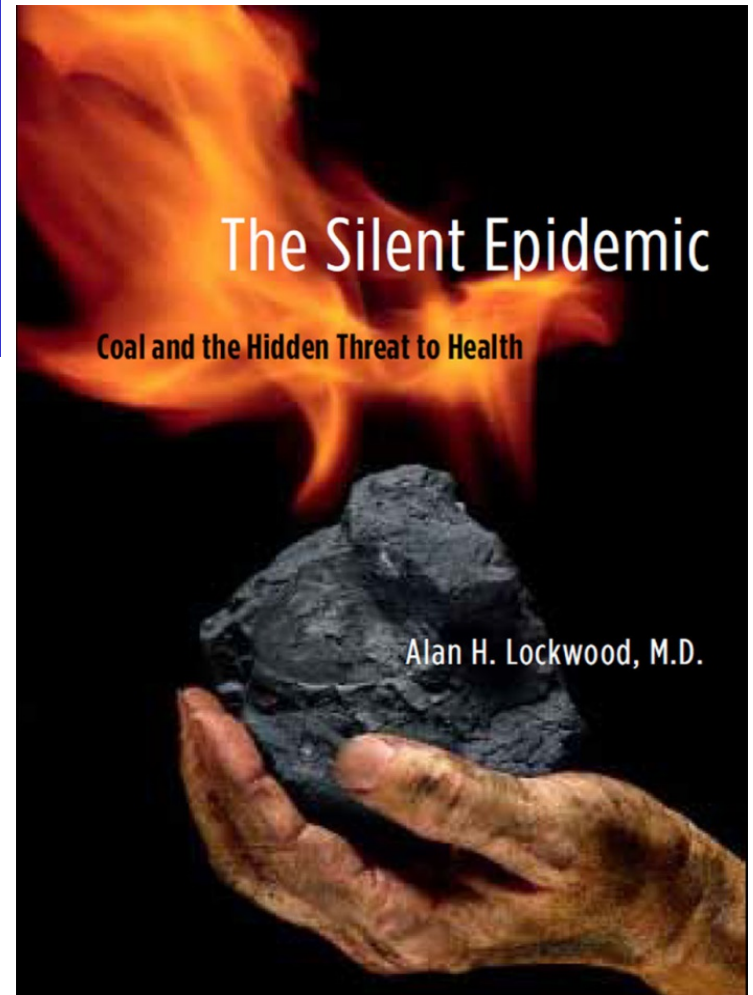


National Primary Care Week October 5-9, 2015

COAL & HEALTH: **PAST, PRESENT, AND FUTURE**

Alan H. Lockwood, MD,
Emeritus Professor of Neurology
University at Buffalo
Past President and Co-Chair
Environment and Health Committee
Physicians for Social Responsibility



CME Declarations

- Nothing to declare
- Book royalties donated to PSR

Objectives

- Coal in today's society
- Health effects of coal's life cycle: mining, transport, combustion, waste disposal
- Coal and hazardous air pollutants (HAPS)
- SO_x and NO_x: contributions to heart disease, cancer, respiratory disease, stroke
- Air of the future: CO₂ and ozone
- Climate interventions and "Clean Coal"

Tom Toles, Coal, The Pope: This is Hardball



Air Pollution Damages in 2005

406 Coal Plants: \$62 billion

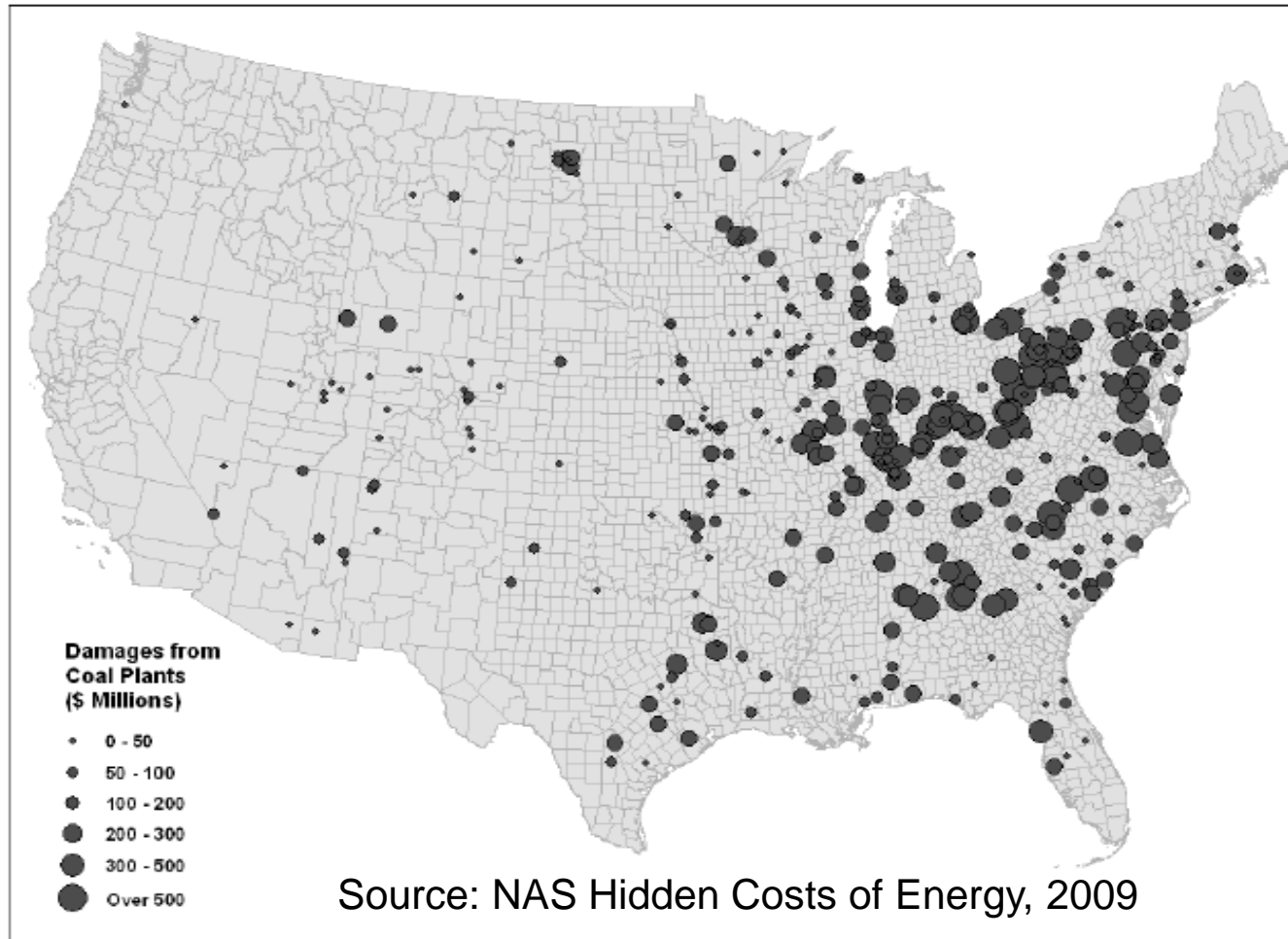
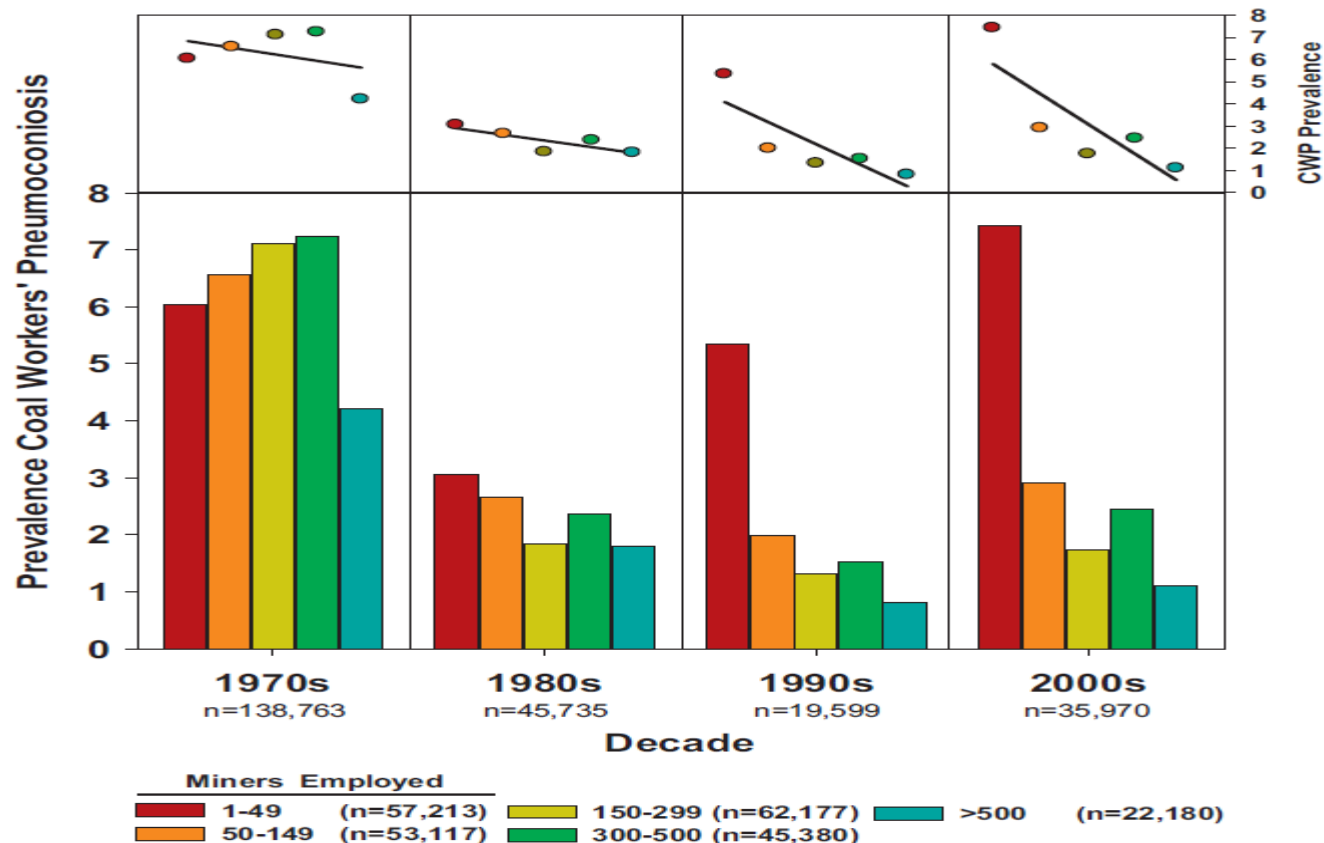


