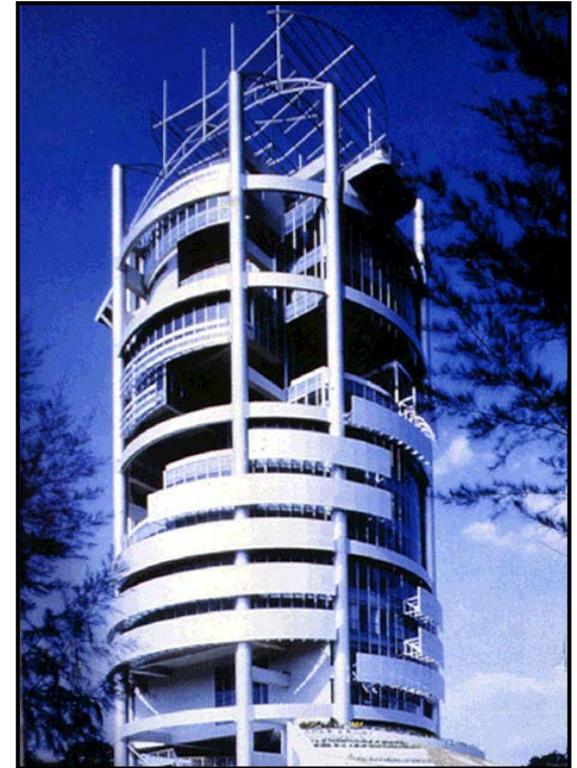
- Reduce end use
- Increase efficiency
- Reduce carbon content
- Geo-engineering

- **Adaptation**

- Water management
- Cooling features

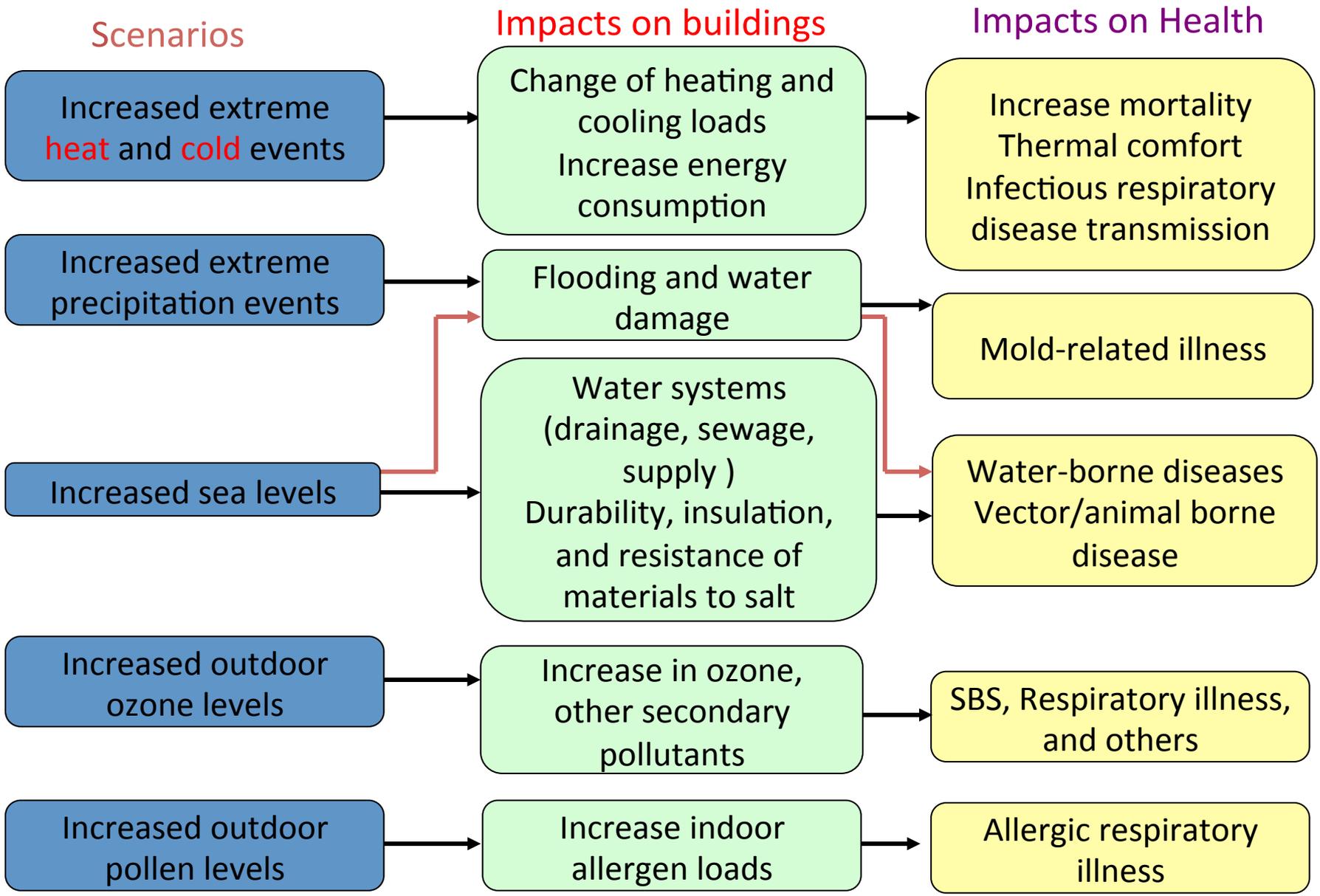


Bank of America Building, NYC  
Cook and Fox Architects  
Photo by Jefferson Siegel 2007

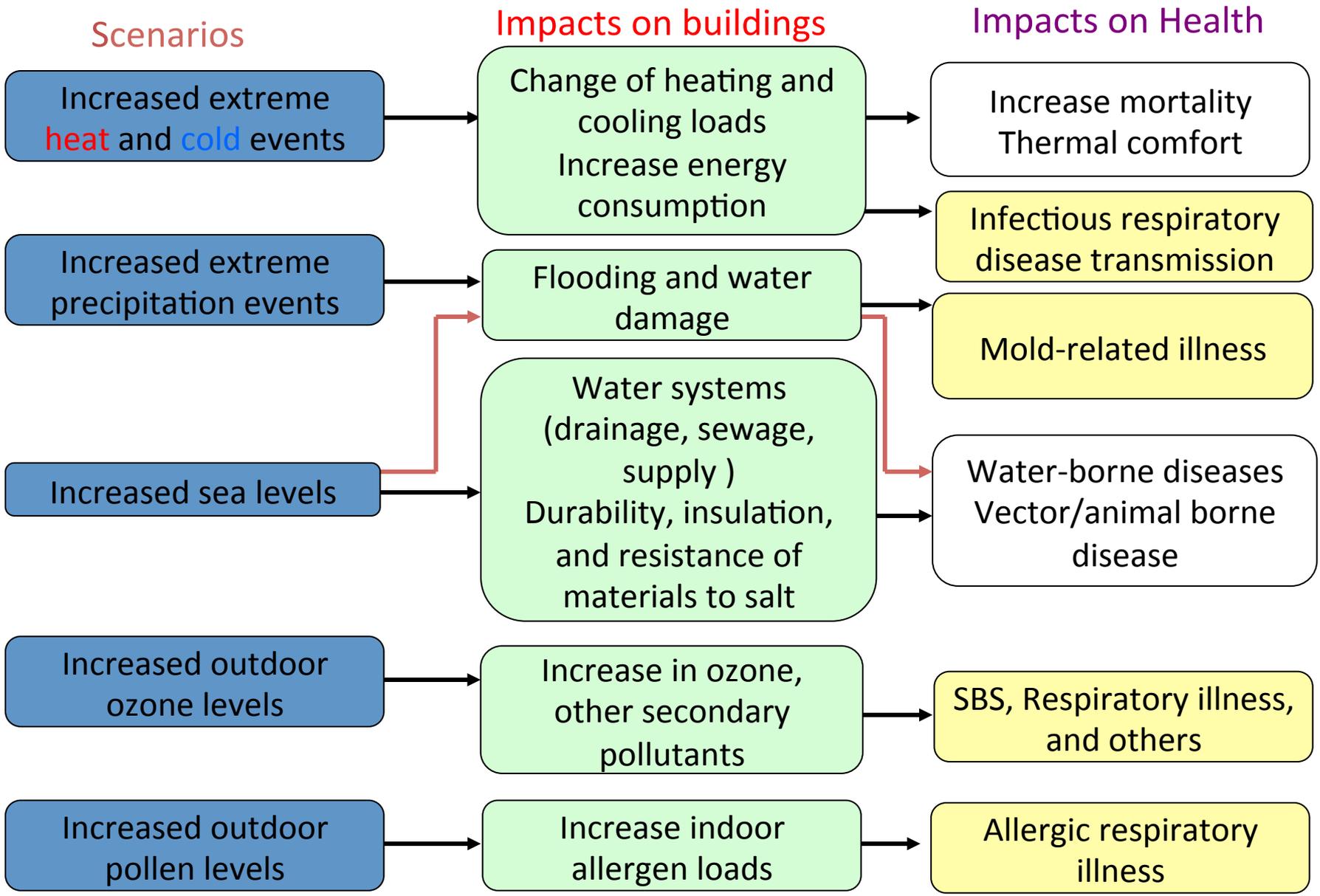


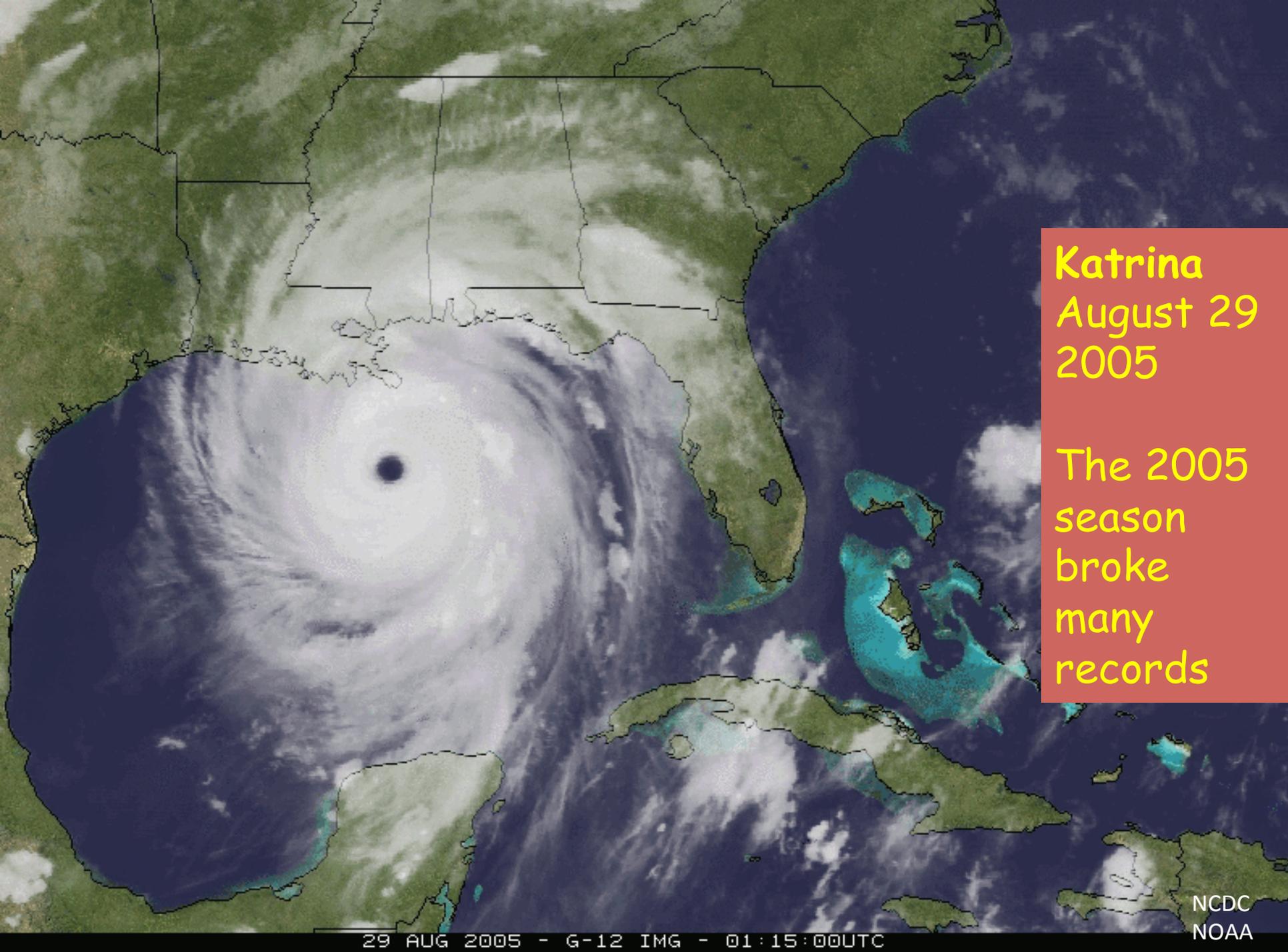
Malaysia Low Energy Office  
Ken Yeang, Architects

