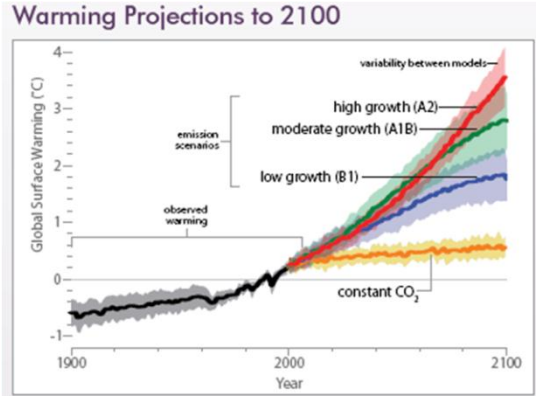
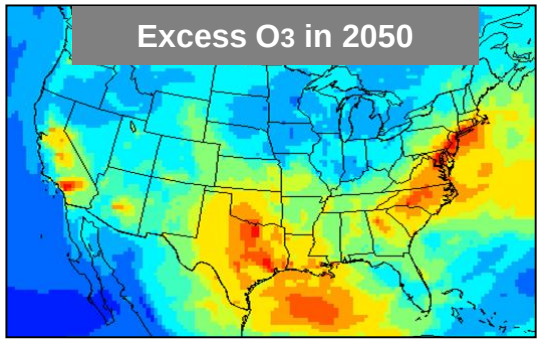
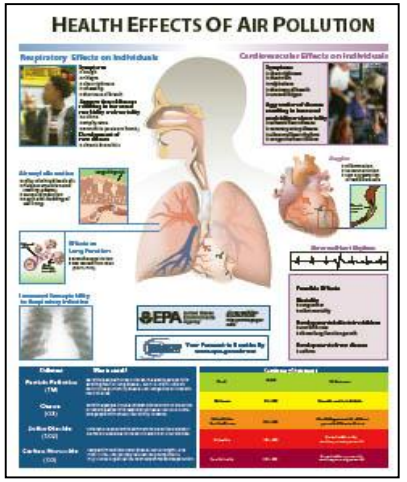
The Confluence of Air Quality, Health and Climate Change: A Challenge to Air Scientists…and Everyone Else

Dan Costa, Sc.D., DABT
National Program Director
Air, Climate & Energy
USEPA / ORD
costa.dan@epa.gov





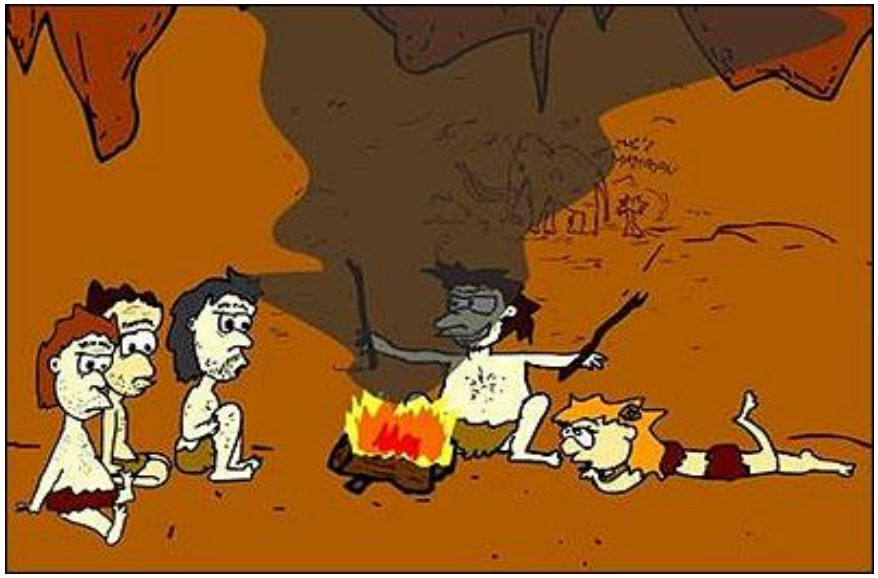


Frontiers in Air Quality Science
June 23-24, 2014

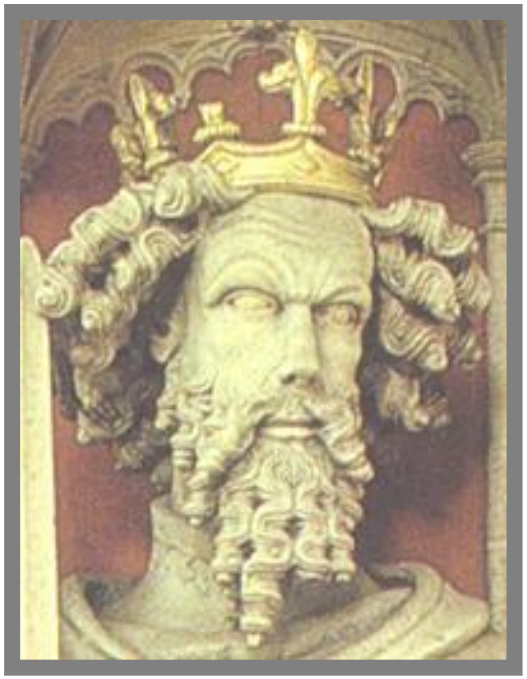
Congratulations – 21 years young!

- Multidisciplined perspective
- Creative science staff
- High level of productivity
- Impact publications
- High relevancy
- Internationally respected
- Targeted outreach

Fire has a Long History



CT scan of a
Peruvian mummy



Smoky Skies

- An Urban Curse -

1306 - King Edward I banned the burning of sea coal in London under penalty of death

1661 - John Evelyn (*Fumifugium*)
"London's inhabitants breathe nothing but an impure and thick mist, accompanied with a fuliginous and filthy vapor,...corruption the lungs and disordering the entire habit of their bodies…"

The Arts Also Spoke of the Smoke…

… to the right and left, was the same inter-minable perspective of brick towers, never ceasing in their *black vomit*, *blasting all things living or inanimate, shutting out the face of day*, and closing in on all these horrors with a dense dark cloud."

The Old Curiosity Shop, April, 1840. Charles Dickens (1812-1870) p. 326…

London Smog 1873

Houses of Parliament, Claude Monet

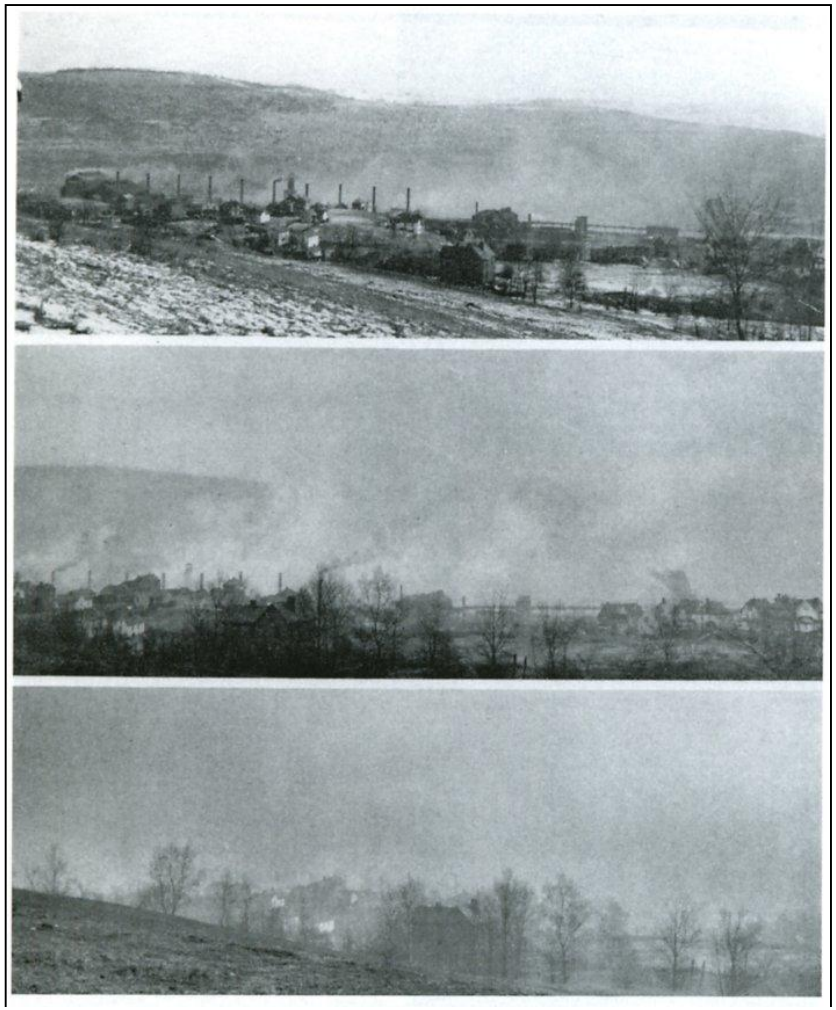
Then Came Disasters in Donora and London

Week of Oct 25, 1948…

- 20 people died; 7000 (50%) population affected
- Those with pre-existent pulmonary and cardiac disease were most affected

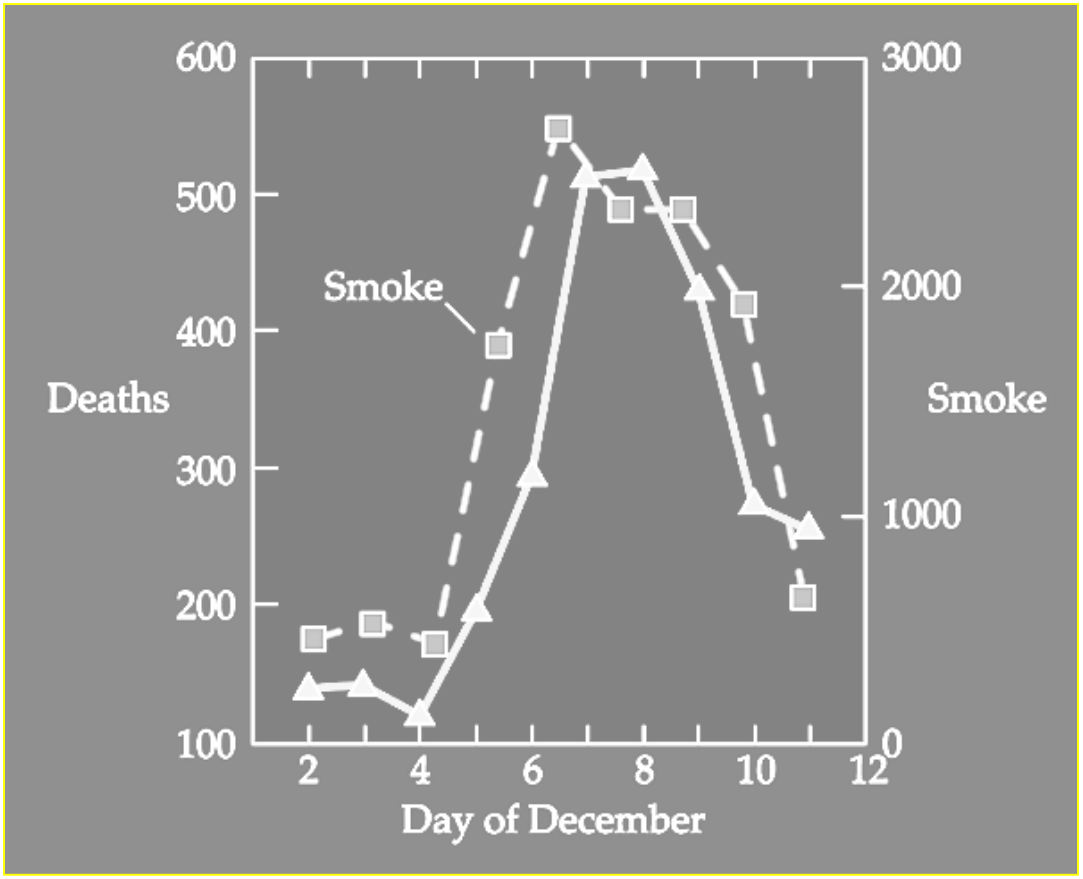
Credit: Pittsburgh Post-Gazette

1948: Donora, PA at noon.