FIGURE 2-6 Air pollution damages from coal generation for 406 plants, 2005 (2007 USD). Damages related to climate changes effects are not included.

Coalworkers Pneumoconiosis Fell for years after 1969 law



Source: AS Laney & MD Attfield, Occup Environ Med, 2010

West Virginia, Where You Live Counts

- As coal production increased, health status worsened and rates of cardiopulmonary disease, lung disease, cardiovascular disease, diabetes and kidney disease worsened.
- Example result for COPD: odds ratio and 95% confidence interval
 - ❑ Less than 4 million tons: 0.969 (0.596 – 1.577)
 - ❑ More than 4 million tons: 1.559 (1.069 – 2.272)

Source: Hendryx & Ahern, Am J Public Health, 2008

Coal Transport

- About 70% of all rail traffic is related to coal transport
- Rail accidents are much more common per ton-mile than road traffic
- Diesel locomotives emit particulates that are harmful to health
- Trucks produce particulates from diesel engines and wear and tear of roads

Source: Lockwood, AH, The Silent Epidemic, MIT Press, 2012

Two Killed in Coal Train Derailment, August 12, 2012



Coal Ash

- We burn about 1 billion tons of coal each year
- This produces about 100 million tons of coal combustion waste
- As pollution control devices become more efficient as mandated by the Clean Air Act, the ash becomes more toxic
- Ash is poorly regulated and often stored under substandard conditions
 - Repositories commonly unlined
 - Heavy metals, e.g., arsenic, leak into water supply

Source: Lockwood AH, The Silent Epidemic, MIT Press, 2012

Kingston spill, December 22, 2008

- Dam failed holding back a 84 acre area
- 1.1 billion gallons released
- At dozens of other sites, arsenic and other toxicants have leached into ground water

Aerial Image Of Kingston Ash Slide 12/23/08



Air Pollutants

- **Criteria Air Pollutants: harmful to health and environment, have National Ambient Air Quality Standards (NAAQS)**
 - Carbon Monoxide
 - Lead
 - Nitrogen Dioxide
 - Particulates (10 and 2.5 micron aerodynamic diameter)
 - Ozone
 - Sulfur Dioxide
- Mercury

Hazardous Air Pollutants (HAPS) Released by Coal Combustion (from over 60)

- Oxides of sulfur
- Oxides of nitrogen
- Arsenic
- Beryllium
- Cadmium
- Chromium
- Mercury
- Nickel
- HCl
- HF
- Acreolin
- Dioxins
- Formaldehyde
- Uranium and Thorium