# Climate Change, Indoor Environments and Health



# Climate Change, Indoor Environments and Health





**Katrina**  
**August 29**  
**2005**

The 2005  
season  
broke  
many  
records

# Dampness, moisture and flooding

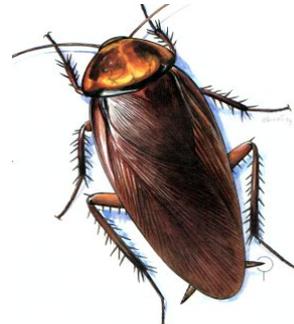
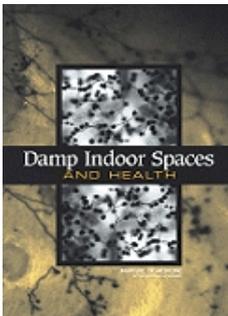
**Extreme weather** and flooding events that penetrate buildings— which may become more frequent or severe in the future — **increase the number of people at risk for health conditions related to standing water, wet building materials, and sustained high indoor humidity.**



# Dampness, moisture and flooding

Reiterated from *Damp Indoor Spaces and Health* (IOM, 2004)

- Damp indoor environments favor house dust mites and the growth of mold and other microbial agents, standing water supports cockroach and rodent infestations, and **excessive moisture may initiate or enhance chemical emissions from building materials and furnishings.**
- Damp indoor spaces are associated with initiation or exacerbation of a number of respiratory ailments.



# *Health Effects of Molds*

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- Allergies and asthma
- Infections
- Irritation
- Cognitive
- Other effects



# *Dampness in buildings and health effects---NORDAMP*

- Scientific review of all the epidemiological studies (590)
- Other Reviews
  - *Damp* IOM NAS
  - CHMC
  - WHO-Europe
- DAMPNESS increases relative risk OR 1.4—2.2
- Cough, wheeze, asthma, tiredness, headache, airway infection

# *MOLDS THAT HELP US*



PENICILLIUM





MICROFUNGI by Gravensen, Frisvad and Samson Munksgaard 1994

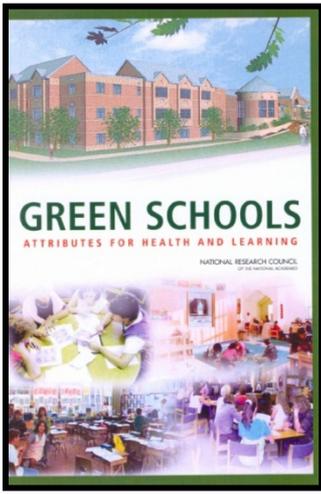
Based on surveys, approximately **half of U.S. homes** have visible evidence of a dampness problem or mold contamination.

(Source: Lawrence Berkley National Laboratory.

<http://www.iaqscience.lbl.gov/dampness-summary.html>)

About **23% of asthma cases** in the U.S. are related to mold and dampness in homes.

(Source: Mudarri, D & Fisk, W. 2007. Public Health and Economic Impact of Dampness and Mold )



# Green Schools

[www.nap.edu](http://www.nap.edu)

“moisture problems in buildings are common in all climates of the United States”

“more than 75 percent of all building envelope (foundation, walls, windows, roof) problems are caused by excess moisture”

(Source: Green Schools: Attributes for Health and Learning. 2007. Committee to Review and Assess the Health and Productivity Benefits of Green Schools, National Research Council)

# U.S. electricity blackouts skyrocketing

Thom Patterson, CNN August 9, 2010

## STORY HIGHLIGHTS

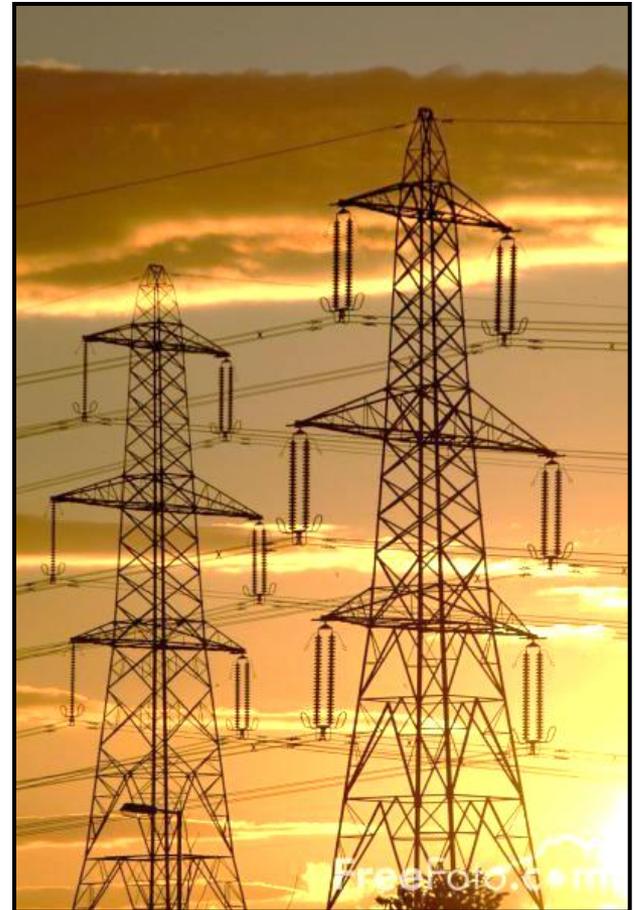
*Non-disaster U.S. power outages up 124 percent since early '90s*

**U.S. electricity reliability low compared to some nations**

**SMART GRID fix \$1.5 Trillion**

Experts: "Smart grid" would avert blackouts,  
save billions

Austin "Easy Button" controls tens of thousands of  
Texas thermostats



# Power Outages Cost Lives



- Jonkman (2009) estimate that two-thirds of the 771 known fatalities of Hurricane Katrina were the direct result of flooding .
- **One third of the fatalities were associated with flood-related circumstances including lack of access to potable water or medical services and exposure to extreme heat as a result of power outages.**

**Reactions to weather emergencies pose public-health risks. CDC reports increase in CO poisonings from emergency electricity generators.**



# After Katrina FEMA provided thousands of mobile homes

- CDC measured formaldehyde in >500 trailers (winter 07/08)
- Average 77 ppb
- Expected 10-20 ppb
- Range 3-590 ppb
- **7,081 households offered immediate move to motel/hotel**

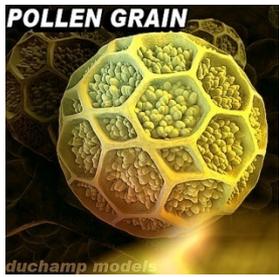


## CUSTOMER FACT SHEET ON THE NEW CALIFORNIA FORMALDEHYDE REGULATION (continued)

Comparison of Worldwide Formaldehyde Standards for Composites (using equivalent U.S. large chamber test values)

Standard	European E1	Japanese F***	Japanese F****	CPA EPP	CARB Phase I (2009)	CARB Phase II (2011)
Maximum Emission Level (ppm)	0.14	0.09*	0.05*	0.20	0.18 (PB) 0.21 (MDF)	0.09 (PB) 0.11 (MDF)

\*Standard applies only to structural building materials and built-in cabinets



# Pollen production increases with CO<sub>2</sub>

Researchers have suggested that pollen levels in outdoor air may rise as a consequence of higher CO<sub>2</sub> levels, warmer temperatures, and concomitant longer growing seasons resulting from climate change (Ziska et al., 2009), which would have consequences for health outcomes like allergic rhinitis, asthma, and atopic dermatitis (Reid and Gamble, 2009).

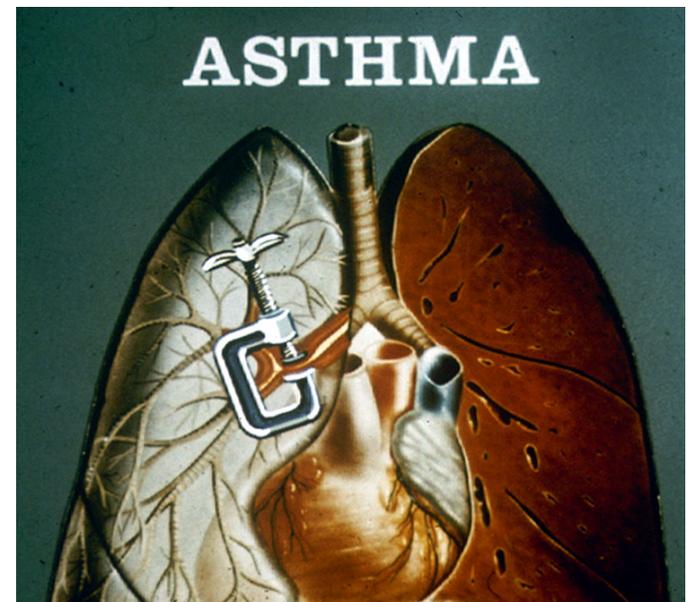
Ziska LH, et al. 2009. *Environmental Health Perspectives* 117:155-158.

Reid CE, Gamble JH. 2009. *Ecohealth* 6: 458-470.



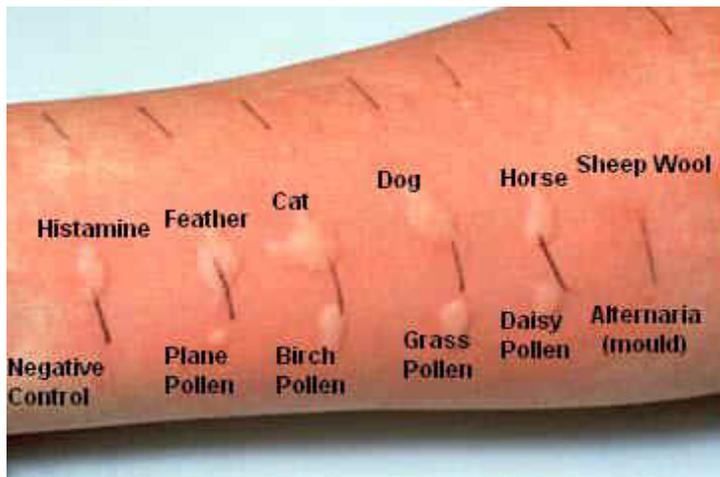
# Infectious agents and pests

The ecologic niches for house dust mites will change in response to climate change. Locations that are hotter and drier and have increased use of air conditioning will tend to have fewer dust mite infestations. Decreased use of heating systems in winter because of milder conditions may result in increased dust mite populations.



# Infectious agents and pests

- Climate change may also lead to shifting patterns of indoor exposure to pesticides as building owners respond to infestations of pests whose ranges have changed.