Source: D. Davis, *When Smoke Ran Like Water,*

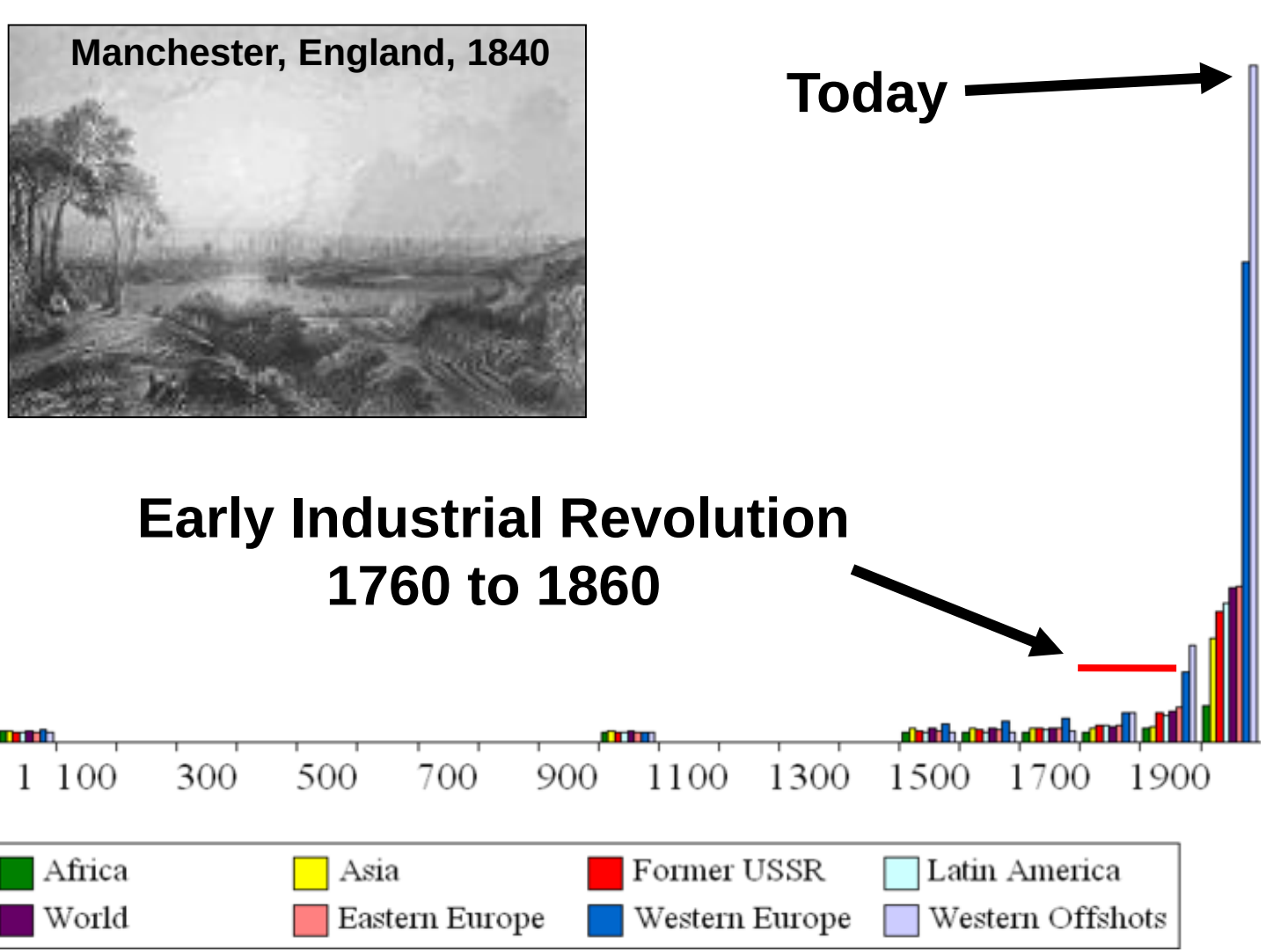
Then Came Disasters in Donora and London



Not only did thousands succumb quickly, but survivors who got sick and recovered had shorter life spans

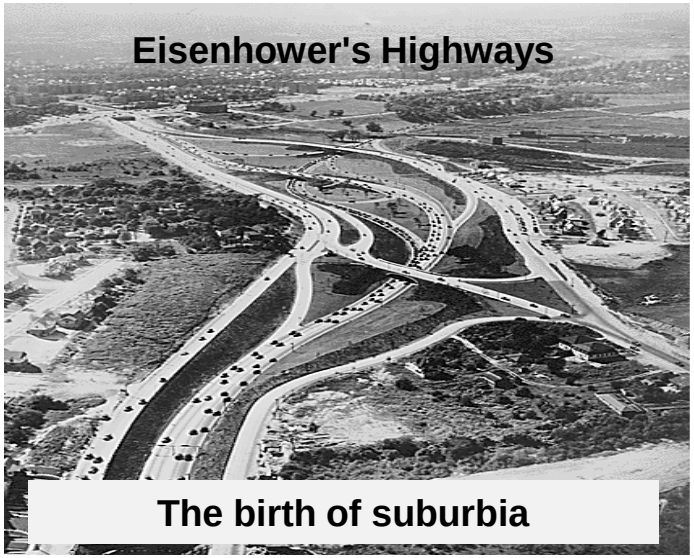
Fire Brought Global Economic Growth

Output / Person (Year 1 to 2003)



Smoky Skies Also Meant Prosperity…

1950s



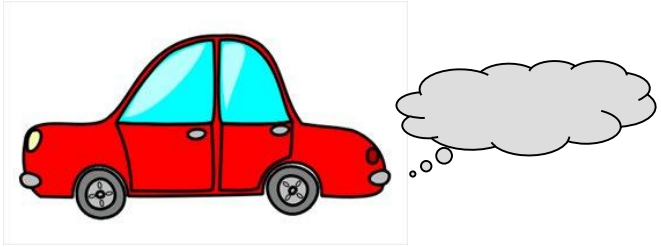
The Tide Began to Turn with Legislation

- UK 
  - Clean Air Act (1956)
  - National Survey (1961) – monitoring network
  - Enhanced Urban Network (1992)
- USA 
  - The Air Pollution Control Act (1955)
  - Clean Air Act (1967)
  - Clean Air Act Amendment (1970)
    - Established EPA
    - NAAQS and HAPs
  - CAA Amendment (1990) – Major Refinements

Clean Air Act Amendments of 1970

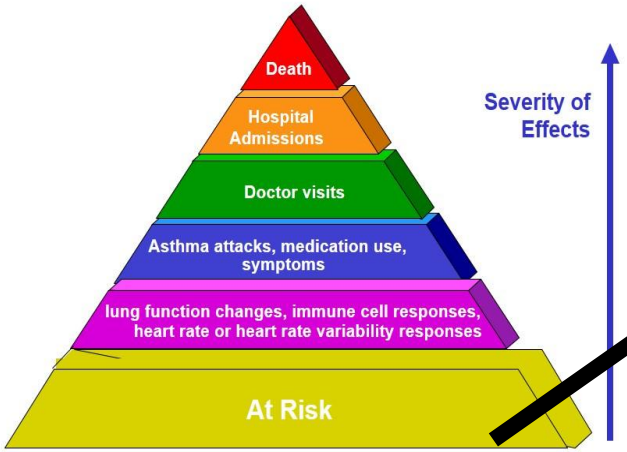
- **Established *National Ambient Air Quality Standards* (NAAQS) for most common pollutants (Criteria Air Pollutants).**
- **Assessment of NAAQS adequacy every 5 years**
- **NAAQS would be health based – cost not a factor**

- **Criteria pollutants for which there are NAAQS**
  - Photochemical oxidants
  - Particulate matter (TSP – now $PM_{2.5}$ and PM_{10})
  - Nitrogen oxides (now NO_2)
  - Sulfur dioxide
  - Carbon monoxide
  - Hydrocarbons (no longer exists)
  - Lead
  - [CO_2]… CAA authorization 111(d)