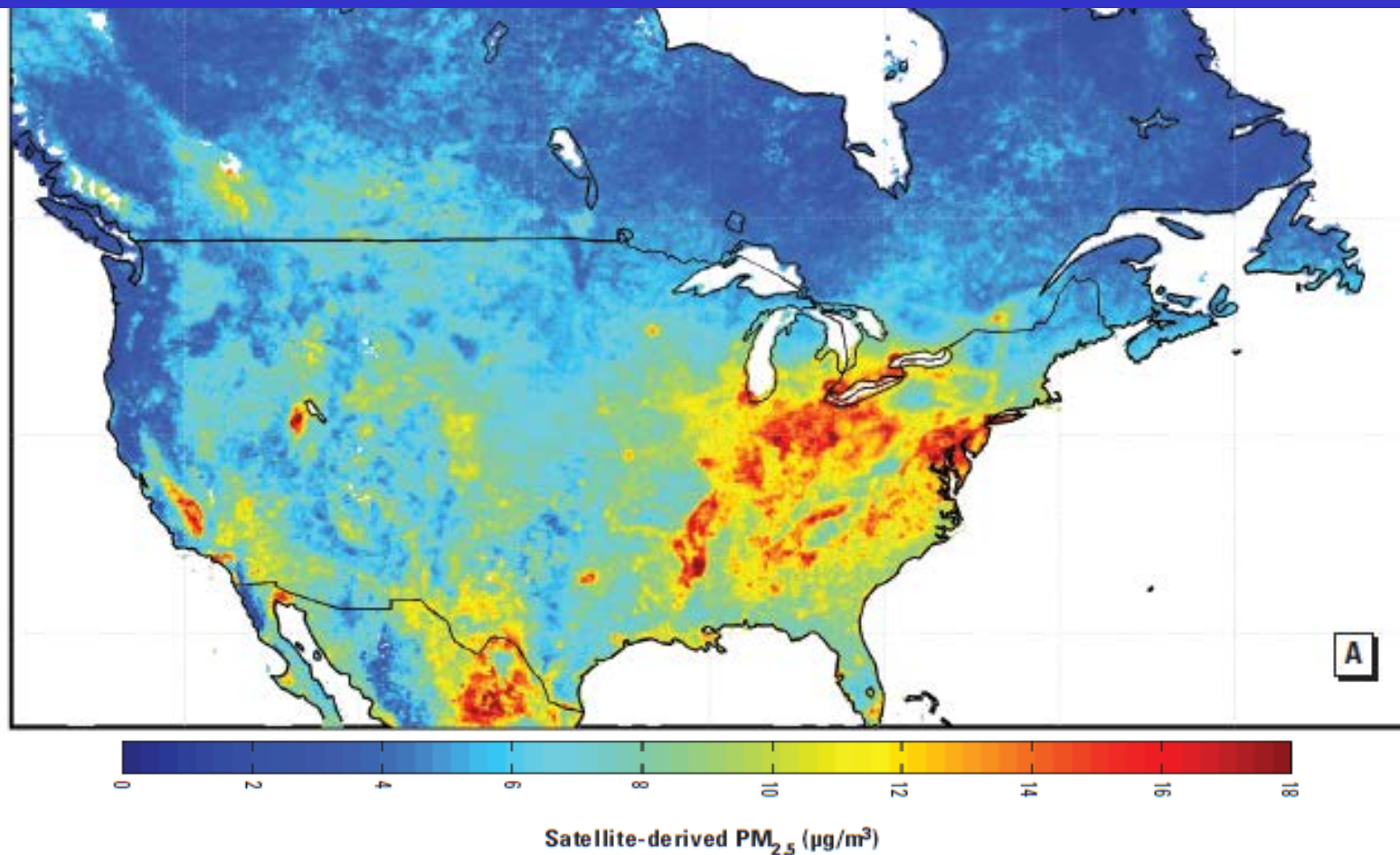
Source: EPA Report to Congress, publication 453/R-98-004a

Leading Causes of Death Due to Disease in Americans

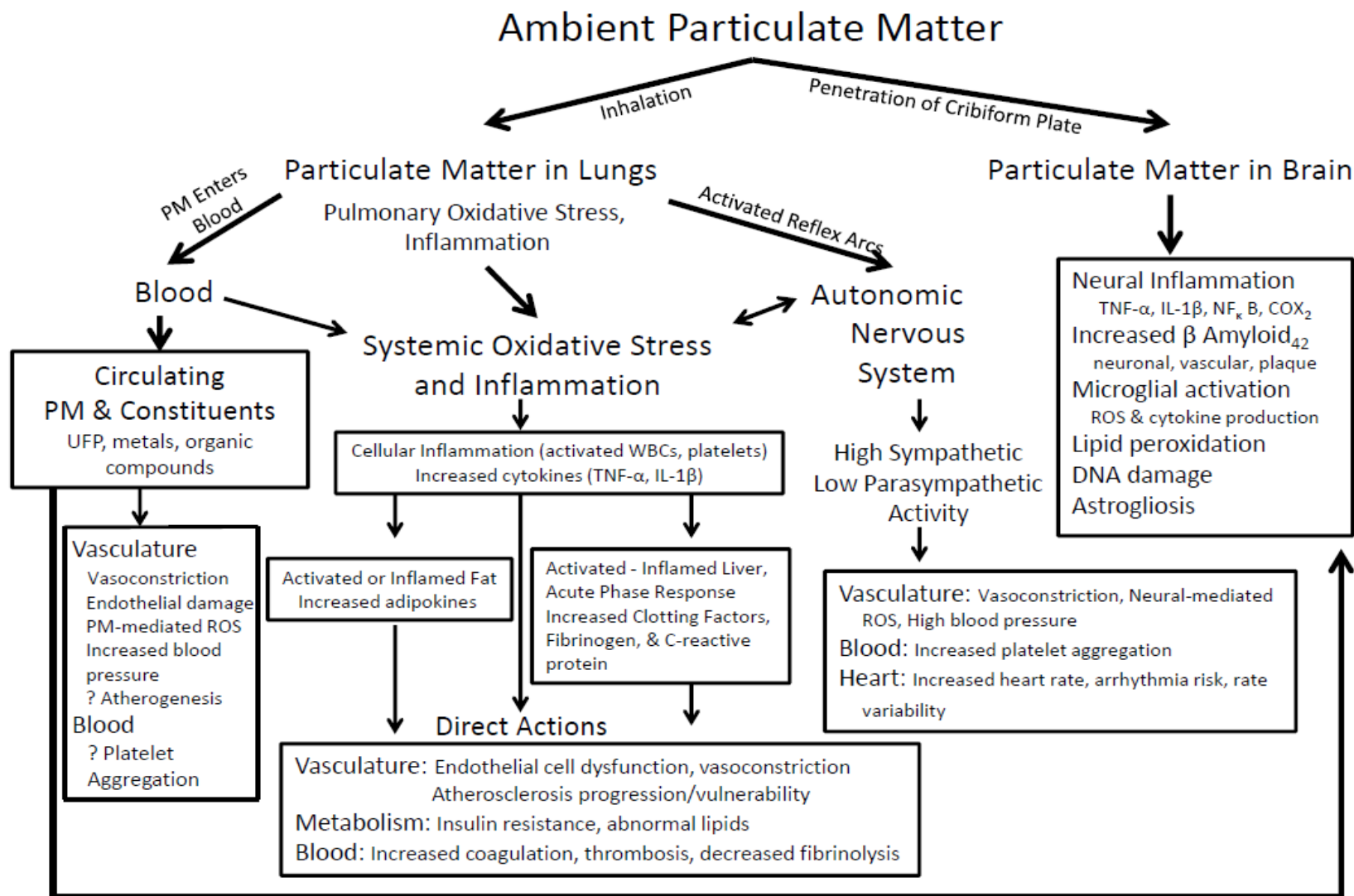
- **Heart Disease – leading cause in US – 611,103 in 2013**
 - Myocardial Infarct
 - Congestive Heart Failure
 - Fatal Arrhythmia
- **Malignant neoplasms – Second leading cause in US, 584,881 deaths in 2013**
- **Respiratory disease – third leading cause in US – 149,205 in 2013**
 - Asthma (esp. kids)
 - Emphysema
 - Bronchitis
 - Cancer
- **Stroke – Fourth leading cause in US, 128,978 deaths in 2008**

Source: CDC, 2015, 2013 data (most recently available)