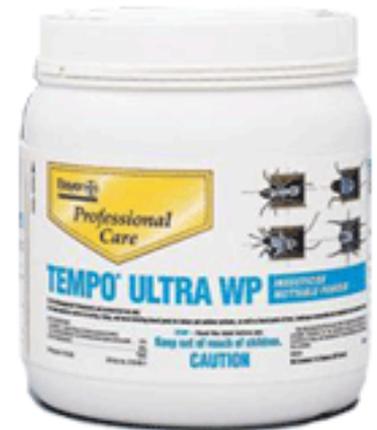


# *Public Housing Residents use of pesticides: 93% in NYC, 83% in Boston*

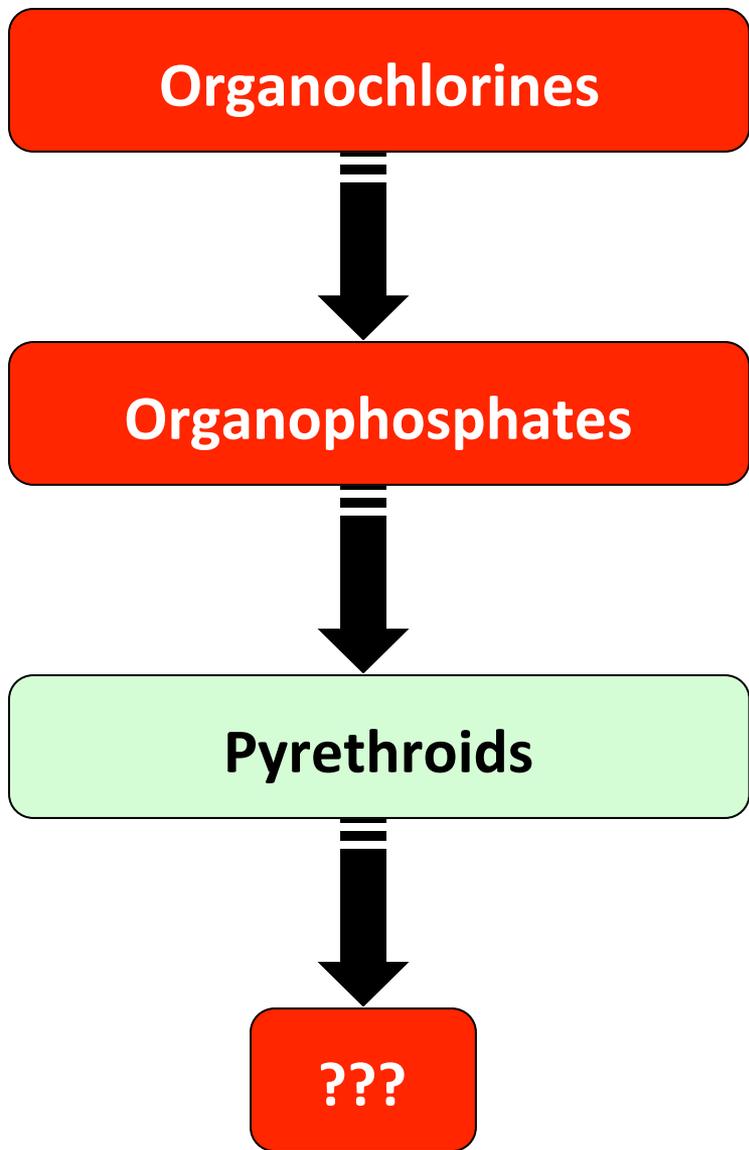


# Household Pesticides

- Active ingredients change!
- During our study, we saw ...
  - Organophosphates
    - Black Jack Roach & Ant Killer
    - Raid Ant Bait
    - Raid Ant Controller
  - Pyrethroids
    - Black Jack Roach & Ant Killer
    - Raid Ant & Roach Killer
    - Hot Shot Roach & Ant Killer
    - **Tempo 20 WP Insecticide**
    - **Chinese Chalk**



# Pesticide Usage



Banned:

- DDT (1972)
- chlordane (1998)

Banned:

- diazinon (2001)
- chlorpyrifos (2000)

Current ingredients:

- permethrin
- cypermethrin
- etc.

# Pesticide and Chemical Exposure (PACE) Study

## Collaboration between Harvard and FAMU:

Center for Healthy Options and Innovative Community Empowerment (CHOICE)

## Two predominantly African-American communities:

Roxbury, MA (urban)

Gadsden County, FL (rural)



Center for Healthy Options and  
Innovative Community Empowerment



# Understanding trends - legacy

Dust samples (collected in 2006-7)

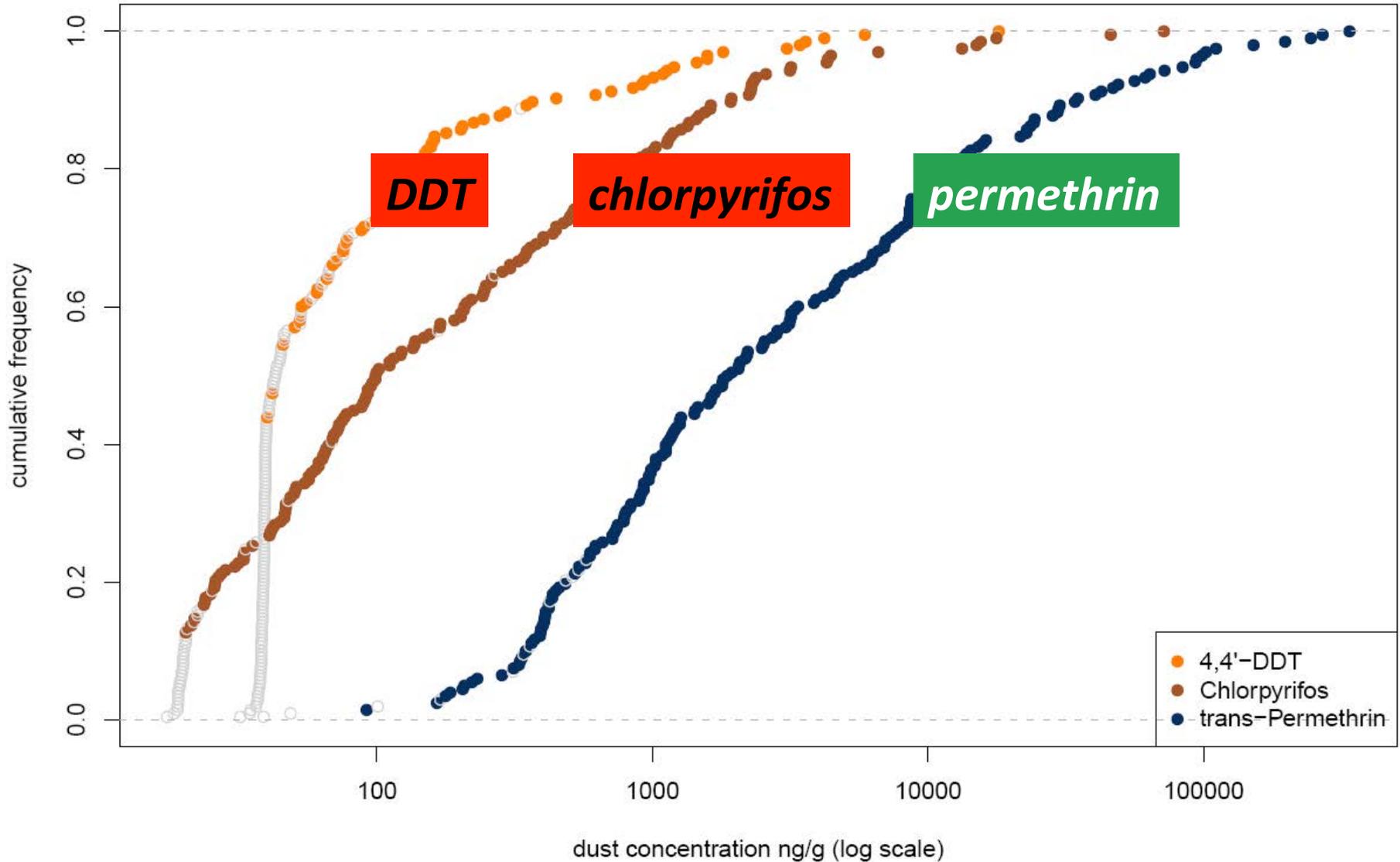
Analyte	Roxbury, MA	Gadsden FL
Chlorpyrifos	64 %	99 %
Diazinon	21 %	45 %
Cyfluthrin	6 %	27 %
Chlordane	14 %	35 %
Cypermethrin	35 %	96 %
cis/trans-permethrin	88 %	100 %
DDT	44 %	25 %

# Understanding trends - legacy

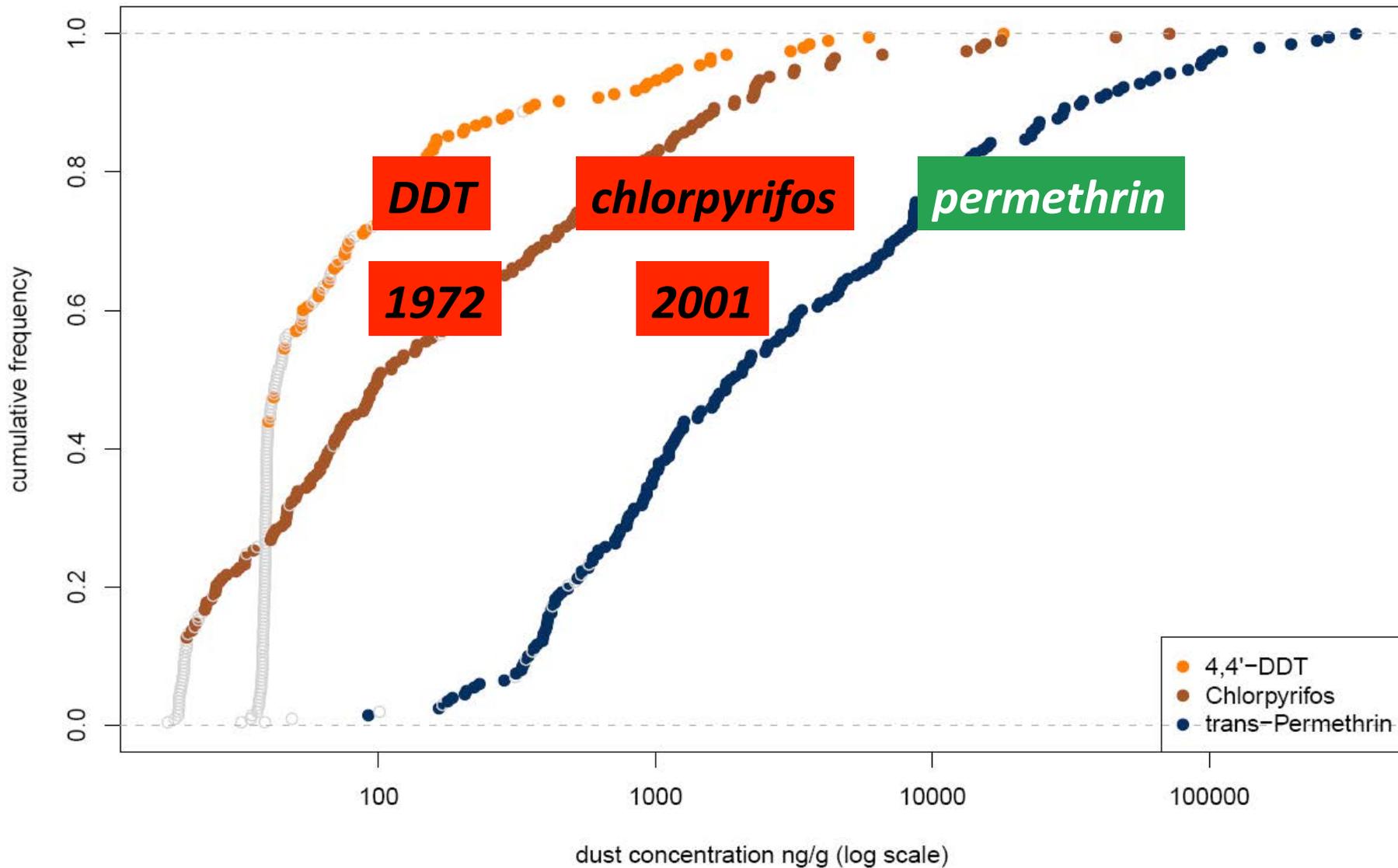
Dust samples (collected in 2006-7)

Analyte	Roxbury, MA	Gadsden FL	Date banned/ restricted
Chlorpyrifos	64 %	99 %	<b>2001</b>
Diazinon	21 %	45 %	<b>2004</b>
Cyfluthrin	6 %	27 %	<b>restricted use</b>
Chlordane	14 %	35 %	<b>1988</b>
Cypermethrin	35 %	96 %	<b>NA</b>
cis/trans-permethrin	88 %	100 %	<b>NA</b>
DDT	44 %	25 %	<b>1972</b>