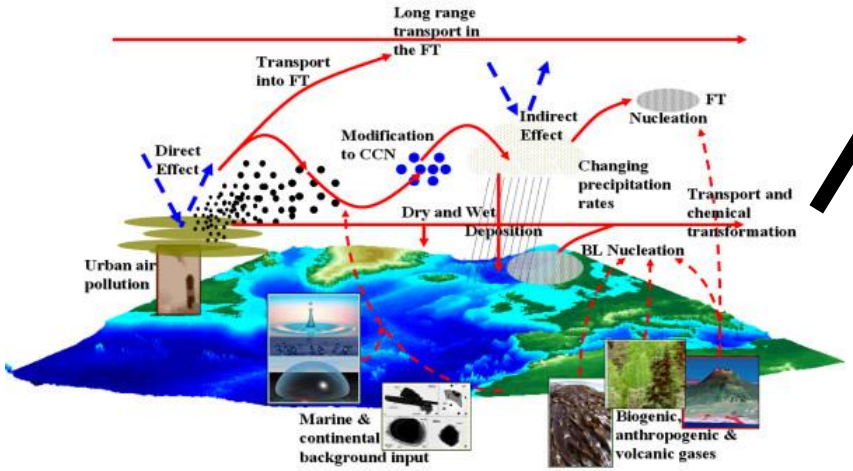


Translating the Science into Regulation

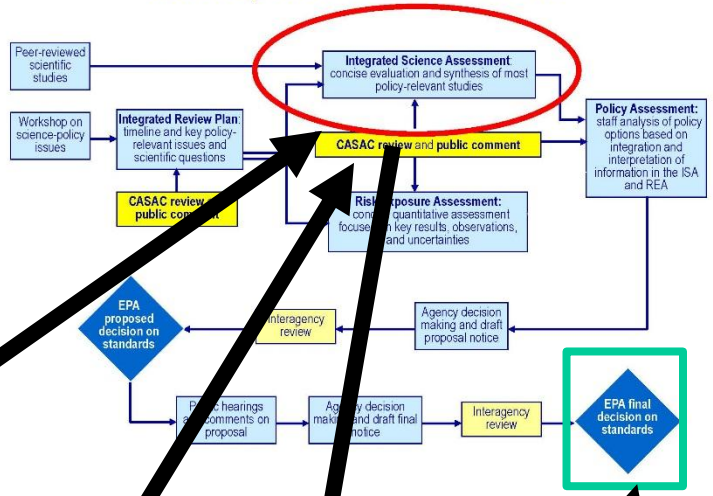
Pyramid of Health Effects for NAAQS



Atmospheric Sciences

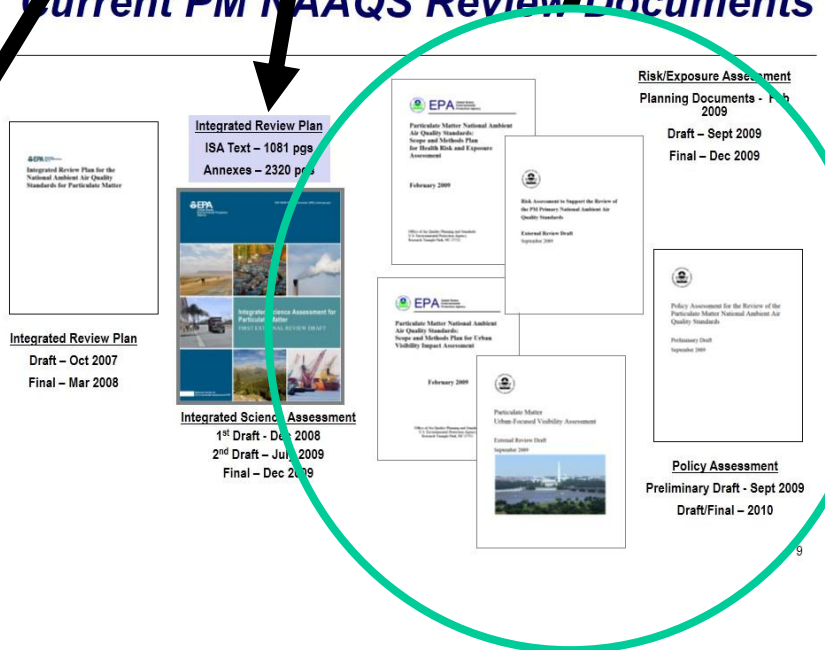


NAAQS Review Process



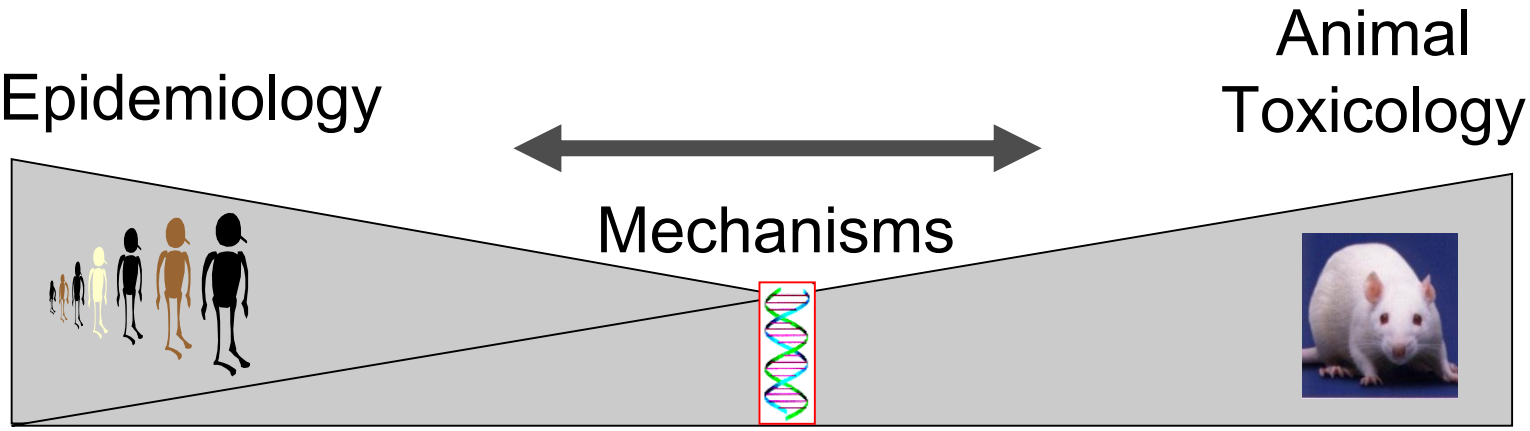
NAAQS

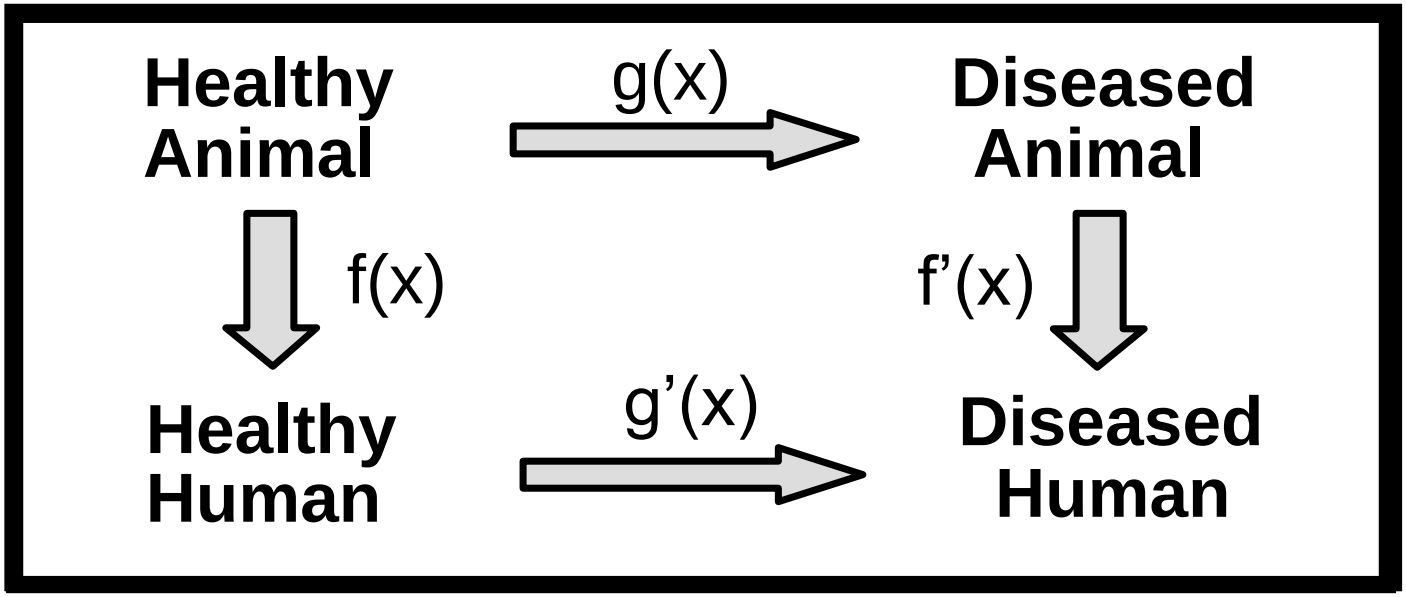
Current PM NAAQS Review Documents



Revolutionary Integration of Health Data

Data Value: Human studies supported by toxicology

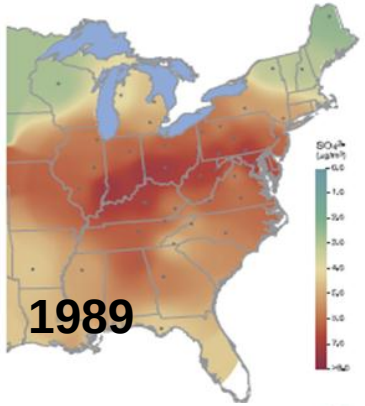


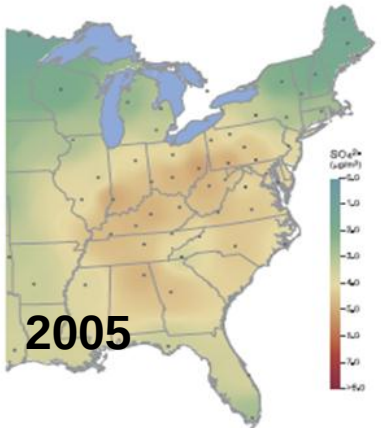


The PM Issue of the '70s/80s was Acid Aerosols

- Visibility impairment was caused by fine particles formed precursors transported over 100's of miles
- Acid aerosols damaged forests
- Acid (H_2SO_4) was thought to be a major pulmonary irritant

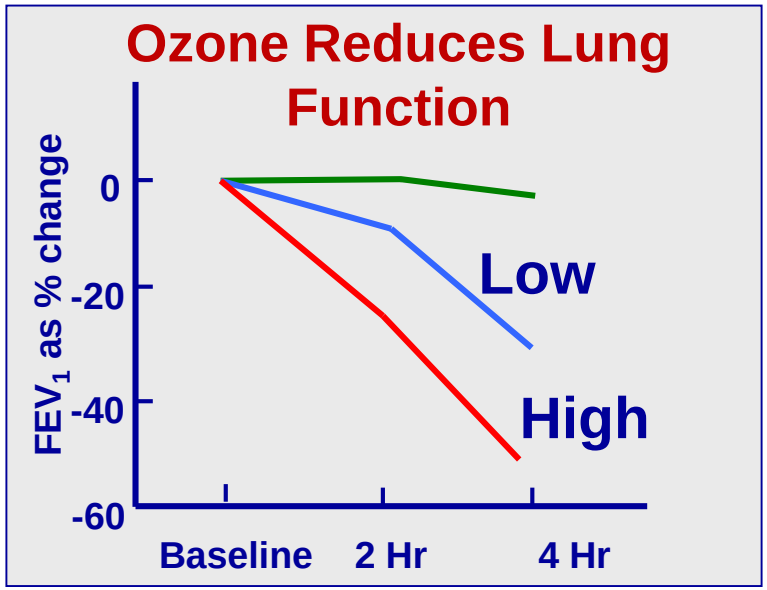
- Smoke reduction & lower sulfur coal and oil
- Acid aerosols didn't have that much effect on breathing mechanics and the epidemiology didn't find much PM effect
- Ozone seemed to be problem loomed

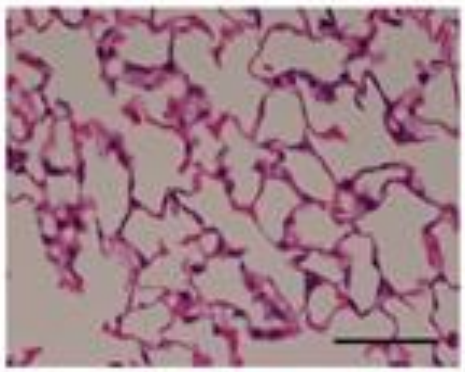


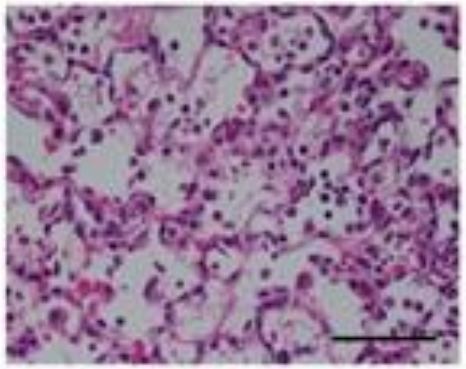


PM Problem was thought… Solved!