Satellite Derived $\text{PM}_{2.5}$ Concentration 2001 - 2006



Source: van Donkellar et al., EHP 2010;118:847



Source: Lockwood, The Silent Epidemic, MIT Press 2012

PM and Cardiovascular Disease

- **Harvard 6 Cities Study:** 26% increase mortality in most *versus* least polluted cities
- **ACS Cancer Prevention Study:** each 10 $\mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$ associated with increases of 4% in all cause and 5% cardiopulmonary mortality
- **Other studies:** show increases in acute myocardial infarct, defibrillator discharges, myocardial ischemia during stress test

Sources: Dockery, et al NEJM 1993;329, 1753-1759, Pope, et al Am J Resp Crit Care Med 1995;151(part 1);669-674, Brook, et al Circulation 2004;109:2655-2671

Air Pollution and Stroke

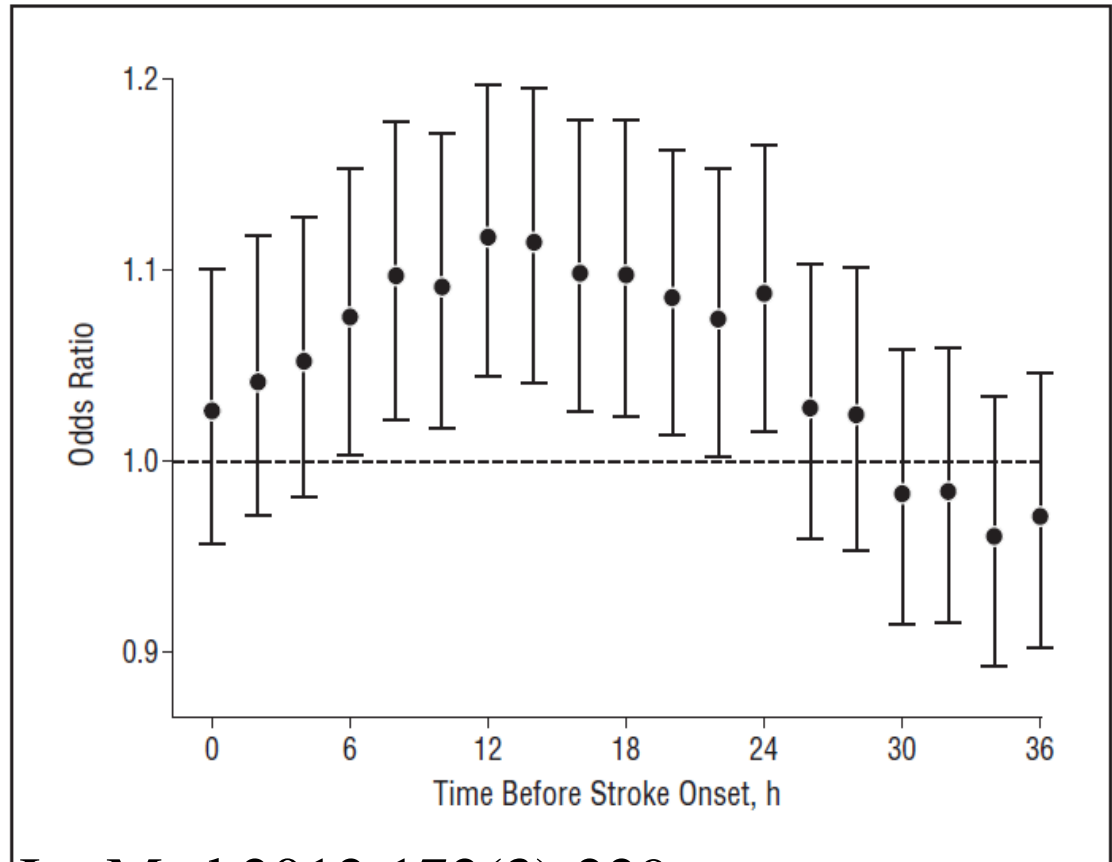
- **Korean Study:** increased ischemic stroke risk with daily increases in suspended particulates and sulfur dioxide, one day lag nitrogen dioxide, and carbon monoxide, and 3 day lag for ozone
- **Taiwan study:** on warm days (≥ 20 C) positive association between PM₁₀, NO₂, SO₂, CO, and O₃ for cerebral hemorrhage and ischemic stroke admissions
- **Women's Health Initiative:** an increase of 10 $\mu\text{g}/\text{m}^3$ in the PM_{2.5} concentration was associated with a 24% increase in the risk for a cardiovascular event and an increased risk for a cerebrovascular event

Sources: Hong et al Stroke 2002, Tsai et al Stroke 2003, Miller, et al, NEJM, 2007

Stroke and PM_{2.5}

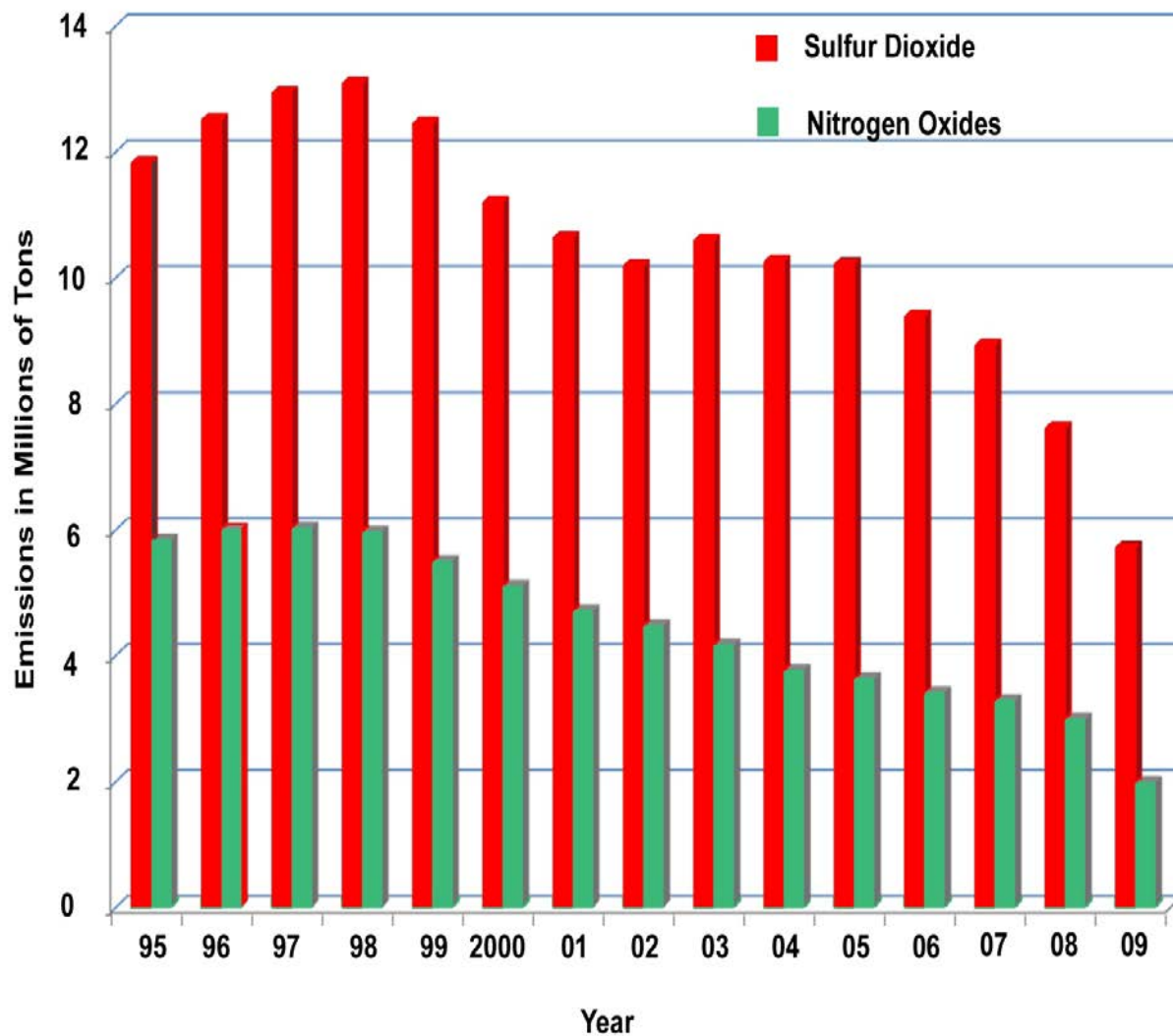
Increase in odds
ratio for stroke
comparing 25th with
75th percentile
increase (6.4 $\mu\text{g}/\text{m}^3$)