# Understanding trends



# Understanding trends



# Other studies

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## Pesticide loadings of select organophosphate and pyrethroid pesticides in urban public housing

RHONA JULIEN<sup>a</sup>, GARY ADAMKIEWICZ<sup>a</sup>, JONATHAN I. LEVY<sup>a</sup>, DEBORAH BENNETT<sup>a,b</sup>,  
MARCIA NISHIOKA<sup>c</sup> AND JOHN D. SPENGLER<sup>a</sup>

<sup>a</sup>Harvard School of Public Health, Harvard University, Boston, Massachusetts, USA

<sup>b</sup>University of California, Davis, California, USA

<sup>c</sup>Battelle M

## Prenatal Insecticide Exposures and Birth Weight and Length among an Urban Minority Cohort

*Robin M. Whyatt,<sup>1</sup> Virginia Rauh,<sup>1</sup> Dana B. Barr,<sup>2</sup> David E. Camann,<sup>3</sup> Howard F. Andrews,<sup>1</sup> Robin Garfinkel,<sup>1</sup> Lori A. Hoepner,<sup>1</sup> Diurka Diaz,<sup>1</sup> Jessica Dietrich,<sup>1</sup> Andria Reyes,<sup>1</sup> Deliang Tang,<sup>1</sup> Patrick L. Kinney,<sup>1</sup> and Frederica P. Perera<sup>1</sup>*

<sup>1</sup>Columbia Center for Children's Environmental Health, Mailman School of Public Health, Columbia University, New York, New York, USA; <sup>2</sup>National Center for Environmental Health, Centers for Disease Control and Prevention, Atlanta, Georgia, USA; <sup>3</sup>Southwest Research Institute, San Antonio, Texas, USA

## Impact of Prenatal Chlorpyrifos Exposure on Neurodevelopment in the First 3 Years of Life Among Inner-City Children

Virginia A. Rauh, ScD<sup>a</sup>, Robin Garfinkel, PhD<sup>a</sup>, Frederica P. Perera, DrPH<sup>a</sup>, Howard F. Andrews, PhD<sup>a</sup>, Lori Hoepner, MPH<sup>a</sup>, Dana B. Barr, PhD, DLS<sup>b</sup>, Ralph Whitehead, MPH<sup>b</sup>, Deliang Tang, DrPH<sup>a</sup>, Robin W. Whyatt, DrPH<sup>a</sup>

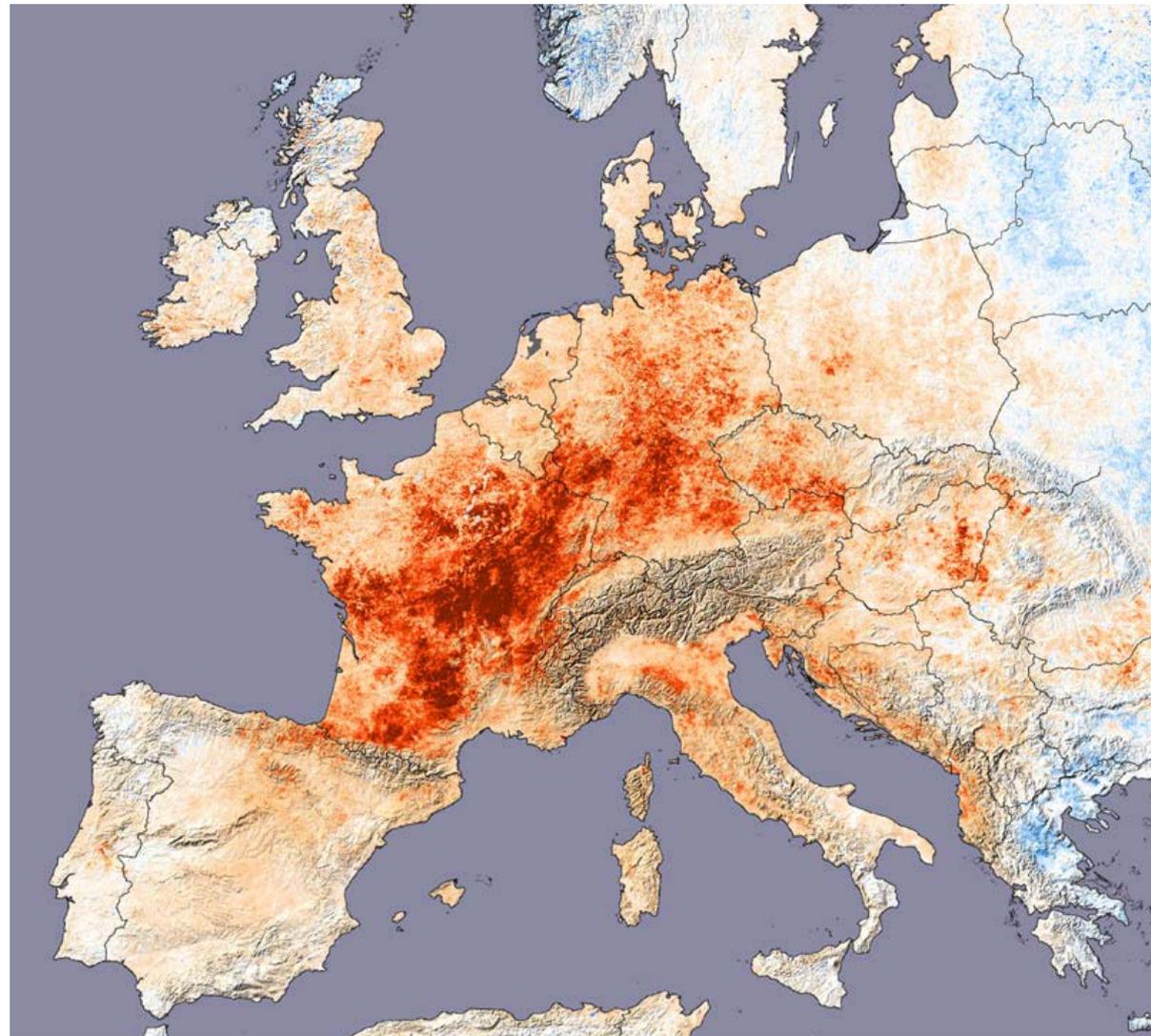
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The authors have indicated they have no financial relationships relevant to this article to disclose.

# 2003 European Heat Wave

Killed more than  
35,000 people.

These conditions  
are forecasted to  
become more  
common by 2040.



Land Surface Temperature difference [K]

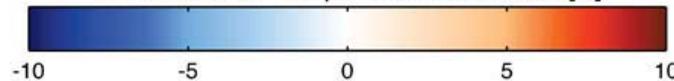
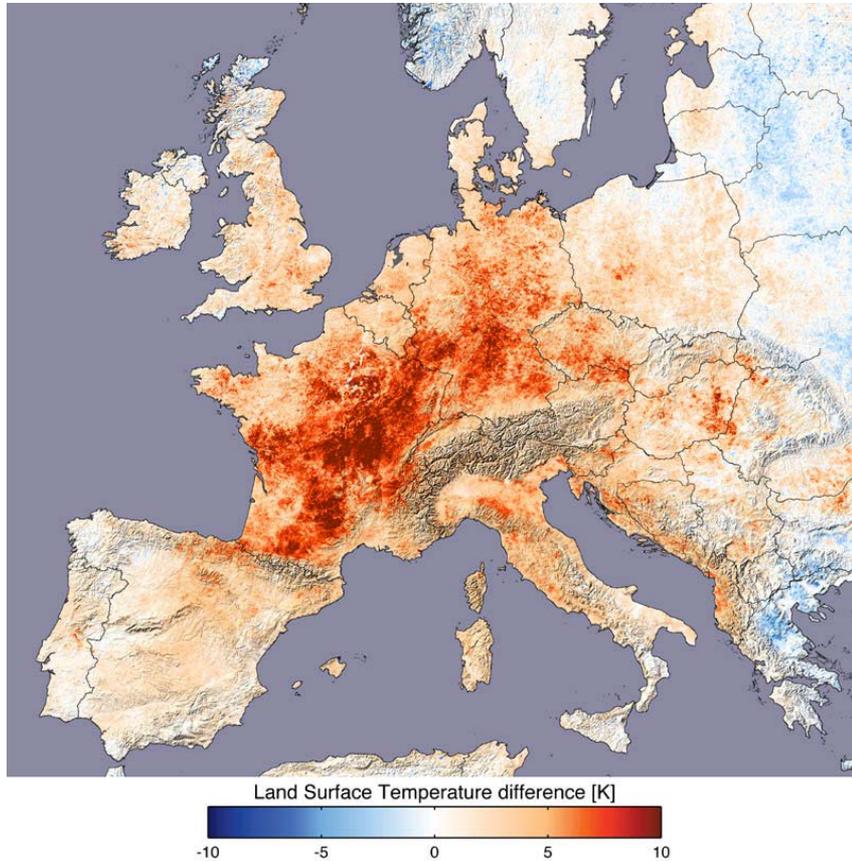


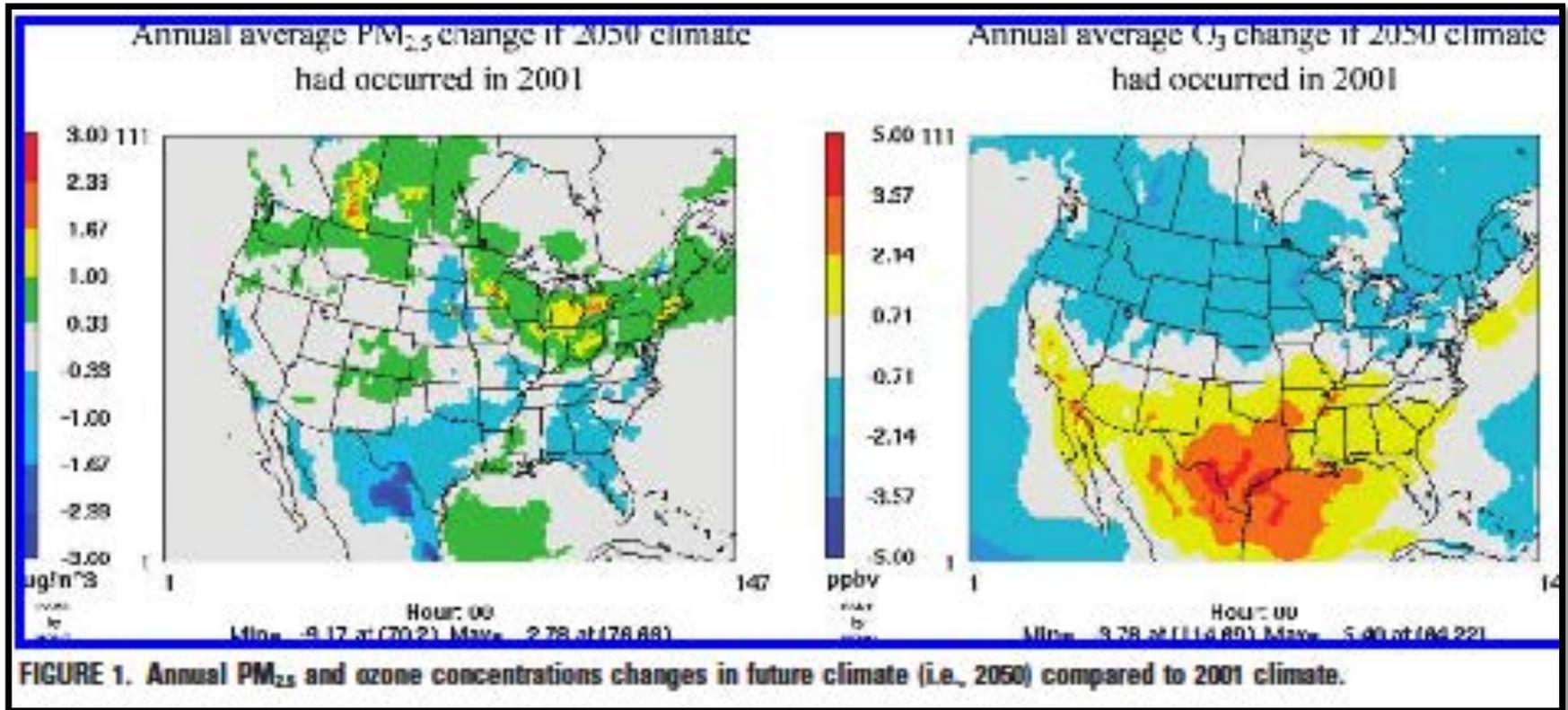
Image courtesy of  
NASA Earth  
Observatory

# Ozone and Heat



**When increased ozone events occur simultaneously with heat waves, mortality can rise by 175%.**

# 2050 Projections of PM<sub>2.5</sub> and O<sub>3</sub>



Tagaris et al. 2009. *ES&T* 43:4979-4988.