1980-1990: The Era of Oxidant Air Pollution



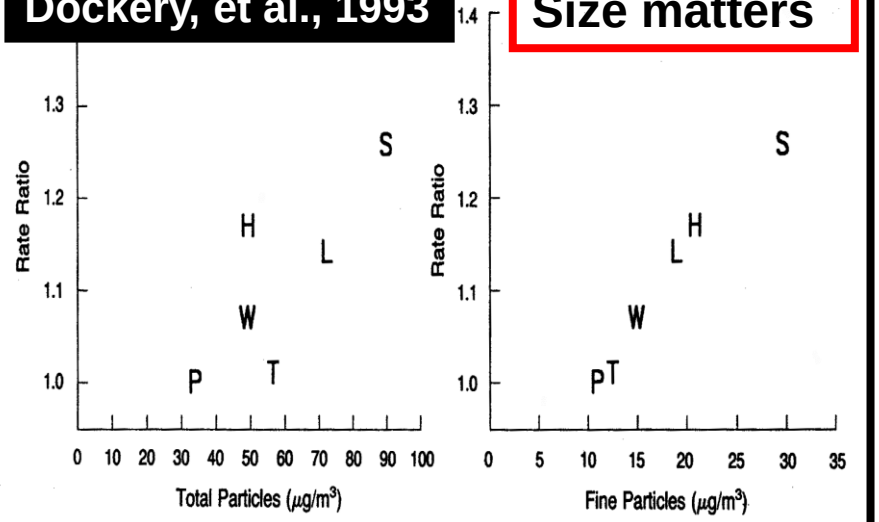




Healthy Lungs Inflammation

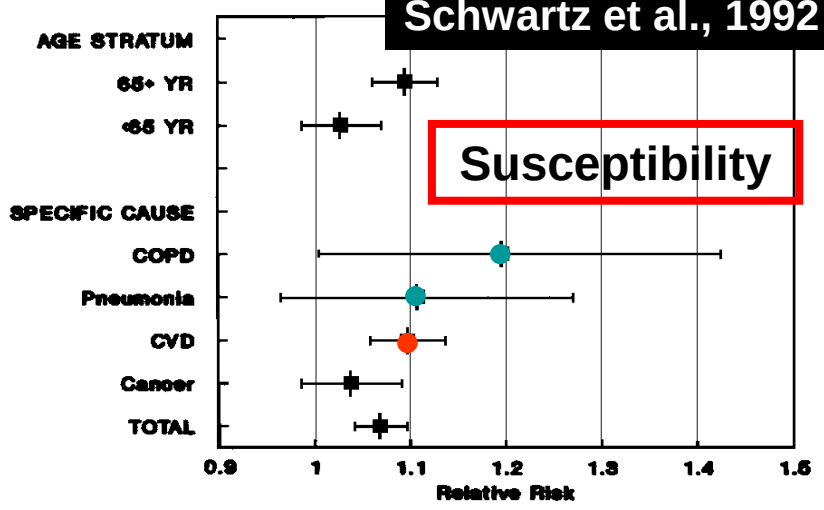
Dockery, et al., 1993

Size matters



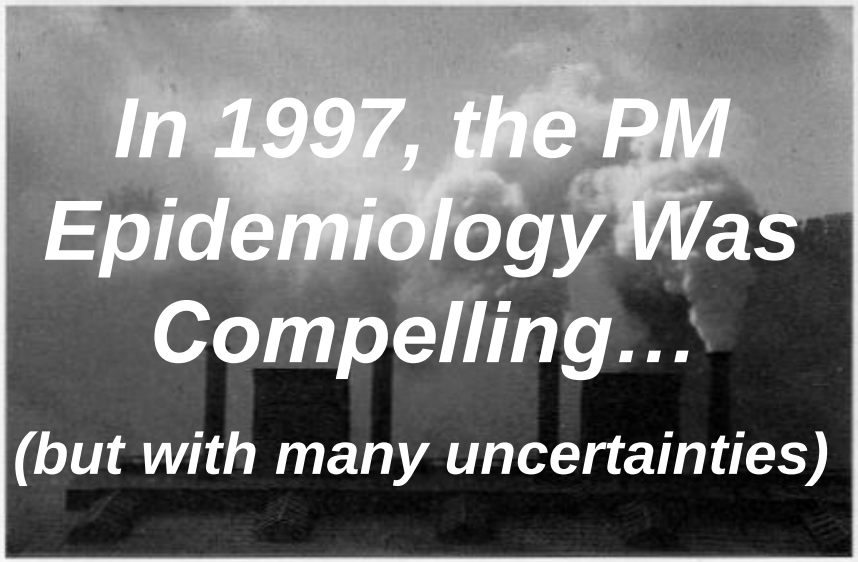
Schwartz et al., 1992

Susceptibility



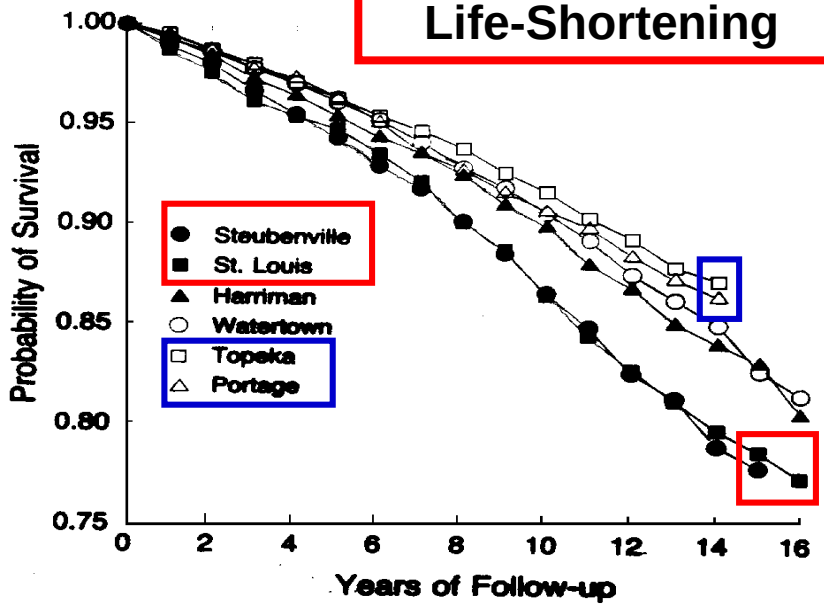
In 1997, the PM Epidemiology Was Compelling…

(but with many uncertainties)



Foundry along Ohio River near Stubenville, OH.
Photo: J. Spengler or D. Dockery

Life-Shortening



THE HERALD-SUN, DURHAM, N.C. THURSDAY, MAY 9, 1996

Air pollution particles are blamed for deaths

By H. JOSEF HEBERT
Associated Press

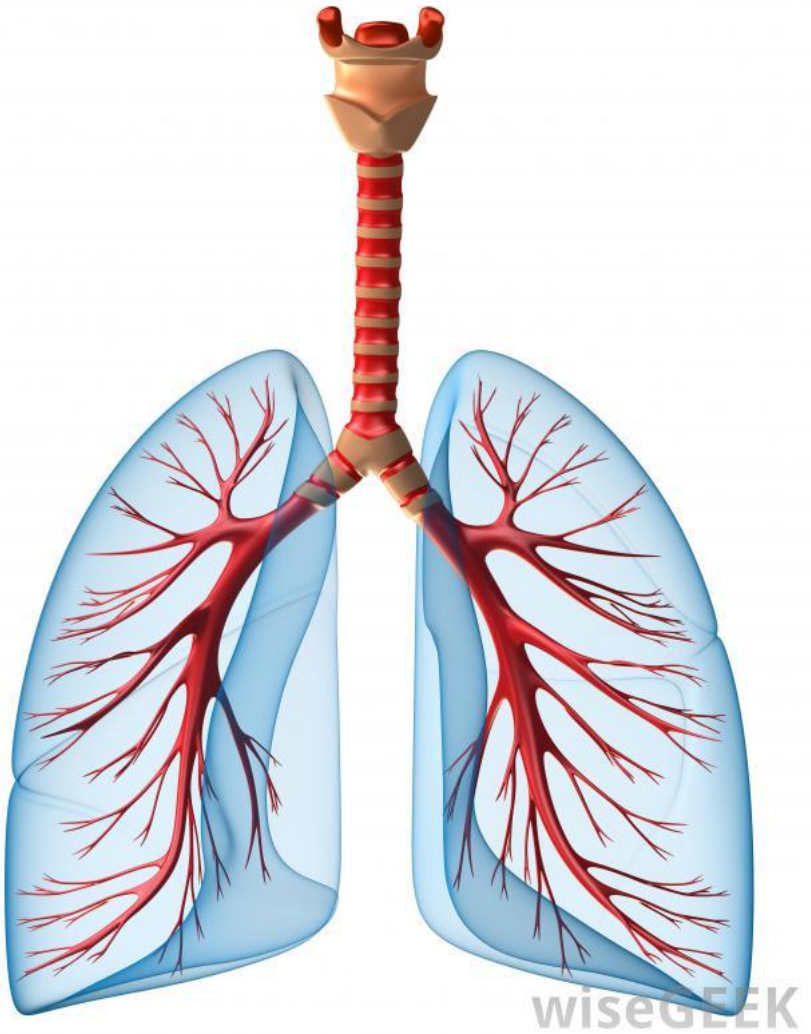
WASHINGTON — Dust, soot and tiny particles in polluted air over the nation's major cities cause tens of thousands of premature heart and lung-related deaths each year, an environmental group said Wednesday.

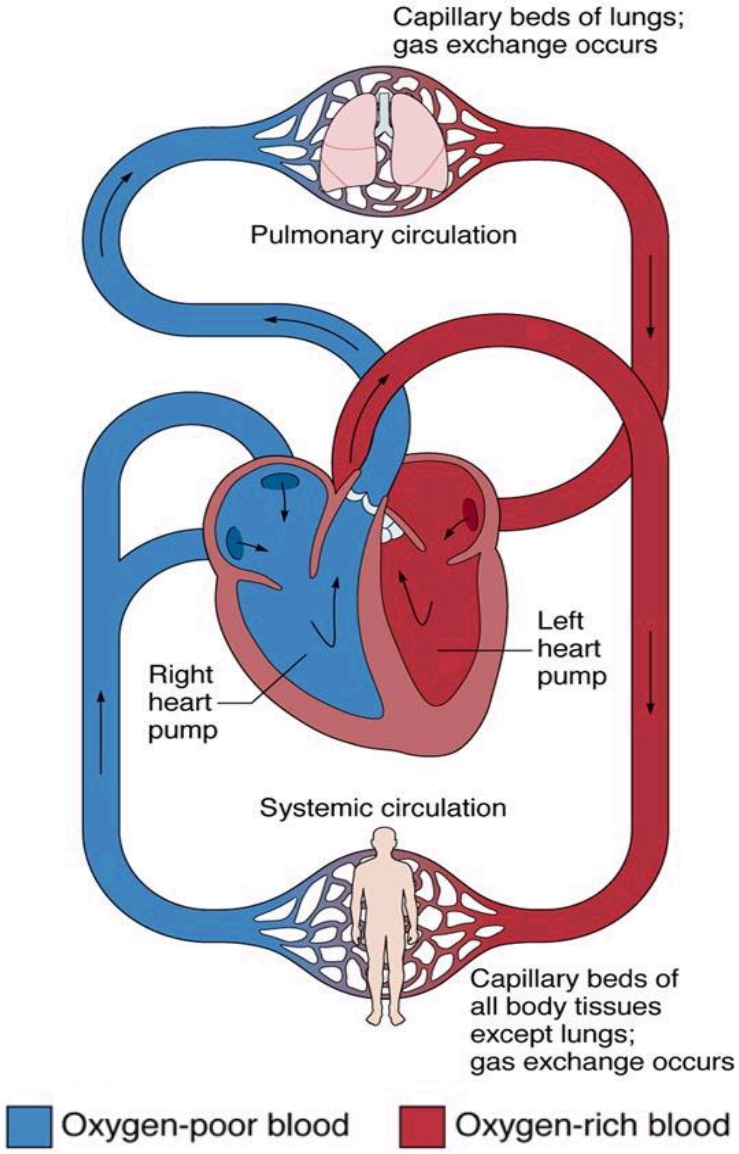
The Natural Resources Defense Council released the findings in a study on air pollution in 239 cit-

The NRDC study projected that as many as 64,000 premature deaths from cardiopulmonary causes "may be attributed to particulate air pollution each year," or about 6.5 percent of the nearly 1 million such deaths annually. Such pollution also has been linked to increased childhood asthma cases and health problems for the elderly.