$P = 0.001$



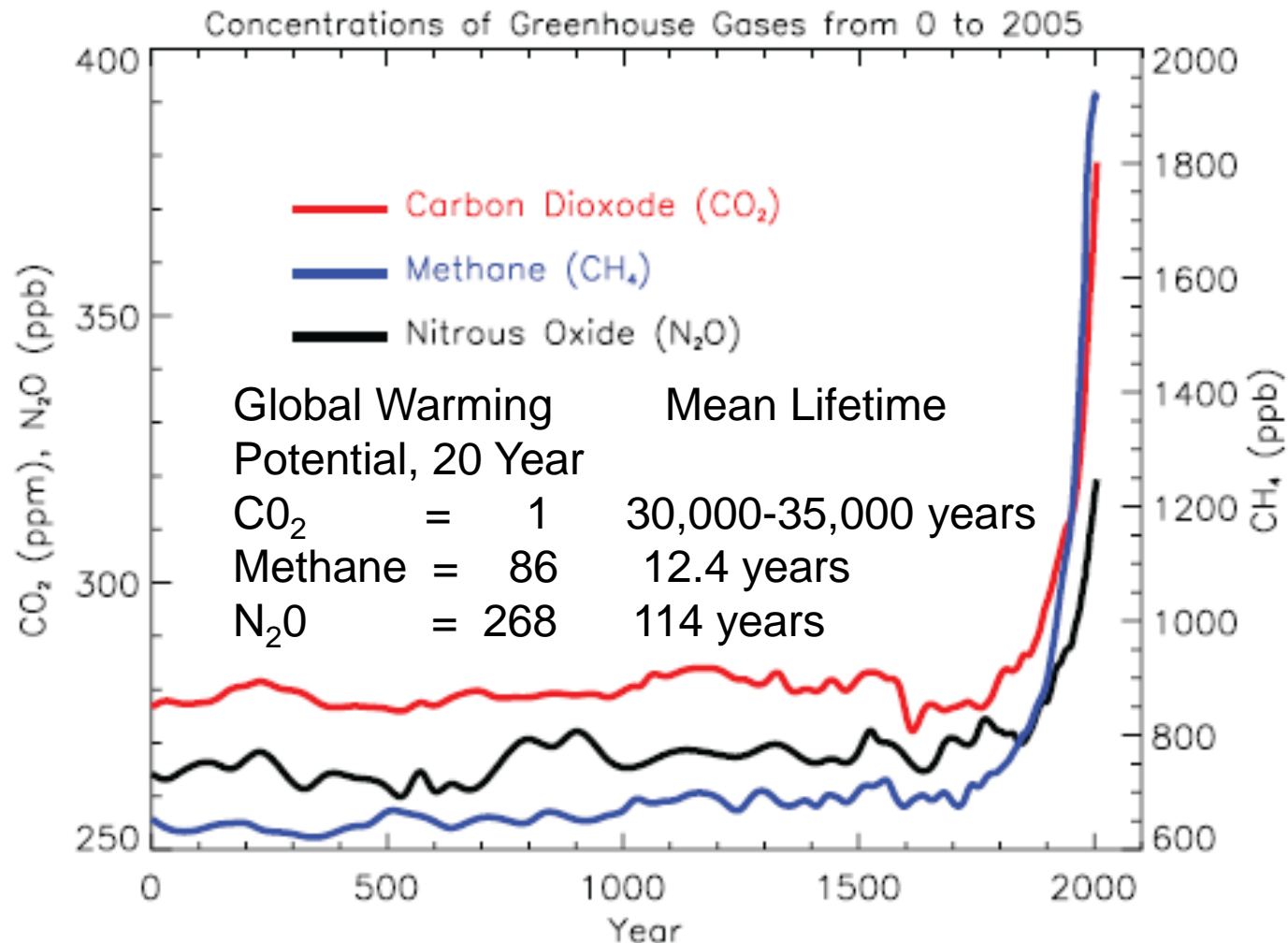
Source: Wellenius Arch Int Med 2012;172(3):229

Sulfur Dioxide and Nitrogen Oxides Emissions Under Clean Air Act, Acid Rain Program