*Increase in outdoor  
Air Pollution will  
impact indoors*



[http://bpsfuelforthought.wordpress.com/  
2012/03/27/colorado-forest-fire/](http://bpsfuelforthought.wordpress.com/2012/03/27/colorado-forest-fire/)

# *Indoor Chemistry*



- VOC's- some organic compounds at typical indoor temperatures react with ozone



- Produce irritating gases and particles

# Airway effects of repeated exposures to ozone-initiated limonene oxidation products as model of indoor air mixtures

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Indoor air

Limonene

Mixtures

Ozone

Repeated exposure

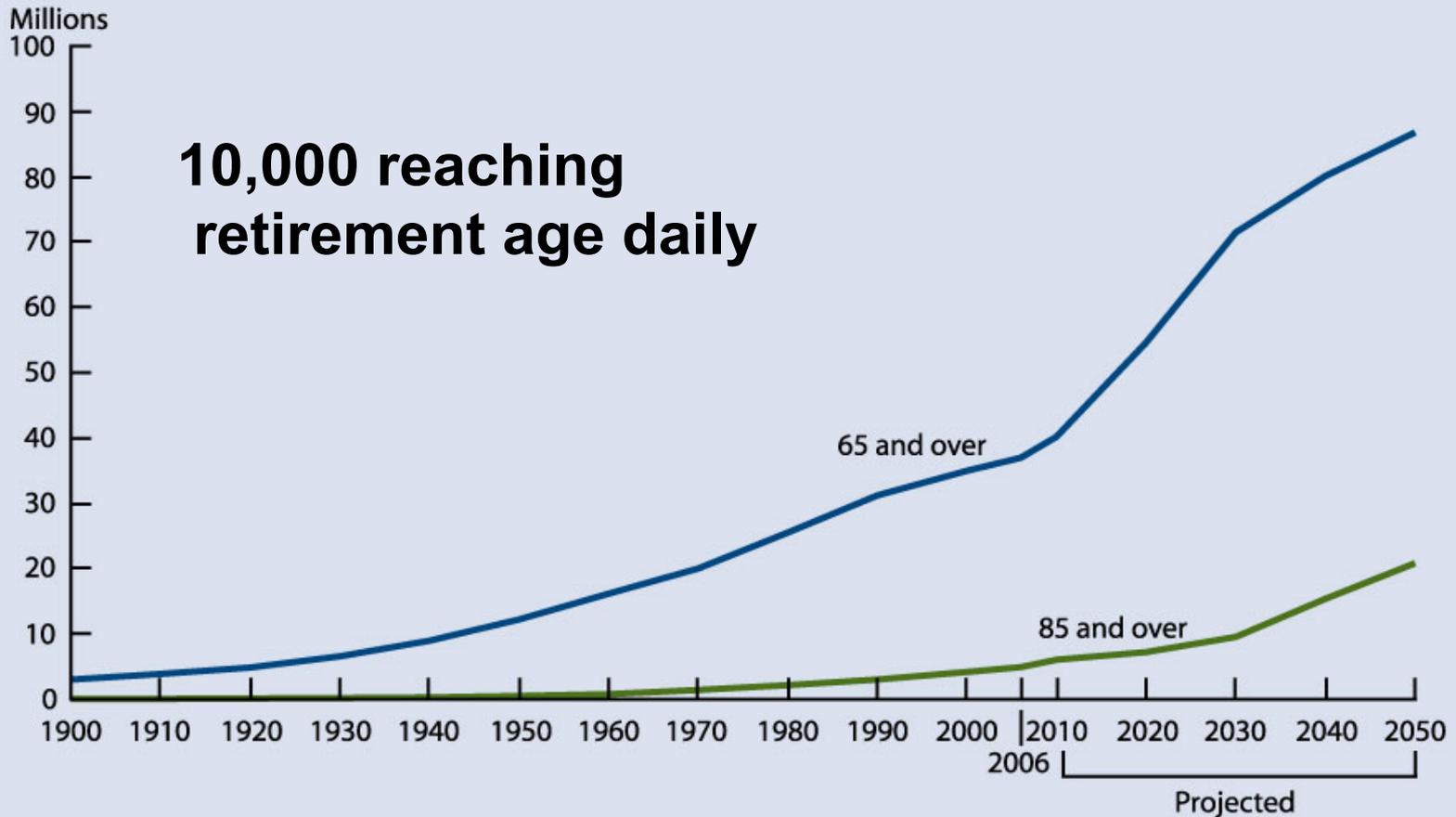
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## ABSTRACT

Repeated low-level indoor air exposure to volatile organic compounds (VOCs) may influence the reporting of sensory irritation in the eyes and airways. The ozone-initiated reaction products of limonene, an abundant VOC, were used as a model of indoor air mixtures to study upper airway (sensory) irritation, bronchoconstrictive and alveolar level effects after repeated exposures. Mice were exposed 1 h/day for 10 consecutive days to: air, limonene (52 ppm/289 mg/m<sup>3</sup>); ozone (0.1 ppm/0.2 mg/m<sup>3</sup>); a reaction mixture of limonene (52 ± 8 ppm) and ozone (0.5, 2.5 and 3.9 ppm) resulting in ~0.05 ppm residual ozone. Neither the limonene nor the ozone exposures alone showed consistent effects on the respiratory parameters. In the limonene/ozone groups, the respiratory rate decreased concentration-dependently with an extrapolated no-effect-level of ~0.3 ppm admixed ozone. Both sensory irritation and airflow limitation were conspicuous effects of the mixtures; sensory irritation appeared rapidly and airflow limitation developed slowly during each exposure. The effects of these parameters did not change with increasing number of exposures. No firm conclusion could be drawn about alveolar level effects. Cells in bronchoalveolar lavage were unchanged irrespective of exposure to air, ozone, and limonene with and without ozone. In conclusion, the study indicated that repeated exposures to ozone-initiated limonene mixtures did not cause sensitization of sensory irritation and airflow limitation. Bronchoalveolar lavage after exposures to ozone, and limonene with and without ozone, respectively, did not show airway inflammation.

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## Number of people age 65 and over, by age group, selected years 1900–2006 and projected 2010–2050



Note: Data for 2010–2050 are projections of the population.

Reference population: These data refer to the resident population.

Source: U.S. Census Bureau, Decennial Census, Population Estimates and Projections.

# Heat Index values and corresponding health threats

		Temperature (°F)															
		80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
Relative Humidity (%)	40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
	45	80	82	84	87	89	93	95	100	104	109	114	119	124	130	137	
	50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
	55	81	84	86	89	93	97	101	106	112	117	124	131	137			
	60	82	84	88	91	95	100	105	110	116	123	129	137				
	65	82	85	89	93	98	103	108	114	121	128	136					
	70	83	86	90	95	100	105	112	119	126	134						
	75	84	88	92	97	103	109	116	124	132							
	80	84	89	94	100	106	113	121	129								
	85	85	90	96	102	110	117	126	135								
	90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127											
100	87	95	103	112	121	132											

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

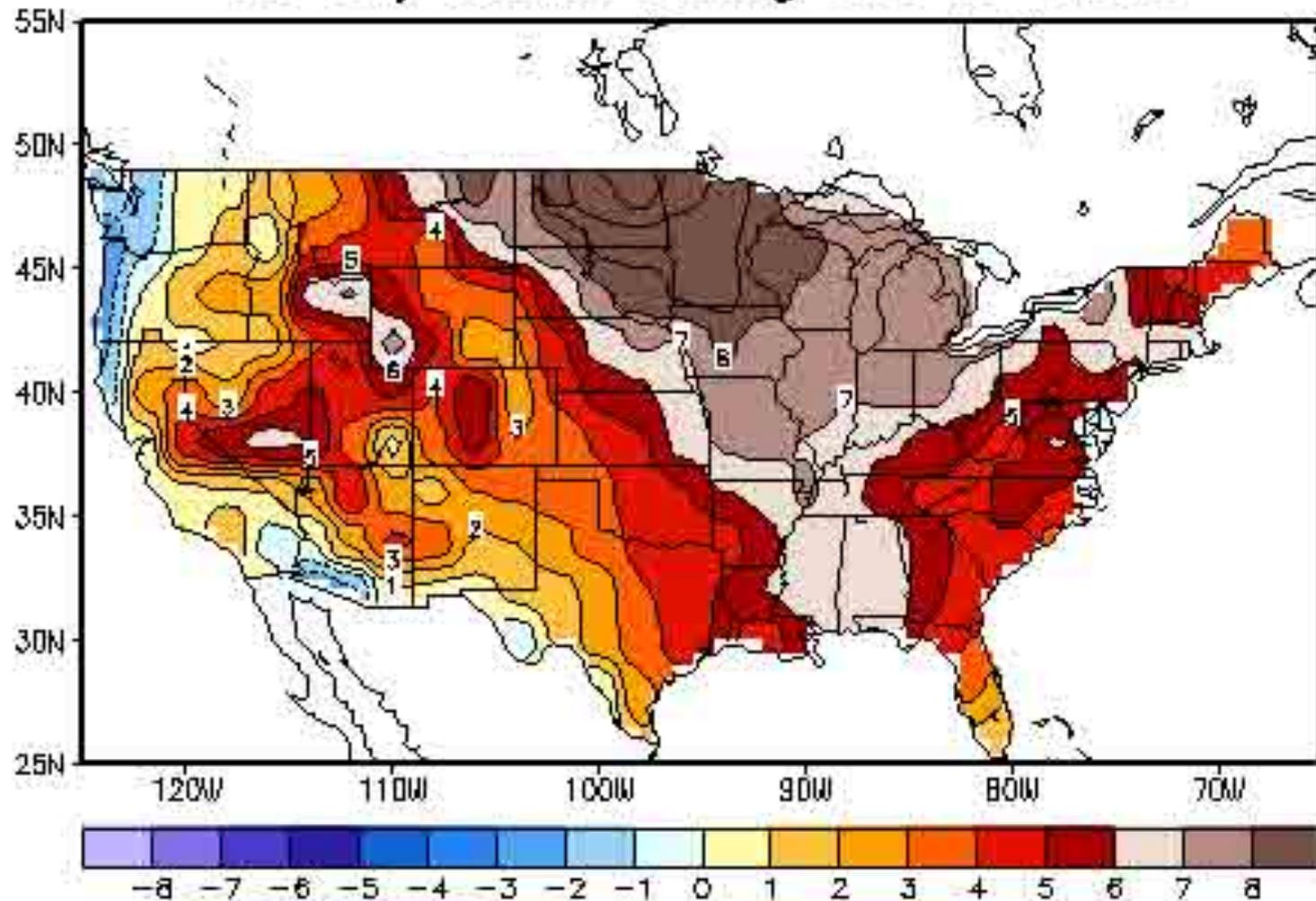
Caution
  Extreme Caution
  Danger
  Extreme Danger

National Weather Service, 2010



# Mean Temp (F) Anomaly

## 90-day mean ending Mar 17 2012





- The first quarter of 2012 broke the January-March record by 1.4 degrees (0.8 degrees Celsius).
- In March, at least 7,775 weather stations across the nation broke daily high temperature records, and another 7,517 broke records for night-time heat.