"People face a risk of prema-

Effects Beyond the Lung





Coherent Evidence that PM affects the Cardiovascular System

772 MI patients

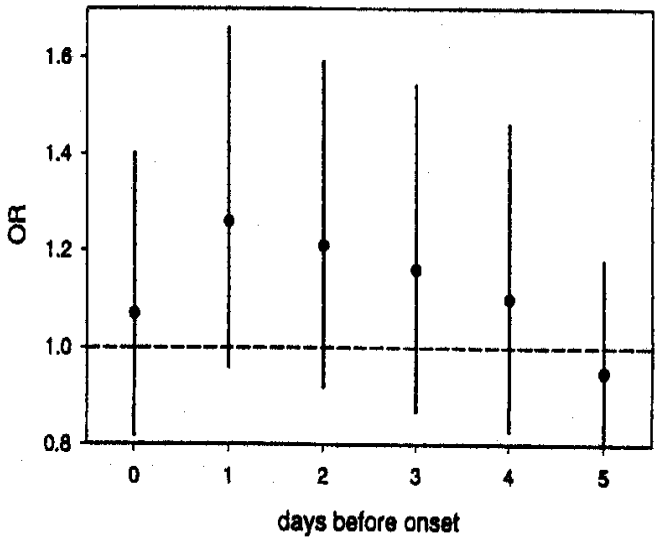
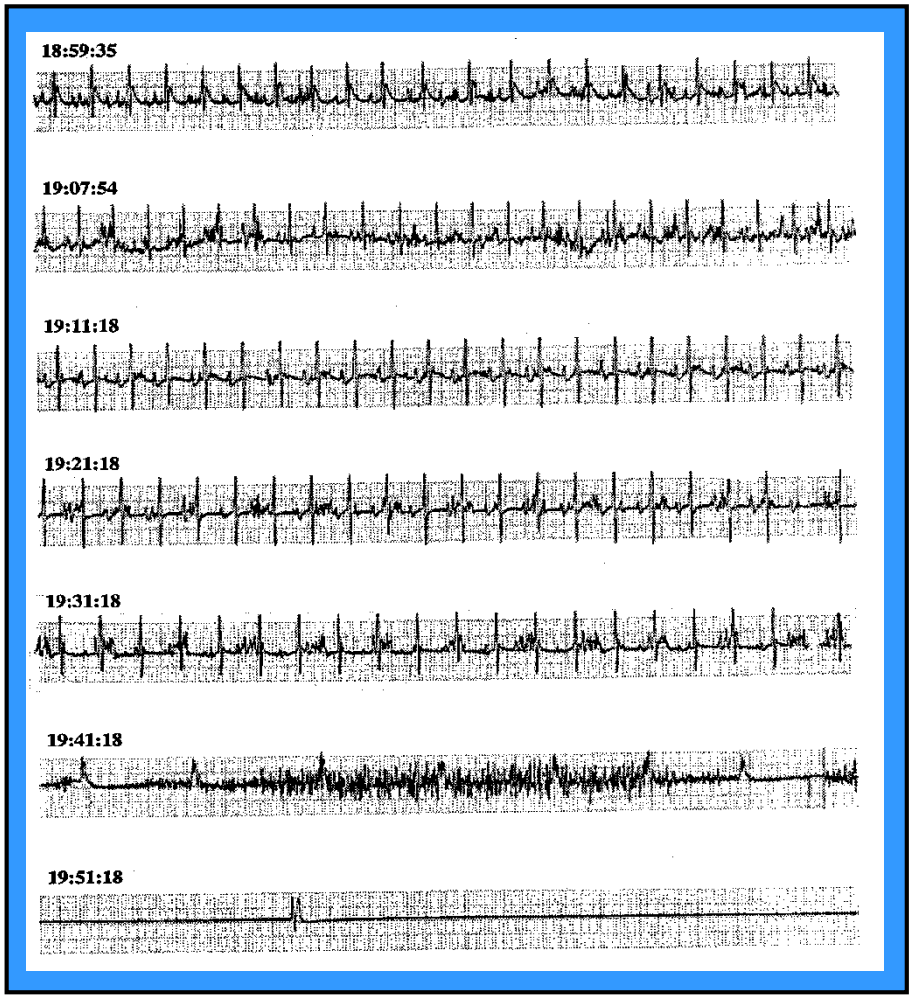


Figure 2. Univariate analyses for association between onset of MI and 24-hour average concentrations of $PM_{2.5}$. Odds ratios and 95% CIs for an increase of 20 $\mu g/m^3$ $PM_{2.5}$.

Peters et al., 2001

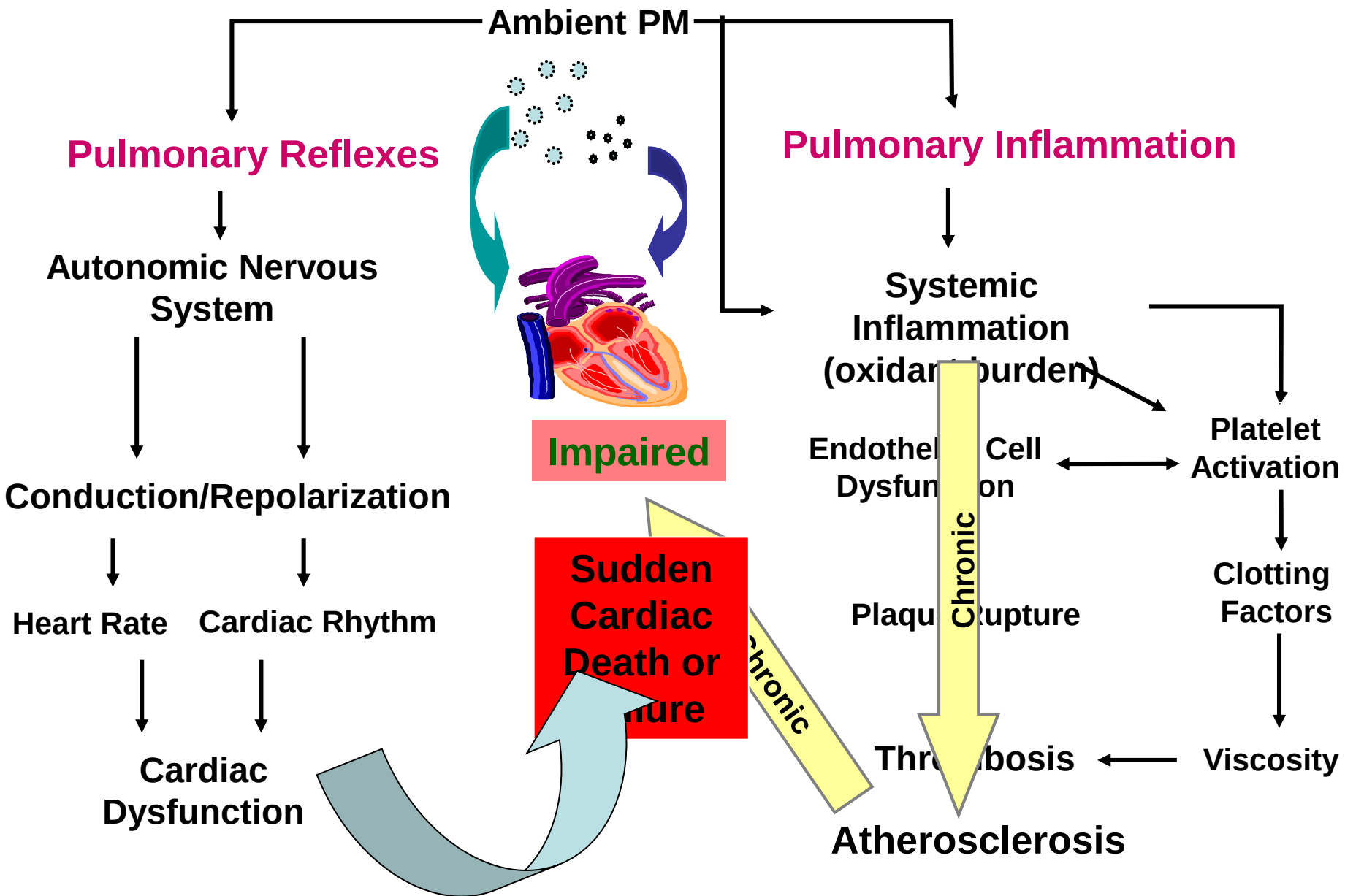
OR = 1.69 (1.13-2.34) for a 20 $\mu g/m^3$ increment in 24-hour $PM_{2.5}$

ECG Abnormalities and death in fly ash exposed hypertensive rats



Watkinson et al., 1998

Potential PM Effects on the Pulmonary-CV System



Last Decade of Research Provided Impetus / Groundwork for:

- Importance of raising awareness among health care providers
- Providing specific recommendations for clinical practice:

AHA Scientific Statement

Particulate Matter Air Pollution and Cardiovascular Disease

An Update to the Scientific Statement From the American Heart Association

Robert D. Brook, MD, Chair; Sanjay Rajagopalan, MD; C. Arden Pope III, PhD; Jeffrey R. Brook, PhD; Aruni Bhatnagar, PhD, FAHA; Ana V. Diez-Roux, MD, PhD, MPH; Fernando Holguin, MD; Yuling Hong, MD, PhD, FAHA; Russell V. Luepker, MD, MS, FAHA; Murray A. Mittleman, MD, DrPH, FAHA; Annette Peters, PhD; David Siscovick, MD, MPH, FAHA; Sidney C. Smith, Jr, MD, FAHA; Laurie Whitsel, PhD; Joel D. Kaufman, MD, MPH; on behalf of the American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism

"The overall evidence is consistent with a causal relationship between $PM_{2.5}$ exposure and cardiovascular morbidity and mortality."

Brook RD, et al. Circulation 2010; 121: 2331-78

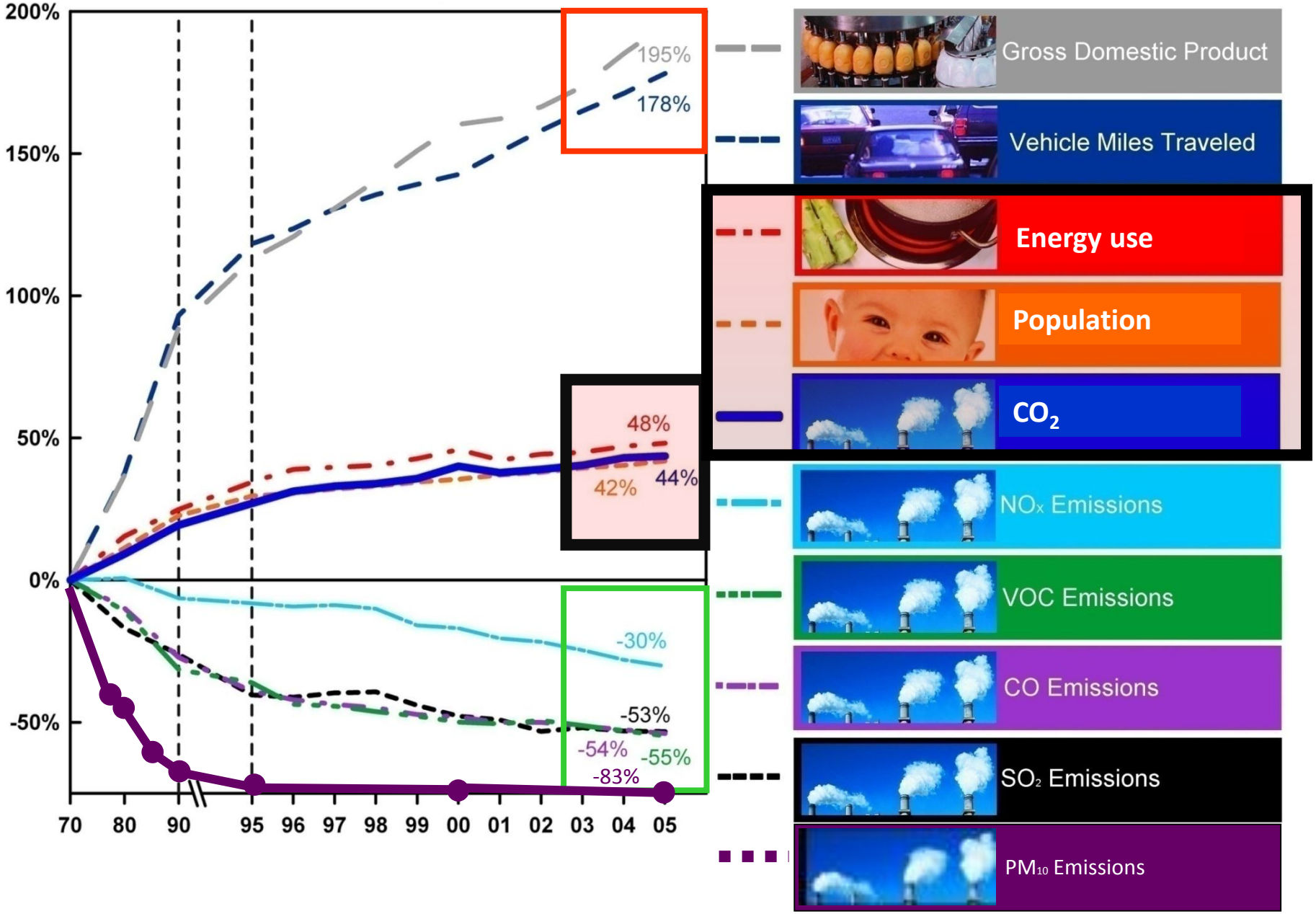
We can see the change

US Benefits Achieved with Pollution Reduction since 1970

- One of the most successful public health programs in American history with a return of more than $30 in benefits for every dollar invested in pollution (PM) reductions.
- In 2010 alone, reductions in fine particle and ozone pollution under the Clean Air Act prevented:
  - 160,000 cases of premature mortality
  - 130,000 heart attacks and 86,000 hospital visits
  - 13 million lost work days
  - 1.7 million asthma attacks
- Life expectancy improvements - ~7 mos over 10 years
- Reduction in acid deposition in lakes, streams & forests
- Improved visibility