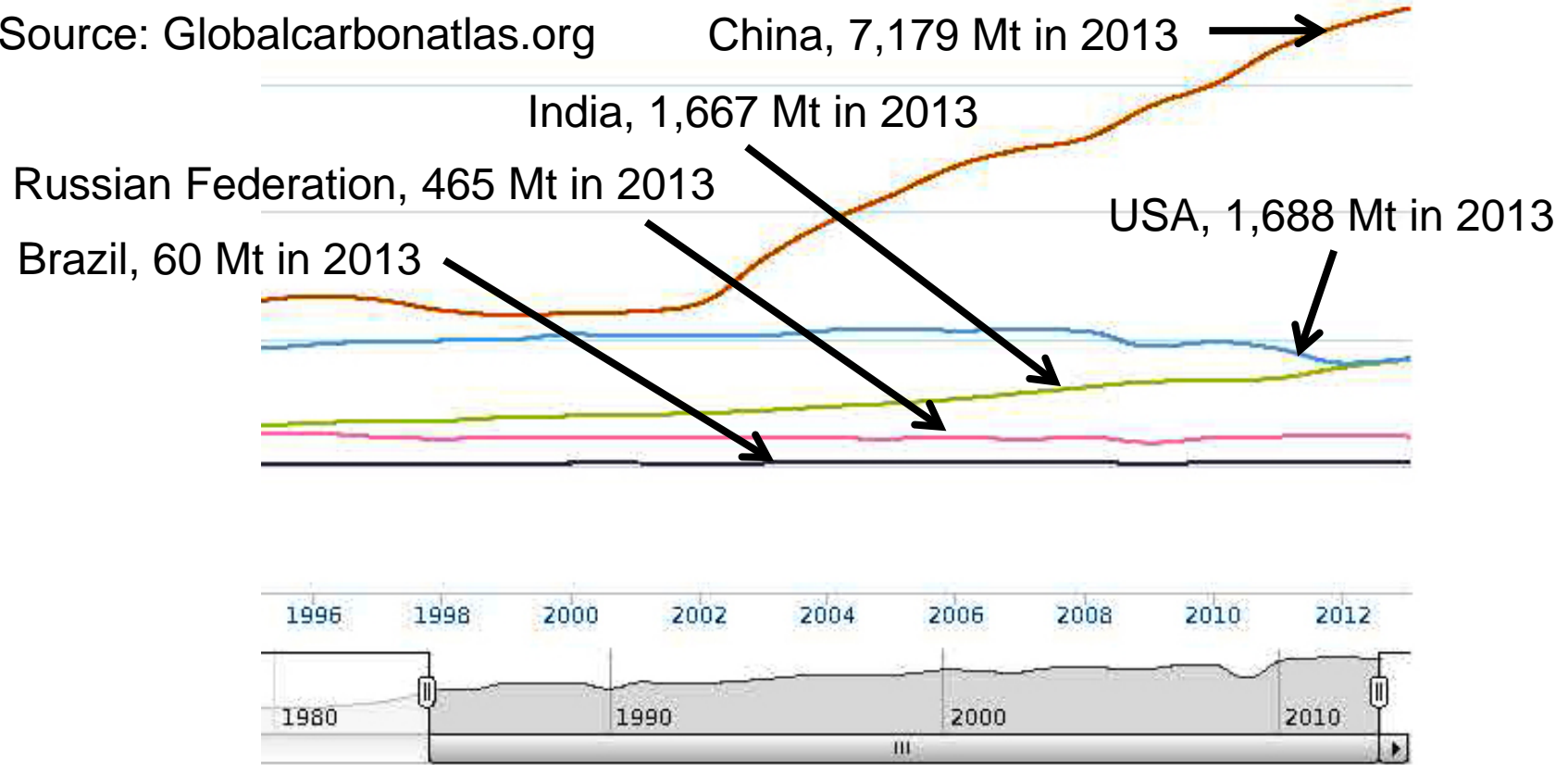
Source:
US EPA

Greenhouse Gases, 0 - 2005



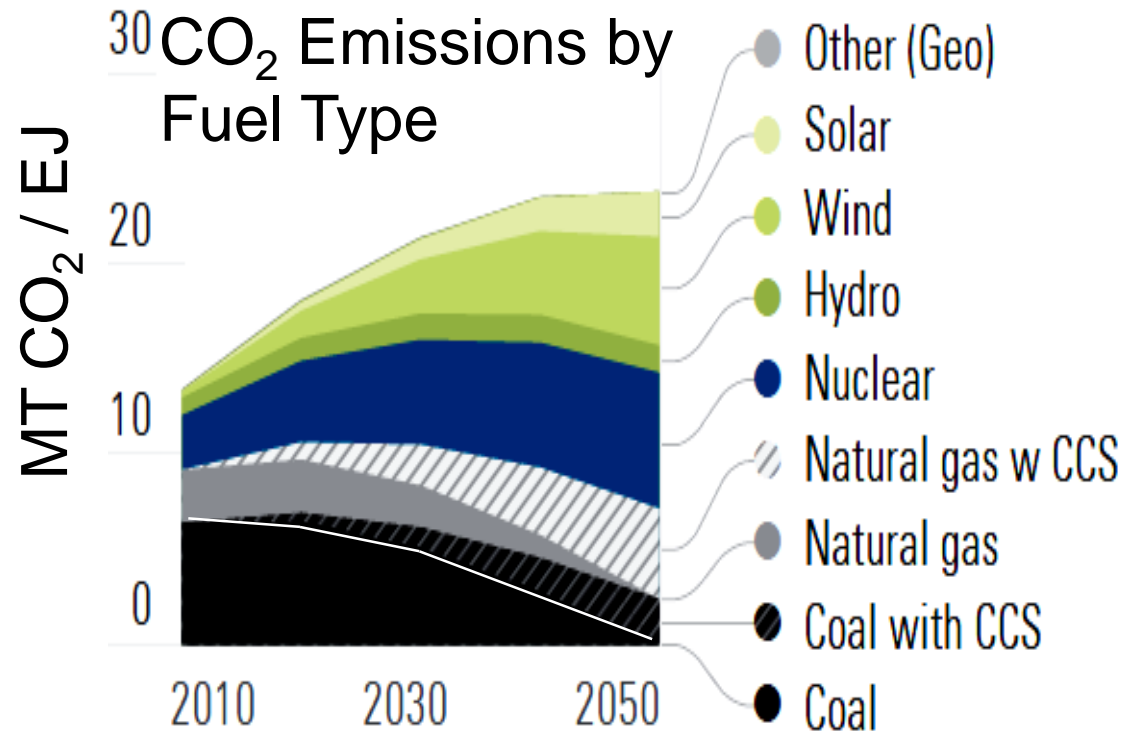
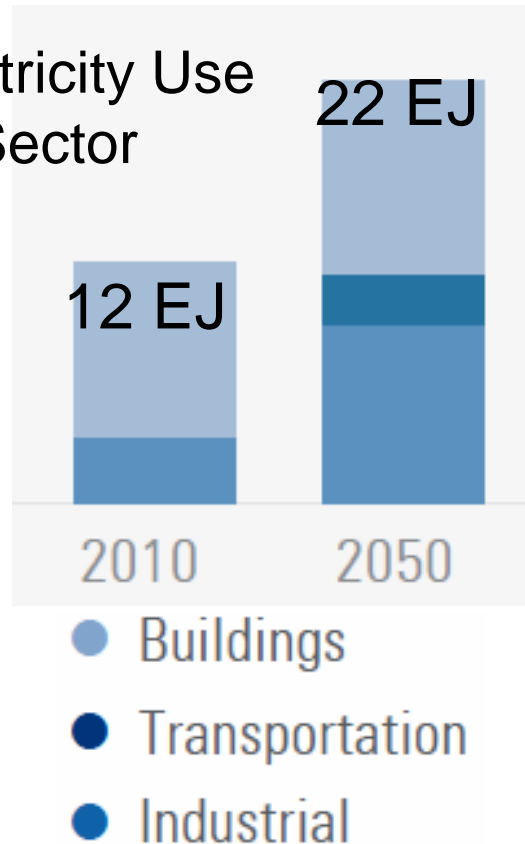
CO₂ Emissions From Coal: 1995-2013 From Over 36 Trillion Total tons/year