# Vulnerable populations and thermal stress

## Biologic factors

- Age (the very young and old)
- Disease (including cardiovascular disease, Hypertension, diabetes, and obesity)
- Medication use (NSAIDs, anticholinergics, diuretics)
- Restricted mobility

## Economic and social factors

- Availability of building air conditioning [AC] or heat
- Availability of natural ventilation (ability to open windows)
- Isolation and Security



# Conventional Roof Top HVAC



# Air Conditioning (AC) Link to Increased SBS Symptoms in Offices

Type of ventilation system

First Author	Year	No of subjects	Natural Ventilation	AC + No Humid.	AC + Steam Humid.	AC + Evap. Humid.	AC + Spray Humid.
Jaakkola	95	868	○	●			
Mendell	96	710	○	●			
Mendell, Burge	90, 87	1459	○	●			
Mendell, Harrison	90, 87	1044	○	●			
Zweers	92	2806	○	●			
Jaakkola	95	335	○	●	●		
Mendell, Burge	90, 87	863	○	●	●		
Zweers	92	3573	○	●	●		
Jaakkola	95	559	○	●	●	●	
Teeuw	94	927	○	●	●	●	
Mendell, Burge	90, 87	1991	○	●	●	■	■
Mendell, Finnegan	90, 87	787	○	●	●	■	■
Mendell, Harrison	90, 87	2080	○	●	●	■	■
Mendell, Hedge	90, 84	1214	○	●	●	■	■
Zweers	92	3846	○	●	●	■	●
Brasche	99		○	■	■	■	■
Hawkins	91	255	○	■	■	■	■



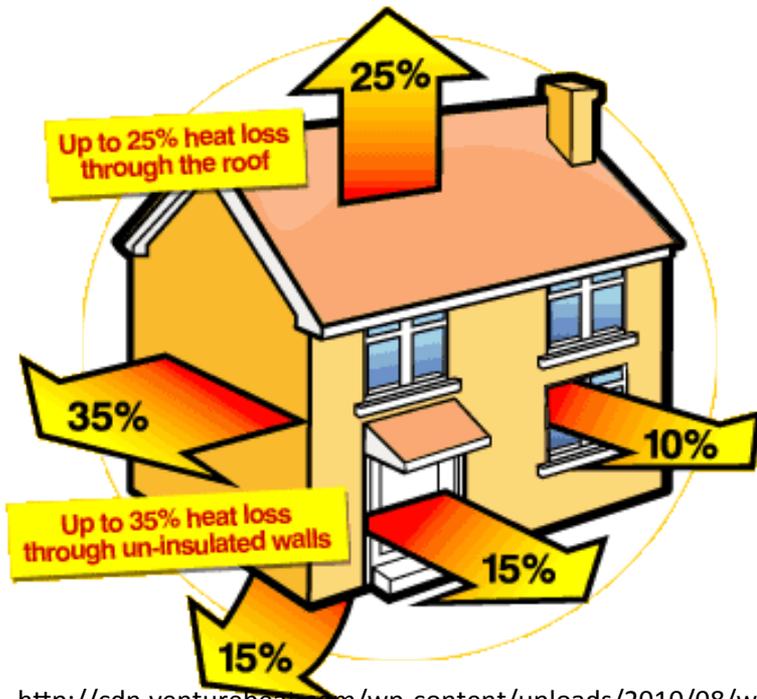
# New Construction and Weatherization



- 1/3<sup>rd</sup> energy for heating and cooling lost due to accidental air leakage.
- Weatherization DOE in 33 years (LIHEAP)
  - 6.4M low-income houses
  - 2010~200,000
  - Training, some certified by Residential Energy Service Network
- Energy Star DOE/EPA
  - 1M homes
  - 2009 20% of 500,000



# Weatherization



<http://cdn.venturebeat.com/wp-content/uploads/2010/08/weatherize.gif>



<http://heatusa.com/wp-content/uploads/2009/06/weatherization-image.jpg>



# February 2011 • Environmental Health Perspectives

By John Manuel



Spheres of Influence | Avoiding Health Pitfalls of Home Energy-Efficiency Retrofits

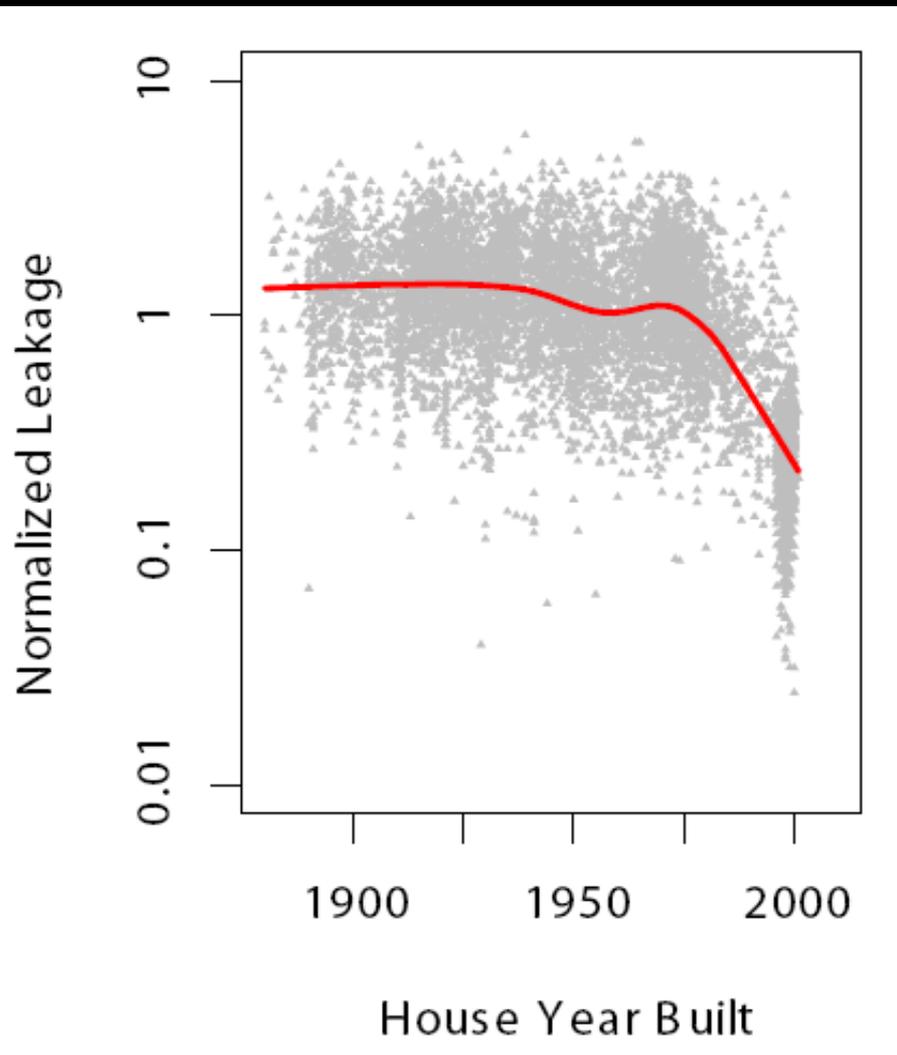
## Avoiding Health Pitfalls of Home Energy-Efficiency Retrofits

.....

**H**ousing consumes 40% of our nation's energy use,<sup>1</sup> making it a prime target for energy-efficiency measures. Steps such as adding insulation, installing high-efficiency HVAC (heating, ventilation, and air-conditioning) systems, and tuning furnaces rank high as simple ways to lower utility bills and improve comfort and indoor air quality. But an energy-efficiency label attached to a product is meaningless if that product is installed incorrectly, and when it comes to green building techniques, the devil is in the details. The complexities of high-tech equipment and the subtle and usually invisible movement of air and moisture in homes mean even experienced and well-intentioned contractors do not get things right in every instance. This can result in health problems for occupants and installers alike.

© 2011 Environmental Health Perspectives

# *Air Exchange Rates has been decreasing in new US Homes*



- Balance between acceptable indoor air quality and energy
- Low ventilation and health

(From Chan et al. 2003, LBL)

# *Moisture capacity of homes*



- 100 years ago with masonry walls houses could hold 500 gls of water
- 50 years ago wood houses could hold 100 gls of water
- Today metal studs, gypsum, & vinyl can hold 50 – 5 gls of water

# *Passamaquady Homes*





*Mold Growth*



*Moisture Trap*

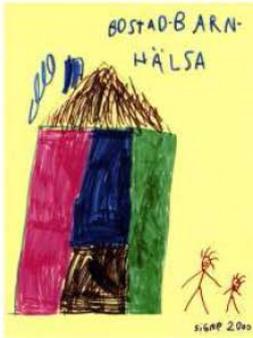
# Infectious agents

Literature supported links between **low ventilation rates and increased risk of allergies, SBS symptoms and respiratory infections**. Temperature, Humidity and Ventilation play a role in the spread of influenza and other respiratory viruses.

Sundell J et al. 2011. *Indoor Air* 21:191-204



# TWO SWEDISH STUDIES



Research for a **healthier** future  
Swedish Environmental Longitudinal, Mother and child, Asthma and allergy study

The importance of early life and diseases in children

## DBH phase 1

Cross-Sectional study  
Baseline  
March 2000

Questionnaire

n=14 077 children (1-5y) (rr=80%)

## DBH phase 2

Case-Control Study

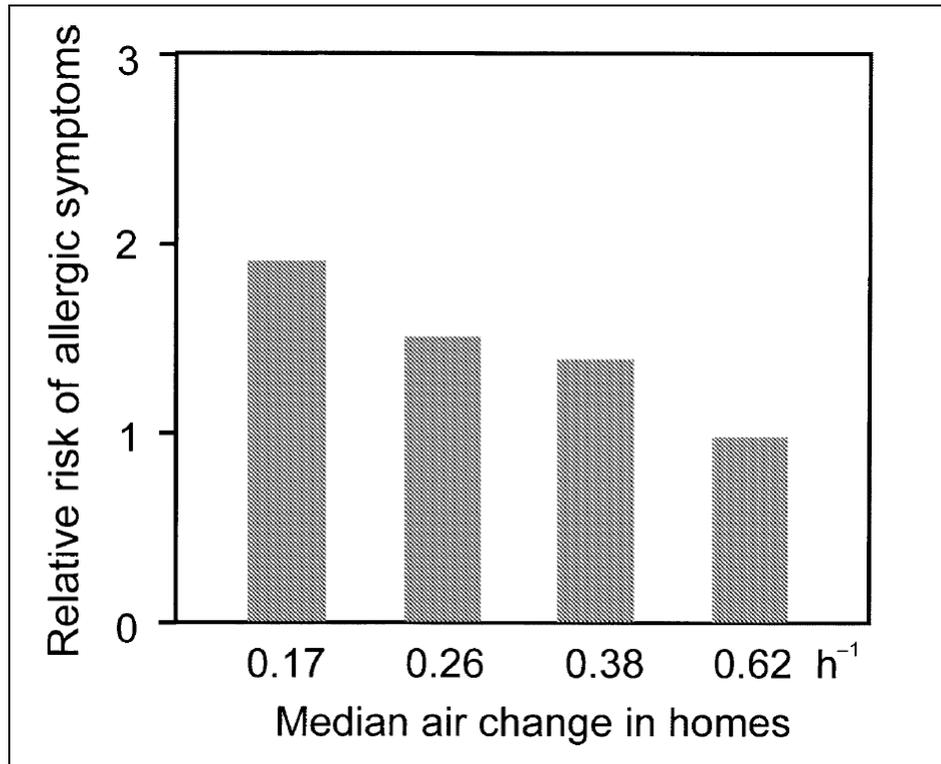
October 2001-April 2002

Professional inspections  
Exposure measurements  
Clinical examinations  
N=200+200 children/dwellings

Indoor Environmental Factors  
and Chronic Diseases in  
Swedish Pre-School Children