Information gathered from Clean Air Act where you live:
http://www.epa.gov/cleanairactbenefits/whereyoulive/

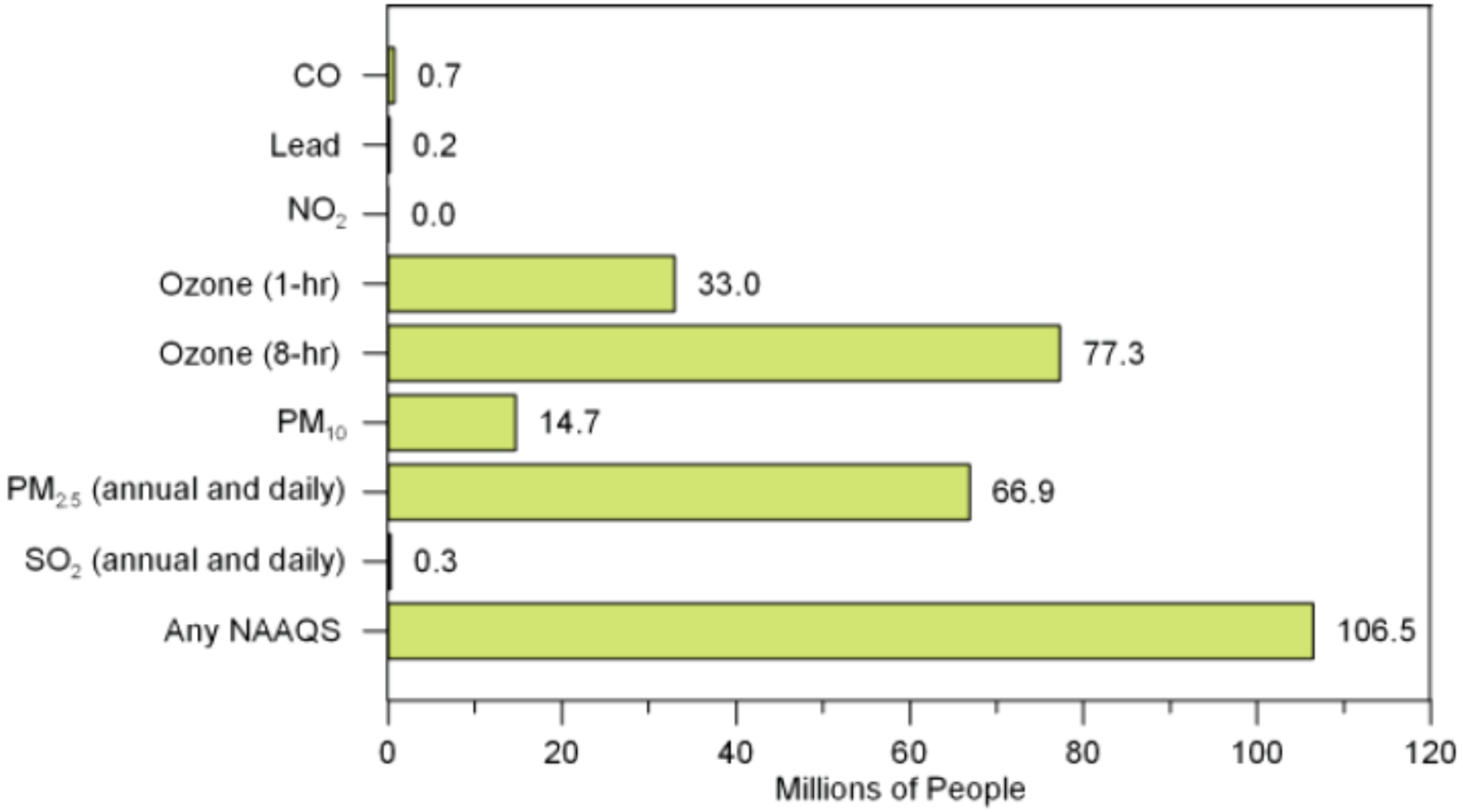
Emission Reductions Drove those Successes…



What's lies ahead?

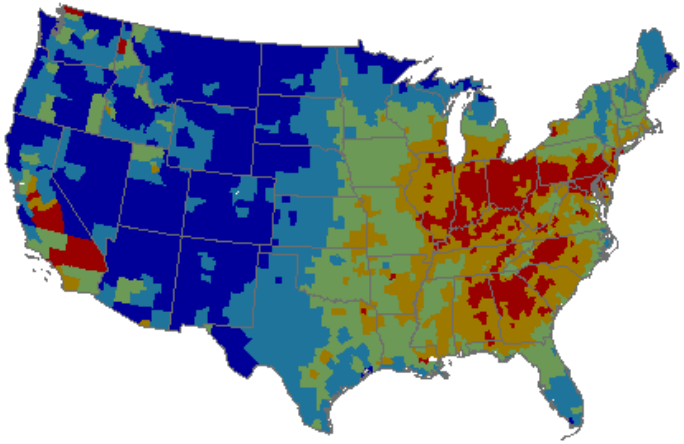
Many Issues Remain Unresolved and New Emerging Issues Appear Even More Complex

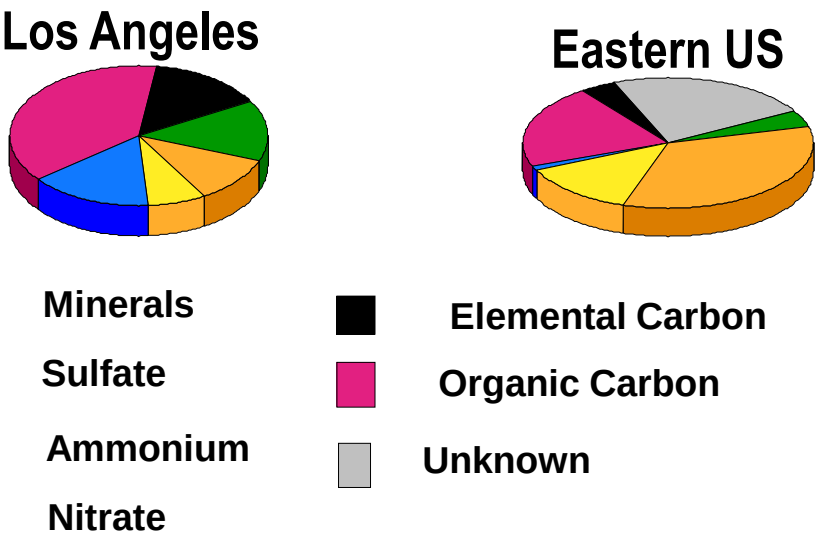
Yet Number of People Living in Areas with Pollutant Concentrations Above the NAAQS as of 2006



Public Health Burden of $PM_{2.5}$

Percentage of $PM_{2.5}$ related deaths due to 2005 air quality levels by county

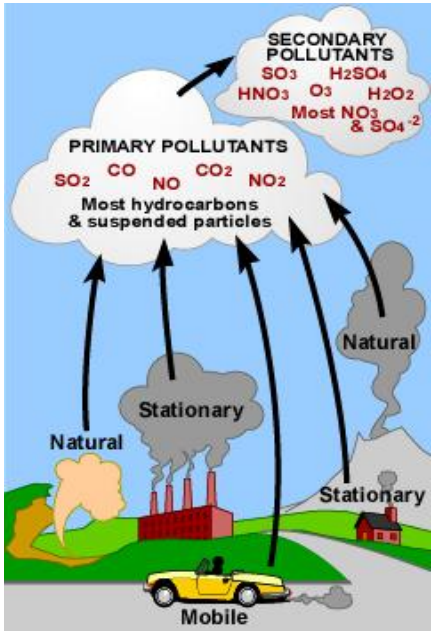




Summary of National $PM_{2.5}$ impacts due to 2005 air quality (Fann et al 2011)	
Excess mortalities (adults)[A]	130 to 320,000
Percentage of all deaths due to $PM_{2.5}$[B]	5.4%
Impacts among Children	
ER visits for asthma (<18 yr)	110,000
Acute bronchitis (age 8-12)	200,000
Exacerbation of asthma (age 6-18)	2,500,000

[A] Range reflects use of alternate PM mortality estimates
[B] Population-weighted value using Krewski et al. (2009) PM mortality estimates

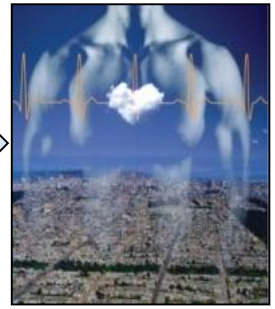
We Now Must Face the Multipollutant Reality - Air Quality

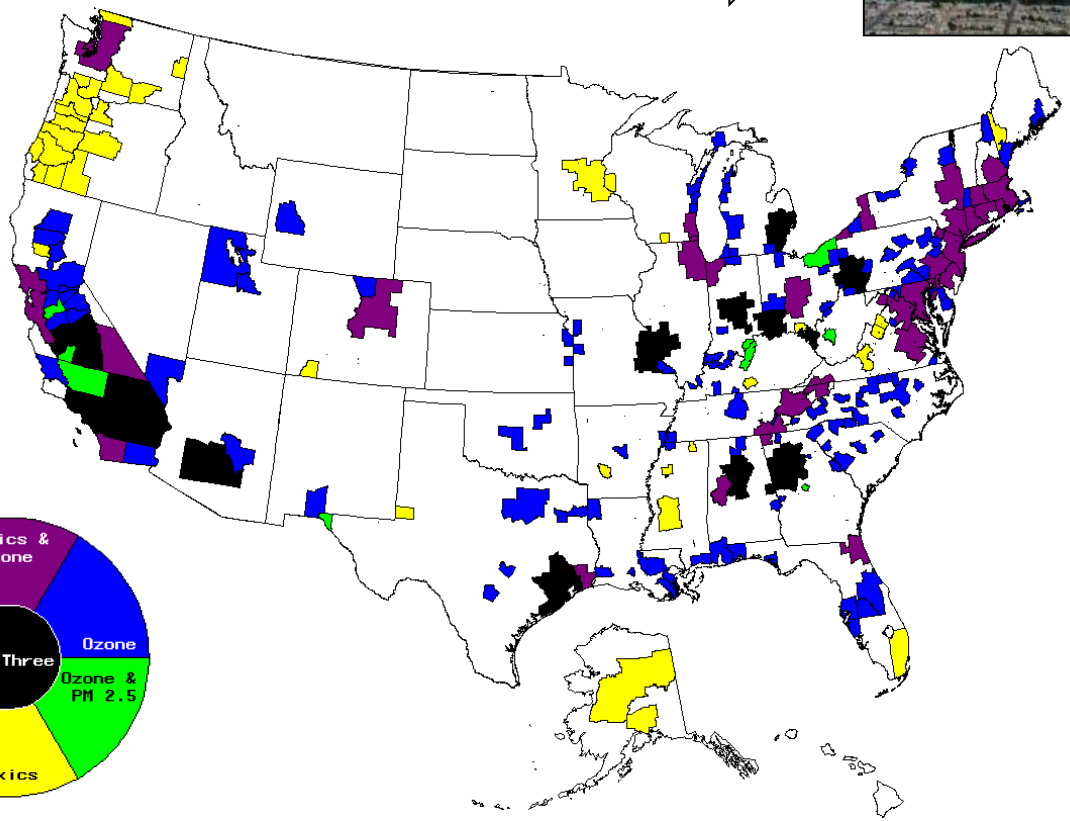


- Anthropogenic
- Natural
- Primary
- Secondary

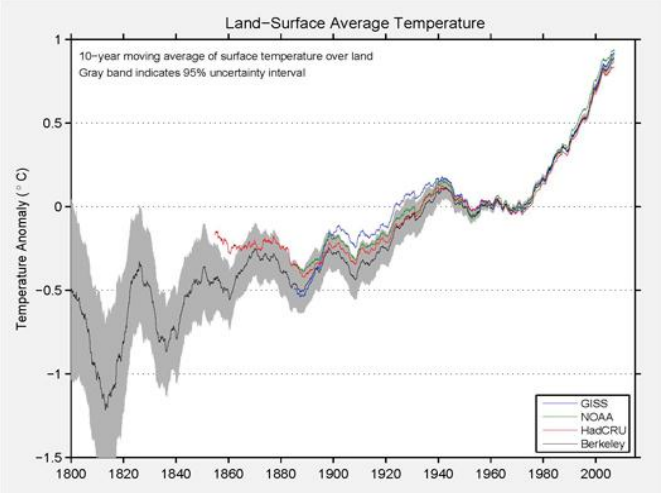
- Transport
- Dispersion
- Transformation
- Infiltration