Source: Globalcarbonatlas.org



US Path to Deep Decarbonization

Electricity Use
By Sector

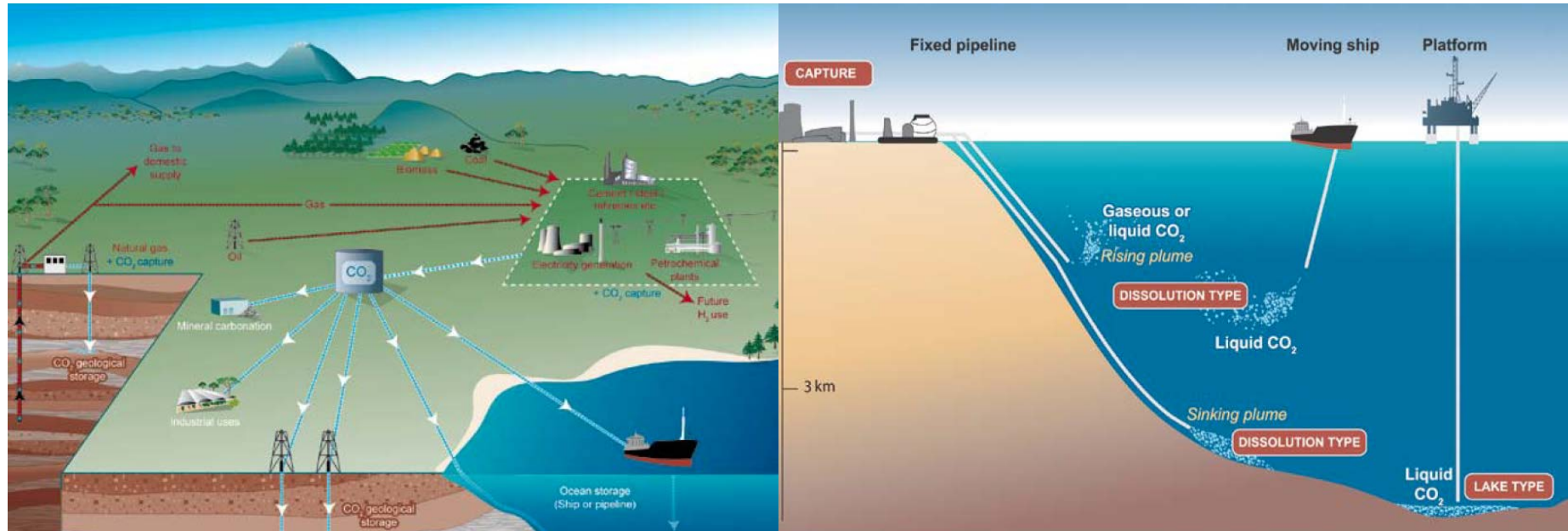


Source: Institute for Sustainable Development
and International Relations

1 EJ = 10^{18} J

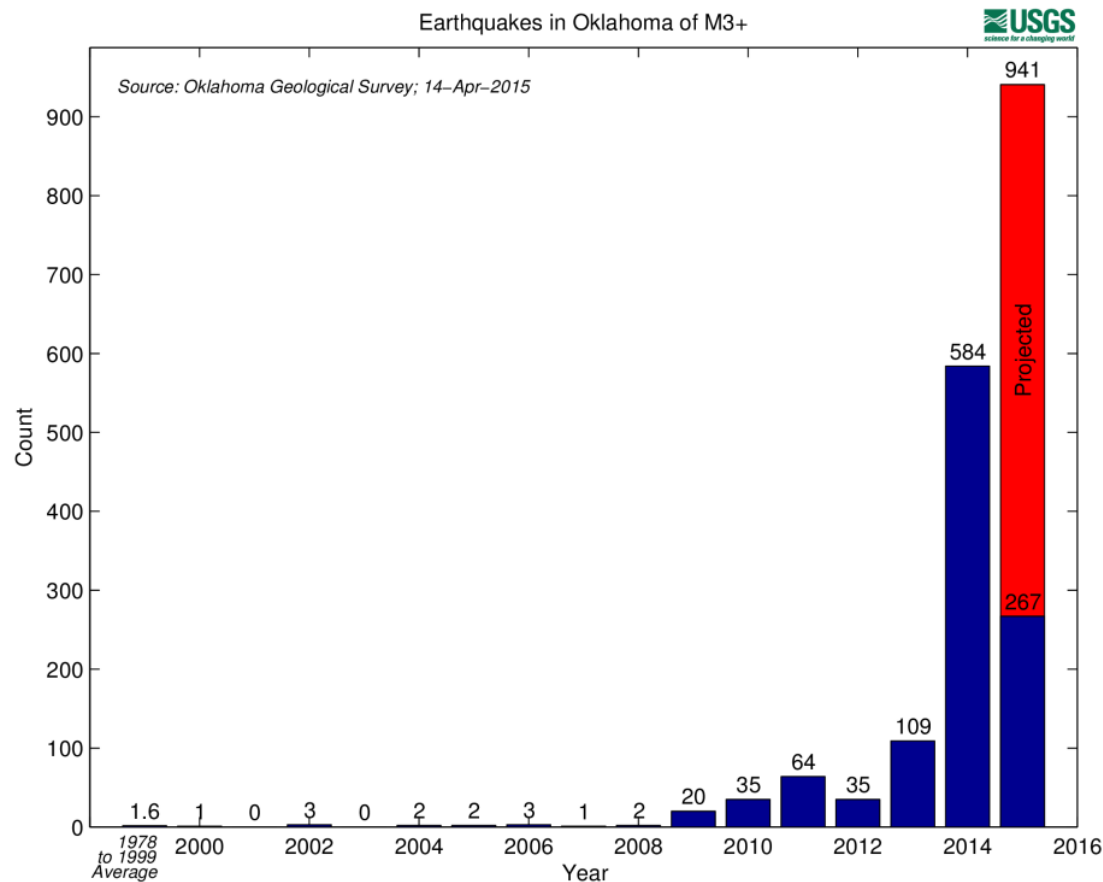
EJ = Exajoule

Carbon Capture and Storage



Source: IPCC CCS Report, 2005

Oklahoma Earthquakes Magnitude 3.0 or Greater



Elements of Carbon Capture and Storage

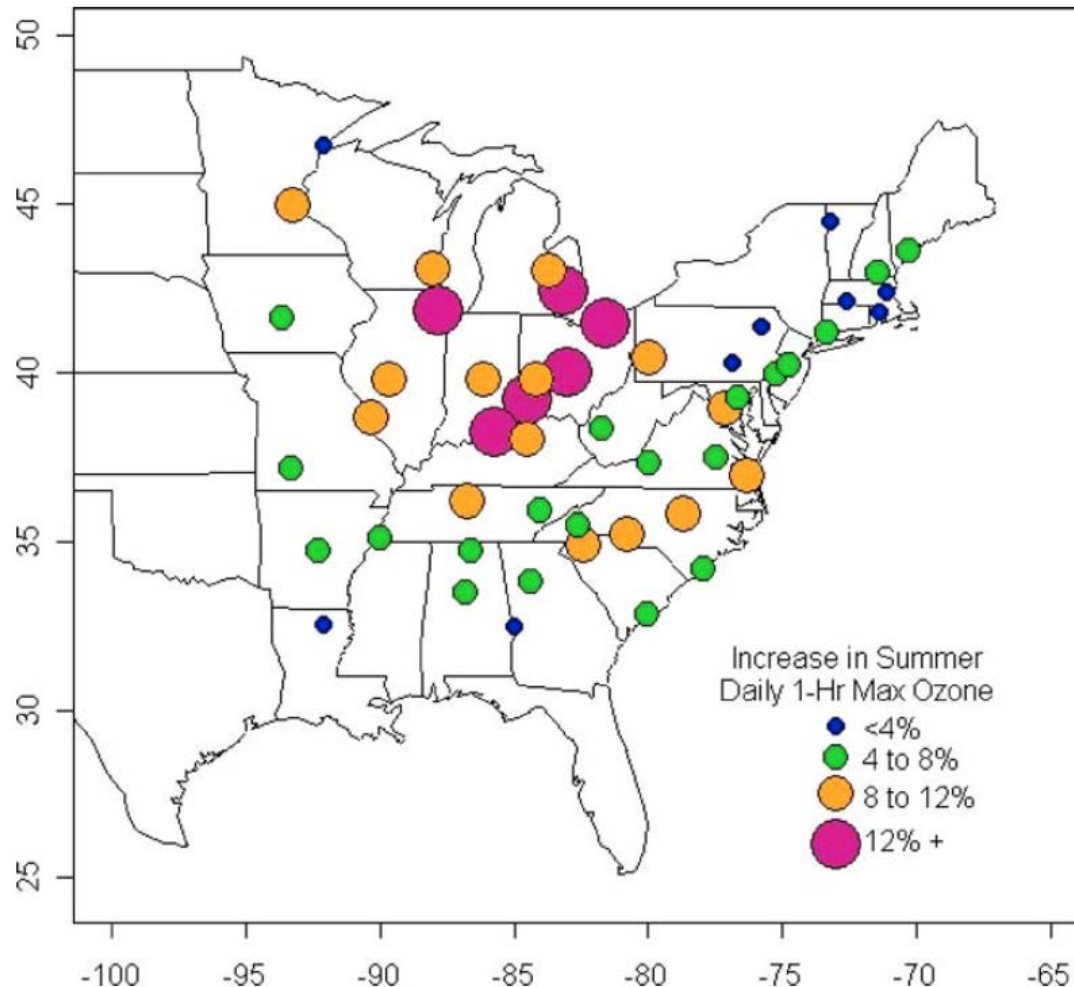
- Production of waste stream with high carbon dioxide percentage (**Capture**)
- Compression and liquification of carbon dioxide
- Transport to disposal site: pipeline
- Disposal in perpetuity (**Storage**)