# Ventilation and Health



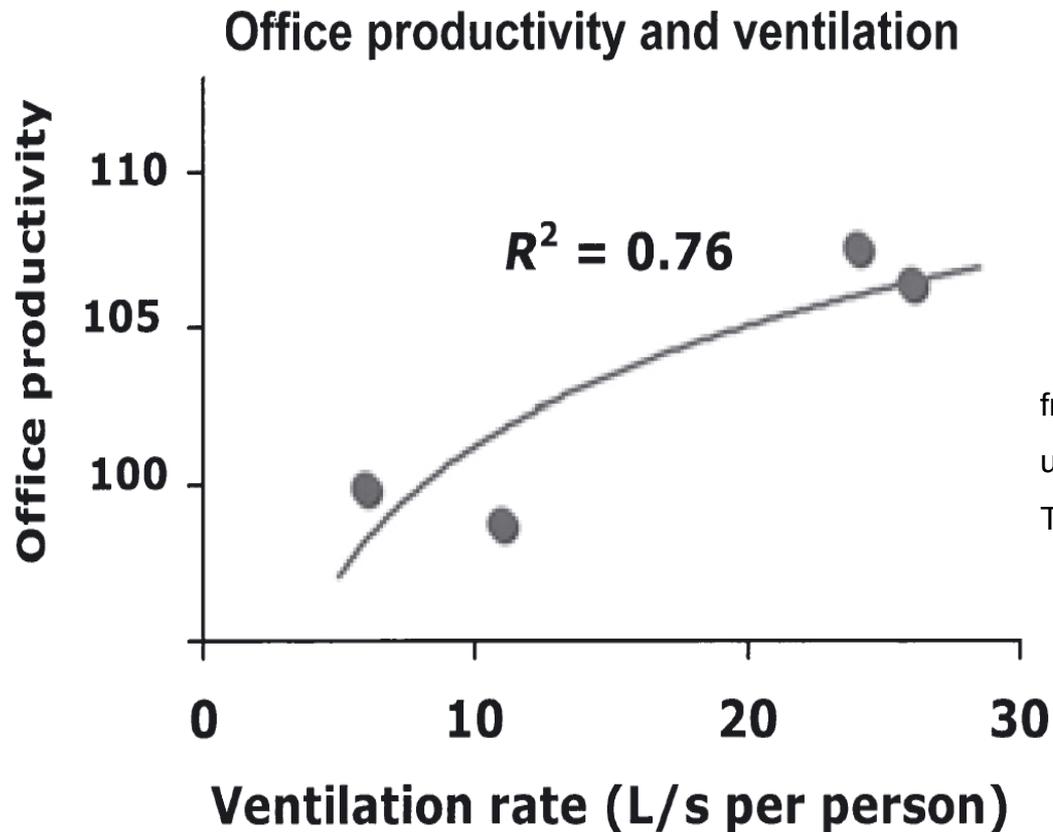
- An association between ventilation rates and health outcomes is biologically plausible.

**Low ventilation rates in dwellings increase the risk of allergic symptoms among children.**

**(Bornehag et al., 2005)**

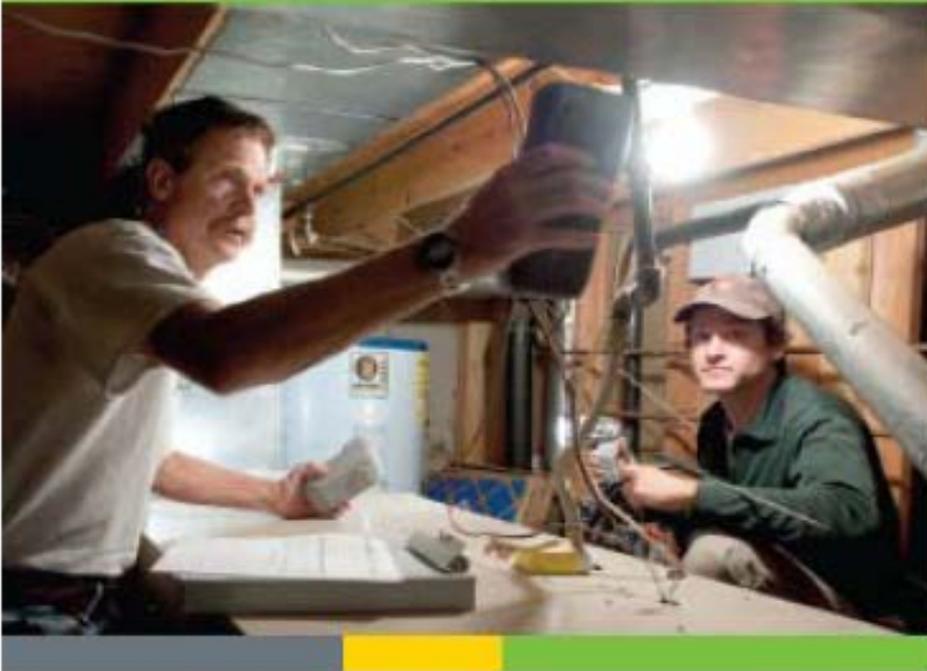
# Inadequate air exchange contributes to numerous IAQ problems

- Moisture and contaminant accumulation
- Thermal discomfort



from Fanger (2007),  
using data from Wargocki et, (2004) and  
Tham et al., (2003)

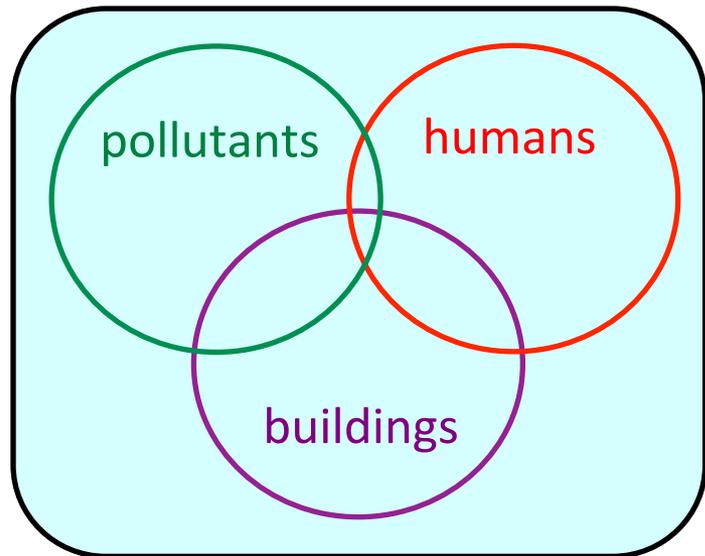
## Workforce Guidelines for Home Energy Upgrades



## DOE Workforce Guidelines:

- over 600 pages (you can heat your house for a week if you have a wood stove)
- organized by energy retrofit:
  - assessment
  - combustion equipment
  - ventilation
  - air sealing
  - heating, cooling
  - insulation
  - crawlspaces and basements
  - electric

# Where's the IEQ?



- IAQ: a balance between emissions and removal.
- Climate change can affect this system in numerous particular ways.
- By increasing the outdoor concentrations and altering indoor spaces climate change is likely to increase associated indoor exposures.

# *Carbon Dioxide an IAQ Issue?*



- 400 ppm global background
- +100 ppm in cities
- < 1000 ppm indoor design levels
- >2000 in many indoor settings

# IMPACT OF CO<sub>2</sub> ON HUMAN DECISION MAKING AND PRODUCTIVITY

Usha Satish<sup>1</sup>

William J Fisk<sup>2</sup> , Mark J. Mendell<sup>2</sup>, Katia Eliseeva<sup>2</sup>,

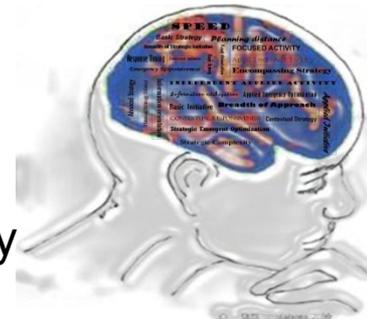
Toshifumi Hotchi<sup>2</sup>, Douglas Sullivan<sup>2</sup>

<sup>1</sup> Department of Psychiatry,

SUNY Upstate Medical University, Syracuse, NY

<sup>2</sup> Lawrence Berkeley National Laboratory, Berkeley, CA

Supported by the U.S. EPA and the SUNY Upstate Medical University



# EXPERIMENTAL APPROACH

---

- 22 participants, controlled exposure study
- Randomized controlled within-subjects blinded design
- 18–35 years of age
- Three CO<sub>2</sub> exposure conditions, with balanced order of exposure:
  - (1) 600 ppm ← all occupant generated
  - (2) 1000 ppm ← ultrapure CO<sub>2</sub> added
  - (3) 2500 ppm ← ultrapure CO<sub>2</sub> added
- All other conditions including ventilation rate were kept constant
- Tests of decision making performance (SMS)
- Survey of PAQ and symptoms (not covered)

# ELEMENTS OF PRODUCTIVITY

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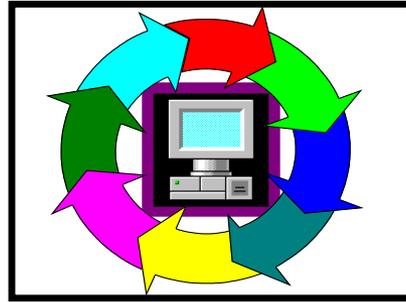
Normal everyday tasks require processing of different types of information

- Receiving information
- Analyzing information
- Utilization of information in a relevant context
- Ability to relate this information to experience
- Ability to retain this information for future

# Measurement of Decision Making Performance: Strategic management Simulation (SMS) – BASICS



Individual



Yielding  
quantitative  
measurements

12437921
43286487
32468327
48326487
32448343

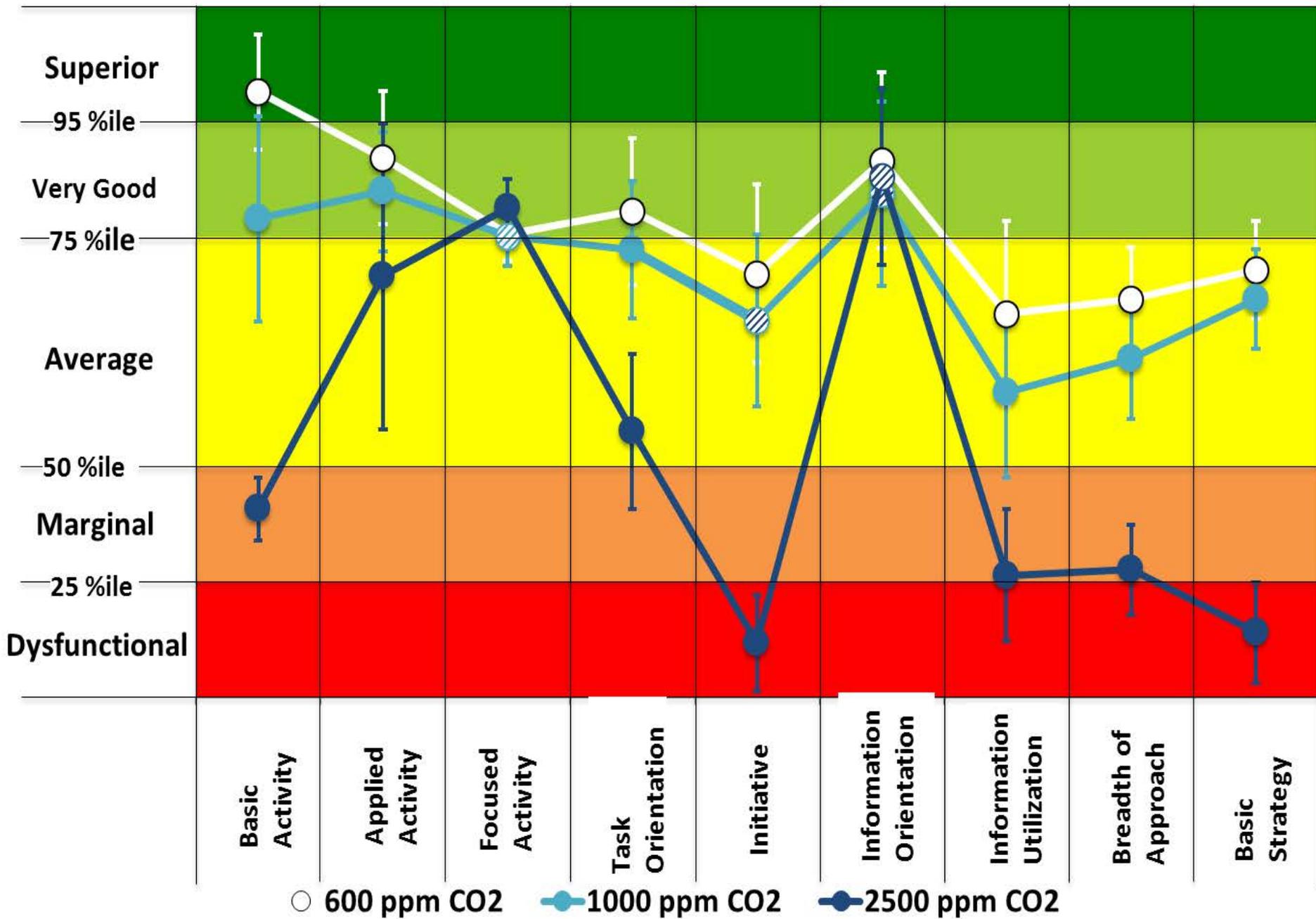
Participates in computer simulation with various possible scenarios with tasks that are potentially complex and volatile, have ambiguity and have delayed feedback

Measured by  
*validated, reliable,  
sensitive*  
scoring mechanisms

Provides results on parameters for “decision making” (e.g., responsiveness, initiative, emergency responses, planning, strategy, etc.)