Exposure

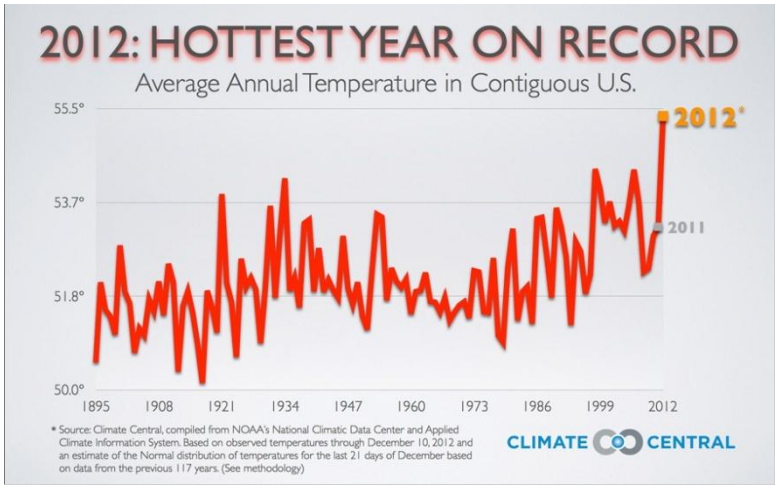


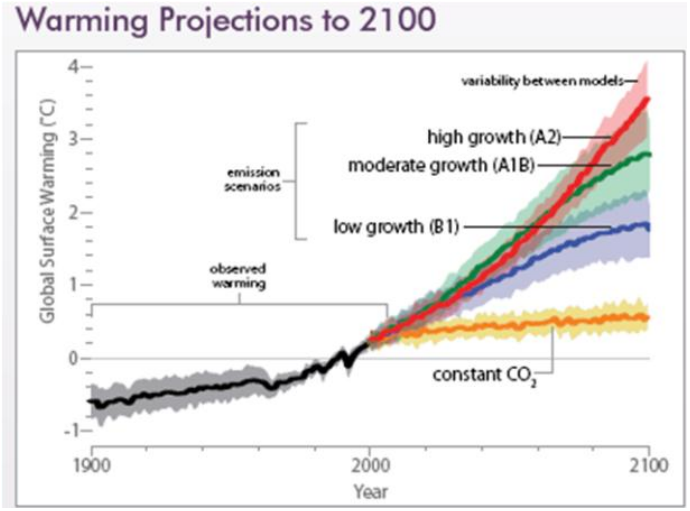


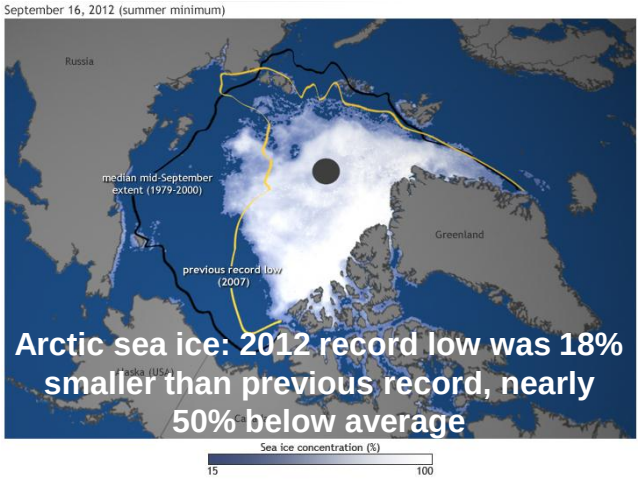
Incoming Data is Mounting…



The Berkeley Earth Surface Temperature Study (BEST), 7/2012





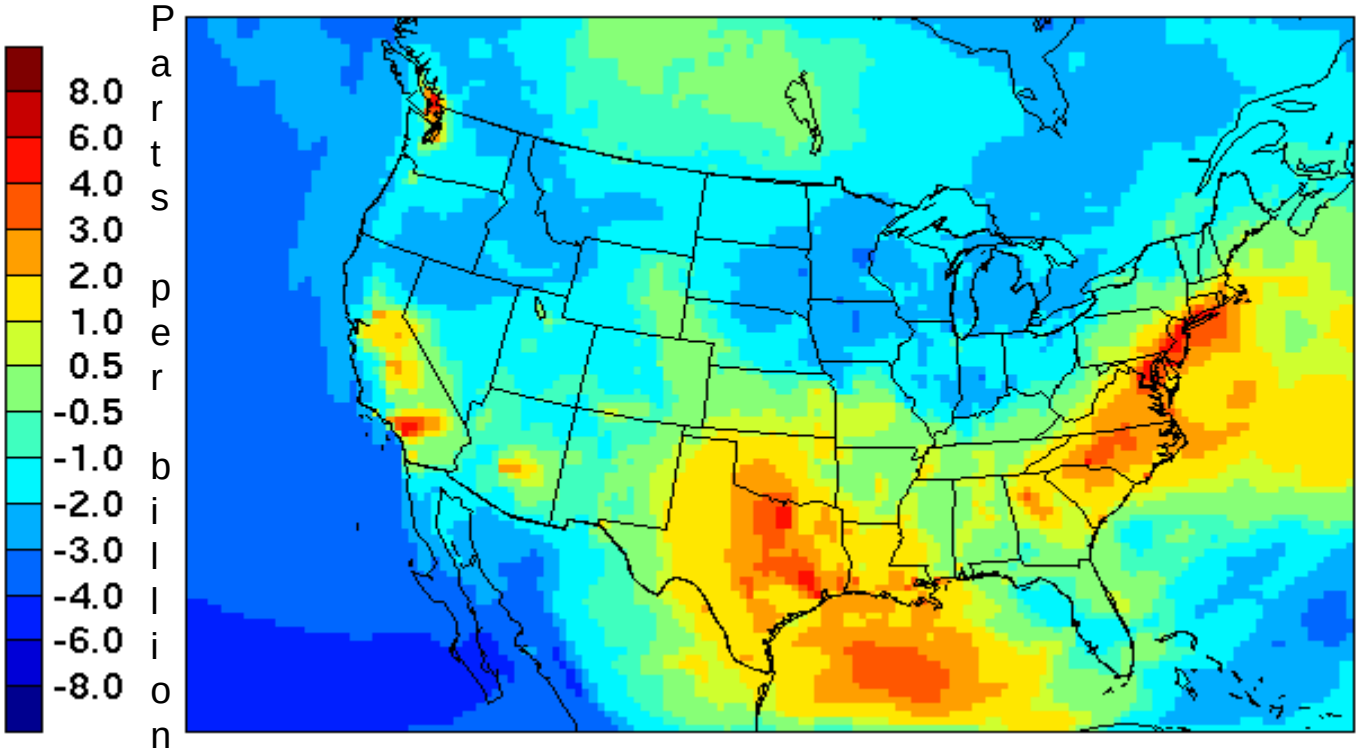


Climate Models Predict More Summertime Ozone with Global Change – Climate Penalty

Model Prediction for year 2050 relative to 2000 using constant emissions

Increased ozone

Decreased ozone

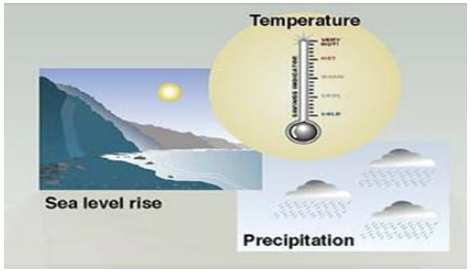


Potential Public Health Impacts of Climate Change

INDIRECT

DIRECT

- **Temp. rise**
- **Sea level rise**
- **Changes in Precipitation**

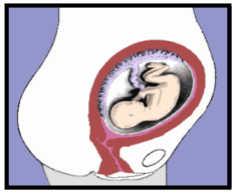


HEAT	Heat stress, cardiovascular failure
SEVERE WEATHER	Injuries, fatalities
AIR POLLUTION	Asthma, cardiovascular disease
ALLERGIES	Resp allergies, poison ivy
VECTOR-BORNE DISEASES	Malaria, dengue, hantavirus, encephalitis, Rift Valley fever
WATER-BORNE DISEASES	Cholera, cryptosporidiosis, campylobacter, leptospirosis
WATER AND FOOD SUPPLY	Malnutrition, diarrhea, harmful algal blooms
MENTAL HEALTH	Anxiety, post-traumatic stress, depression, despair
ENVIRONMENTAL REFUGEES	Forced migration, civil conflict

Cookstoves and Ambient BC

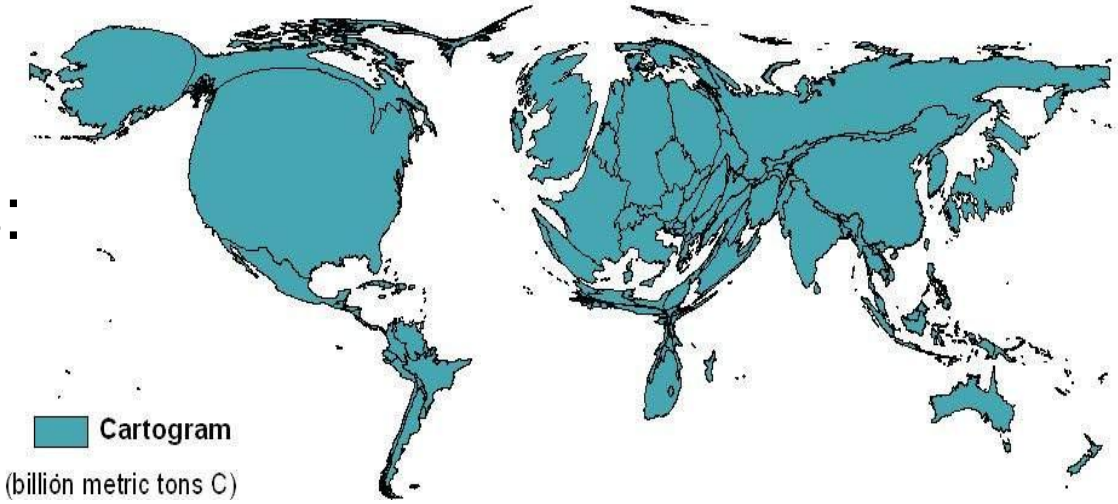
- *UN Foundation Global Alliance for Clean Cookstoves*
- 3M lung related deaths per year worldwide (mostly women)
- Combustion smokes as well as ambient PM have impacts on pregnancy outcomes

- Black Carbon is a major short term climate forcer
- Is BC the culprit or indicator?

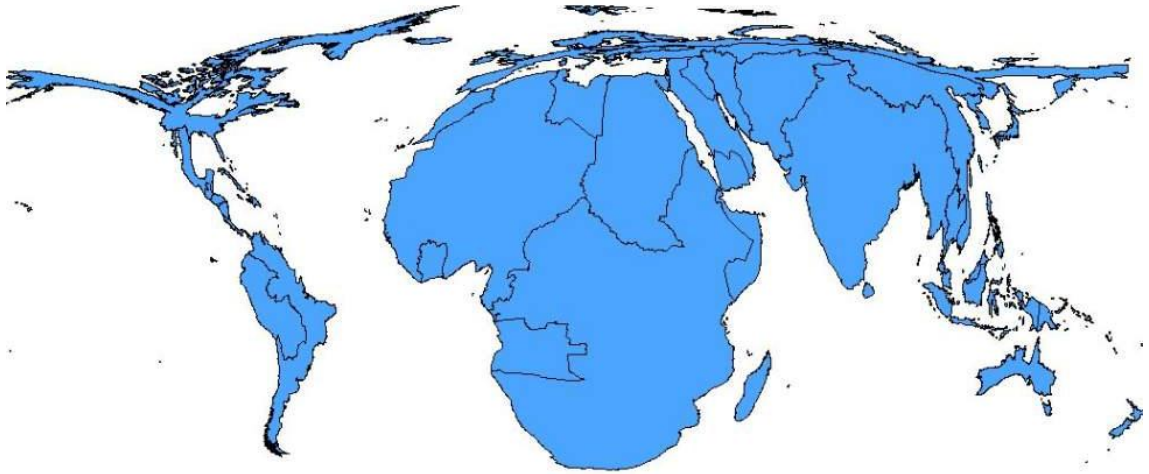


Climate Change: Inequity of Health Impacts

Emissions of greenhouse gases:



Estimated mortality attributed to climate change:



Source: McMichael A.J, 2008

There is a sense of urgency... If we don't move to address energy and climate as two sides of the same coin we will lose out. *Time*, April 23, 2009

Lisa Jackson
EPA Administrator

Out of the Headlines

Global population soars…

- 1 Billion in 1804
- 2 billion in 1927
- 6 billion in 2000
- 7 billion in 2011
- 10-15 billion in 3000

People need …

- Safe food, shelter, clean water, and clean air
- But the key is cheap, “sustainable” energy

Energy is essential for economic and social development

Population growth → Growing demand → Population growth

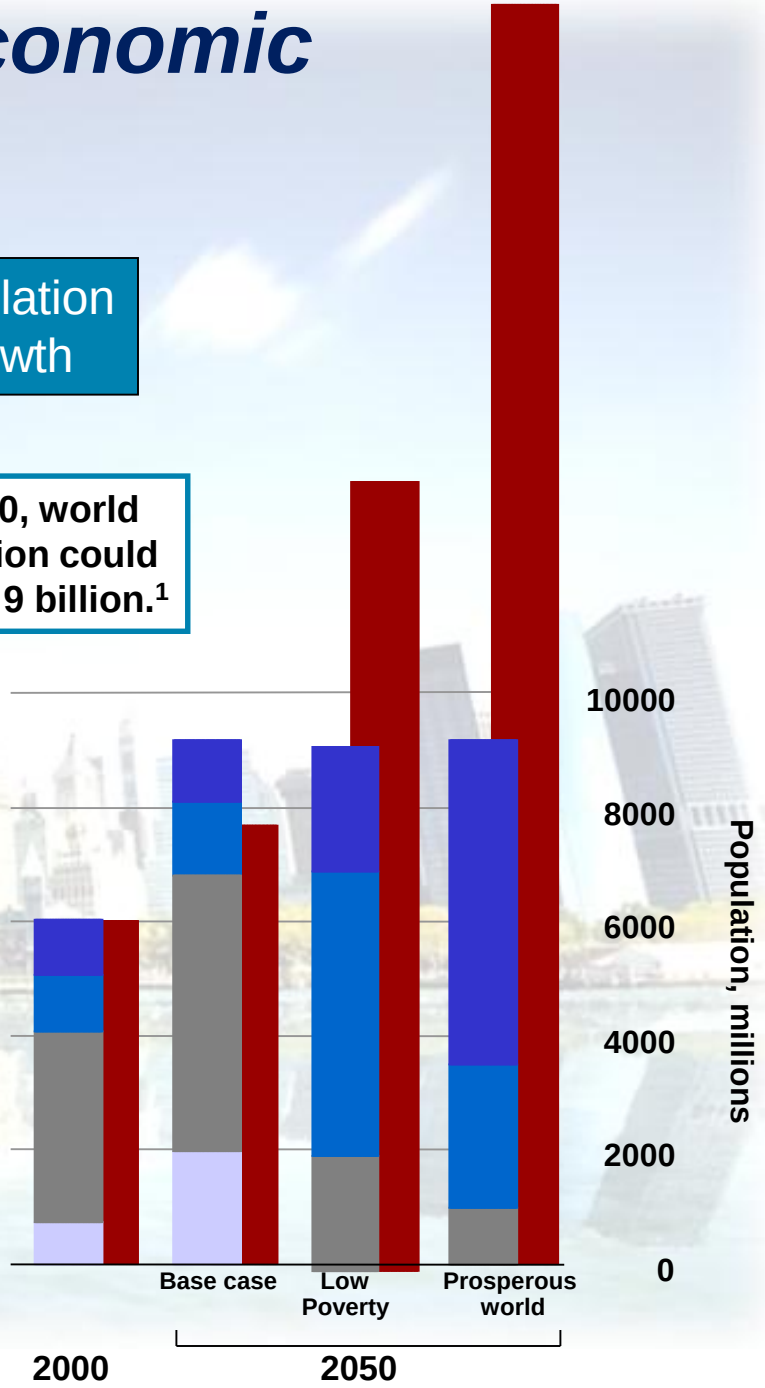
Global pop. divided into income groups:

- **Primary energy**
- **Developed (GDP>$12,000)**
- **Emerging (GDP<$12,000)**
- **Developing (GDP<$5,000)**
- **Poorest (GDP<$1,500)**

By 2050, world population could rise to ~ 9 billion.[1]

Shifting the development profile to a "low poverty" world means energy needs double by 2050

Shifting the development profile further to a "developed" world means energy needs triple by 2050



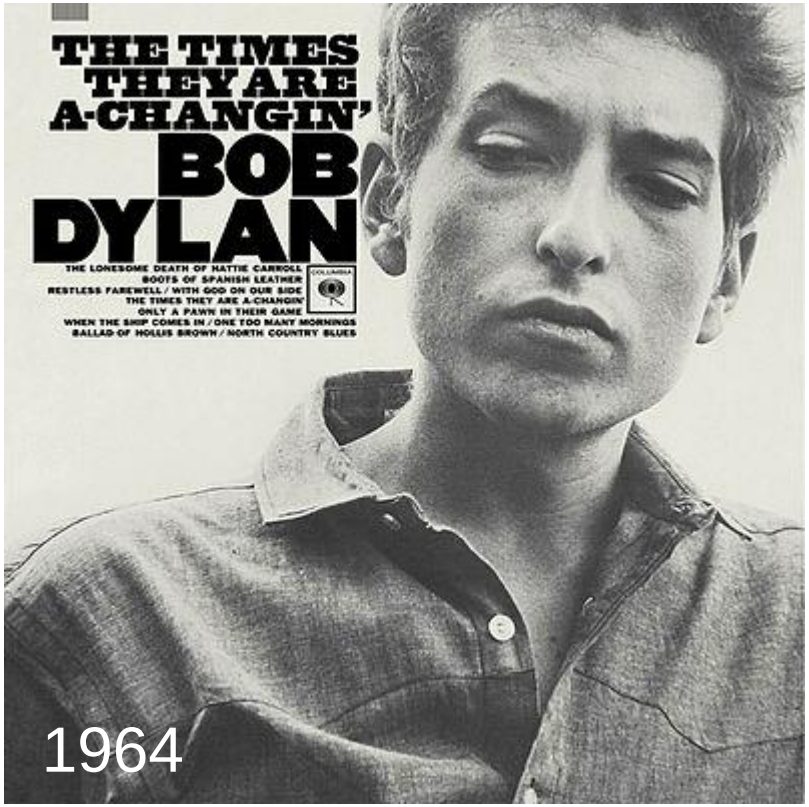
Source: *WBCSD adaptation of IEA 2003*

An Example of the Challenge Before Us

- David Douglas of Sun Microsystems
  - In 15 years the global pop. increases 1B
  - Give each a 60W light bulb
    - 0.7 oz. = 20K metric tons = 15K Priuses
    - Turned on = 60K megawatts
    - Use 4hrs / day == 10K megawatts
  - Power needed: 20 500 megwatt coal fired(?) power plants

Just to turn the lights on!!

From Tom Friedman, *Hot, Flat and Crowded* 2009



The times they are a changin’

US Legal Approach to GHGs

- 2007 Supreme Court ruled in *Mass v. EPA* that GHGs are covered by the CAA
  - Vehicle emissions impact health and welfare
- 2012 Supreme Court ruled favorably on the EPA Endangerment Finding2009
  - Light duty vehicle rule
  - New Source Review – new power plants
- 2014 Proposed Clean Power Rule
  - 30% reduction in C by 2030
  - States have most of the authority

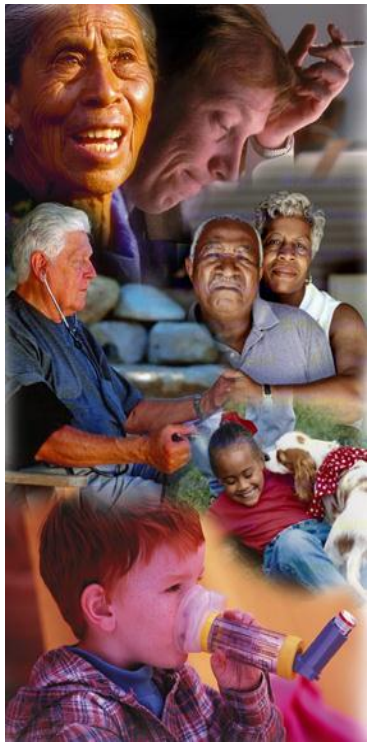
The Energy Landscape is Changing!!!

Williston, ND

Solutions or temporary fixes?

Preparing for Our Health Science Future

Some of My General Perspectives



We need to find "solutions" using the tools we already have - just more creatively!!

- Gone are the days of "the sky is falling"
- "Systems" approaches are essential
- What about *sustainability*?
  - How do we make the right decisions?
- Human Factors
  - Susceptibility – health; genetic; epigenetic; SES
  - A role for human (social) behavior?
- Climate - prepare or adapt?
  - Do we merely slow the decline?
  - What are the impacts of our responses?

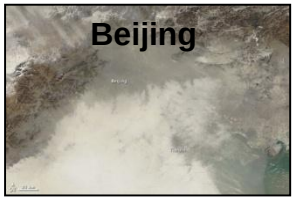
Toxicology of the Future

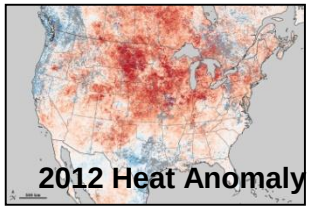
- 21st Century tox
  - Pathways
- Appropriate models
- Susceptibility
  - Frailty
  - Genetic / epigenetic
  - Target repair
  - Homeostasis
- Realistic scenarios
  - Exposures
  - Challenge the DR

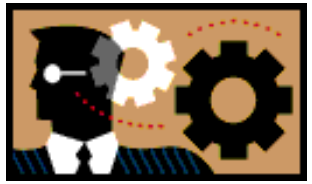
"Never, ever, think outside the box"

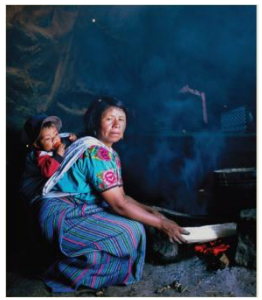
Epidemiology of the Future

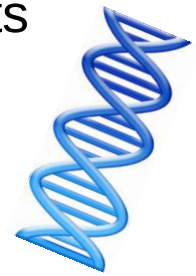
- Moving toward “causality”
- Enhanced statistical designs
  - Multipollutant models in time and space
  - Improved exposure estimates
  - Public health tracking – esp. w/ climate change
  - Susceptibility –short term vs chronic
  - Utilizing social media
- Dealing with moving targets
  - AQ in a changing energy landscape
- Accountability – are we better off?
  - Finding benefits amongst disbenefits
- The “Global Context”
  - Genes in society – nature vs nuture











Putting the Health of Our Planet and Life on It in Perspective

Photo of the Earth taken from Mars by Curiosity, Aug 2012


Thank You