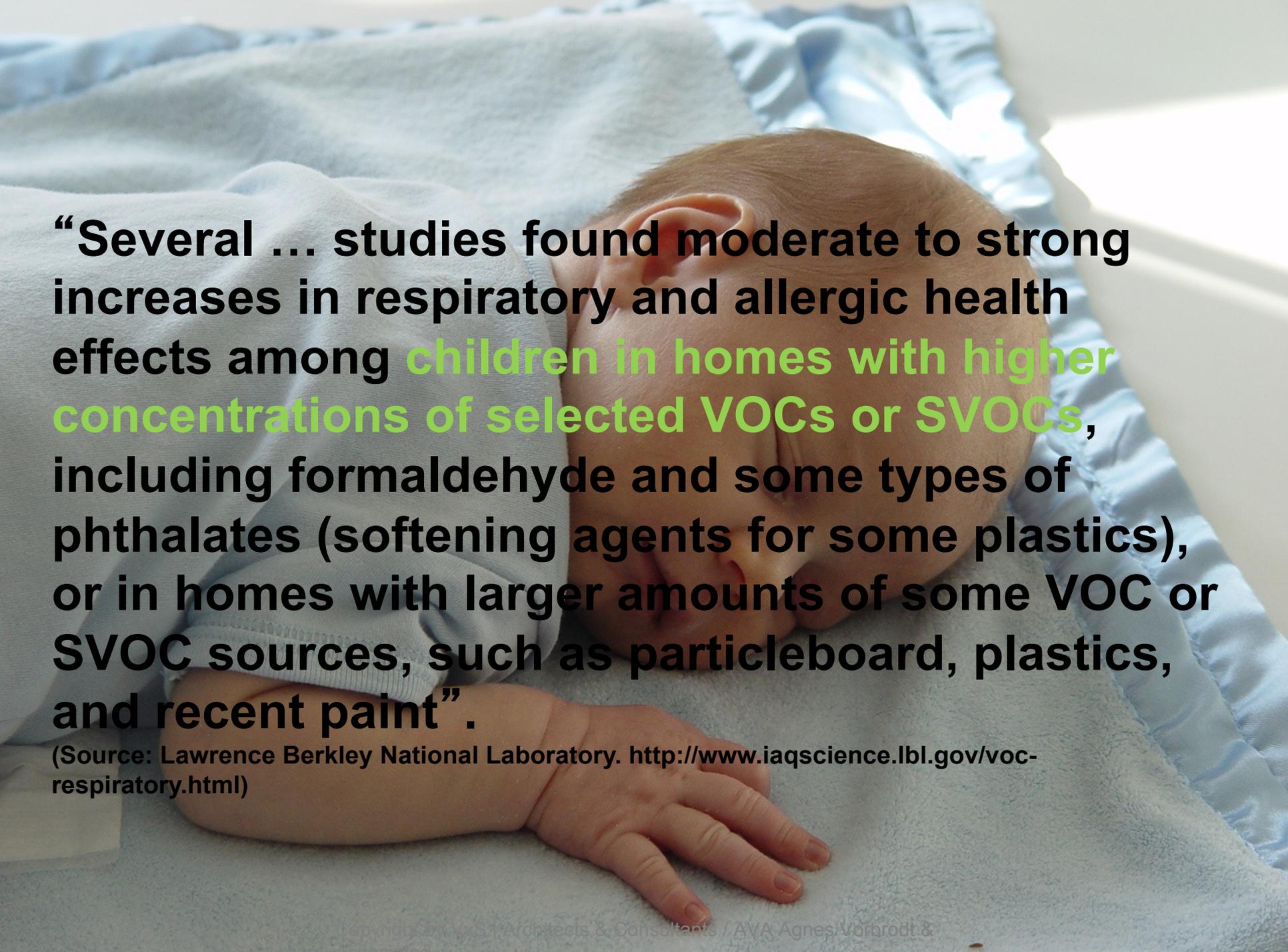


# Impact of CO<sub>2</sub> On Human Decision Making Performance



# Indoor CO<sub>2</sub> Levels

SETTING	REPORTED CO <sub>2</sub> (ppm)		
210 CA Classrooms	1070 (time avg.)	1489 (avg. 1-hr peak)	9.8% > 2000
120 TX Classrooms	1289 (median time avg.)	20% > 2000 (time avg.)	21% > 3000 (peak 1-hr)
100 US Offices	~700 (avg. 10 min peak)	5% > 1000 (10 min peak)	
6 US meeting rooms	1 with time avg. ~ 1000	1 with time avg. ~ 1800	
Passenger Cabins of Commercial Aircraft	Frequently > 1000	As high as 4200 peak	
New Cars, Pickup Trucks	Based on two measured ventilation rates high CO <sub>2</sub> predicted		



**“Several ... studies found moderate to strong increases in respiratory and allergic health effects among children in homes with higher concentrations of selected VOCs or SVOCs, including formaldehyde and some types of phthalates (softening agents for some plastics), or in homes with larger amounts of some VOC or SVOC sources, such as particleboard, plastics, and recent paint” .**

(Source: Lawrence Berkley National Laboratory. <http://www.iaqscience.lbl.gov/voc-respiratory.html>)

# Chemicals in our homes

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# Chemicals in our homes

---



phthalates



flame retardants



phthalates



PAH



PCBs



pesticides



A Sierra Club-Ballantine Book

95¢

POPULATION CONTROL OR  
RACE TO OBLIVION?

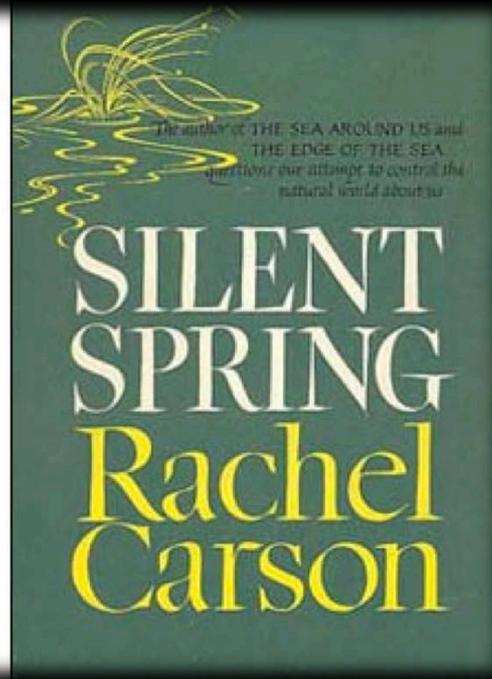
# THE POPULATION BOMB

WHILE YOU ARE READING THESE WORDS  
FOUR PEOPLE WILL HAVE DIED FROM  
STARVATION, MOST OF THEM CHILDREN.

DR. PAUL R. EHRLICH



Foreword by David Brower



The author of THE SEA AROUND US and  
THE EDGE OF THE SEA  
questions our attempt to control the  
natural world about us

# SILENT SPRING Rachel Carson

*So what about me?*



# *My Body Burden of Chemicals*

CHEMICAL	MATRIX	UNITS	MY LEVEL	CDC AVE
Bisphenol A	Urine	$\mu$ g/g creatinine	2.1	2.6
PFOA	Serum	$\mu$ g/L	6.7	3.9
PCBs (PCB 153/168)	Serum	ng/g lipid	69	27.2
Organochlorine Pesticides (DDE)	Serum	ng/g lipid	226	295
Phthalates (MEHP)	Urine	$\mu$ g/g creatinine	20.9	3.99
PBDEs (BDE47)	Serum	ng/g lipid	23.2	20.5
Triclosan	Urine	$\mu$ g/g creatinine	4.3	12.7
Hg in Hair 3.5 ppm				

# The Right to Healthy Indoor Air

Lars Molhave, 2002



Indoor Air 2002, 11 (Suppl. 6): 50-53  
http://www.tandf.co.uk/journals  
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INDOOR AIR  
ISSN 0924-6460

## The right to healthy indoor air: status by 2002

**Abstract** One of the reasons for the inadequate quality of indoor air arises from the poor articulation, appreciation and understanding of basic principles underlying the policies and actions related to indoor air quality. A WHO Working Group derived nine statements on rights to healthy indoor air. The discussions and statements are available as a WHO report. It informs the individuals and groups responsible for healthy indoor air about their rights and obligations, and empowers the general public by making people familiar with those rights. One year after their publication the statements have been adopted as the base for future regulation and guidance. The Board of Directors of the International Society of Indoor Air Quality (ISIAQ) and the participants of two international conferences endorse the use of the statements. No opposition to the statements have been registered. The statements have entered curricula of training courses and have been used in lawsuits.

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**and M. Krzyzanowski<sup>2</sup>**

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<sup>2</sup>Air Quality and Health (AQH), WHO European Center for Environment and Health, Bonn Office, Glienickerstrasse 15, Bonn, Germany

**Key words:** Health, indoor air quality, Sustainability, Responsibility, Resouratory prinitis

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### Introduction

Control of indoor air quality often is inadequate in spite of its significant role in determining health. Tensions often emerge and conflicts occur between persons suffering from indoor air pollution and those whose actions negatively influence indoor air quality. Most exposure to indoor air occurs in private homes, and intervention by public regulation is often considered a violation of personal freedom. Furthermore, commercial interests often have delayed the implementation of indoor air pollution controls in spite of the scientific evidence of harmful health impacts.

To a large extent, the reason for the inadequate quality of indoor air is due to poor articulation, appreciation and understanding of basic principles underlying the policies and actions related to indoor air quality. As a consequence, the general public is not familiar with those principles, and with the rights associated with them.

A World Health Organization (WHO) Working Group was convened to agree on a set of statements on 'The right to healthy indoor air', derived from fundamental principles in the fields of human rights, biomedical ethics, ecologic sustainability. These statements inform the individuals and groups responsible for healthy indoor air about their rights and obligations, and empower the general public by making them

familiar with these rights. Nine statements and comments were established at a WHO Working Group Meeting, Biltoven, the Netherlands, May 15-17, 2000. Twenty-three members of 18 countries attended this meeting. The document can be ordered from [info@ecohbomn.euro.who.int](mailto:info@ecohbomn.euro.who.int).

The original publication was the report from WHO (2000a). Subsequently two publications announced the statements (Molhave, 2000; Molhave and Krzyzanowski, 2000a,b). Added to this are an unknown number of copies downloaded from the WWW. The statements are referred to in other WHO publications (e.g., WHO, 2000b).

### The right to healthy indoor air

In the original report interpreting texts and explanations follows the nine statements. The statements themselves read as follows.

- P1: Under the principle of the human right to health, everyone has the right to breathe healthy indoor air.
- P2: Under the principle of respect for autonomy (self-determination), everyone has the right to adequate information about potentially harmful exposures, and to be provided with effective means for controlling at least part of their indoor exposures.



***John D. Spengler, Ph.D.***  
**Akira Yamaguchi Professor of Health &  
Human Habitation**  
***Harvard School of Public Health***



**Health effects of indoor and  
outdoor  
air pollutants**  
**Harvard Green Campus Initiative**  
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**Sustainability and Environmental  
Management Program and  
Harvard's E-School**  
**[www.extension.harvard.edu/envr](http://www.extension.harvard.edu/envr)**

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