Carbon Capture and Storage: Must deal with 35+ trillion tons per year

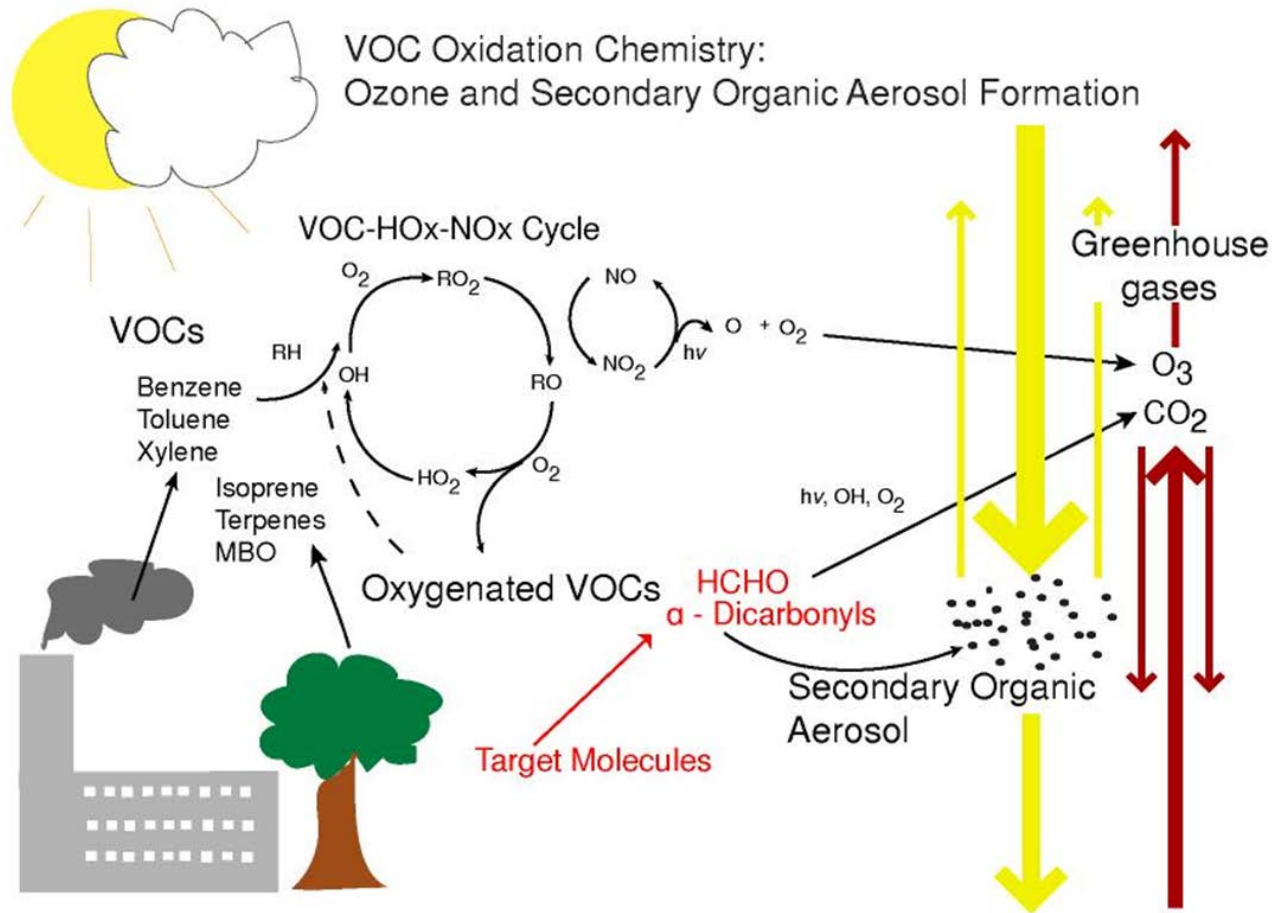
- **Still in experimental stage**
- **Energy intense process**
- **Requires huge new infrastructure**
 - **Modify or construct new generating units**
 - **New pipelines**
- **Unproven long-term storage strategies**
- **Will not be 100% efficient: less may not be enough to prevent climate change**

Increase in Daily Summer 1-h Maximum Ozone: 1990s-2050

Source: Bell et al
Climatic Change
2007;82:61-76



Tropospheric Ozone Formation

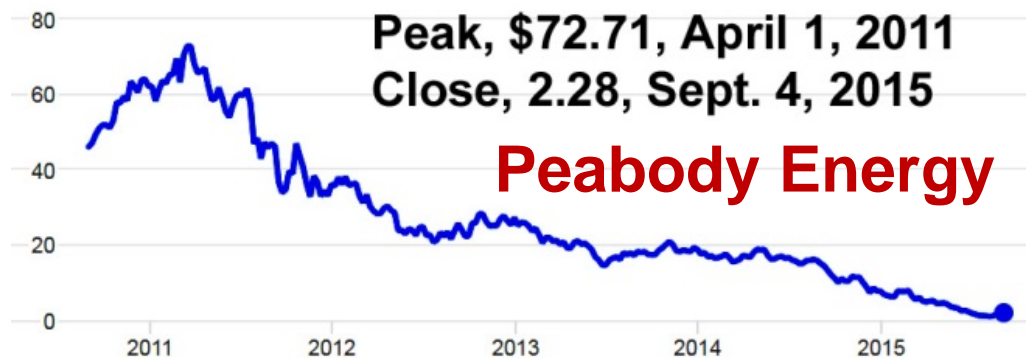
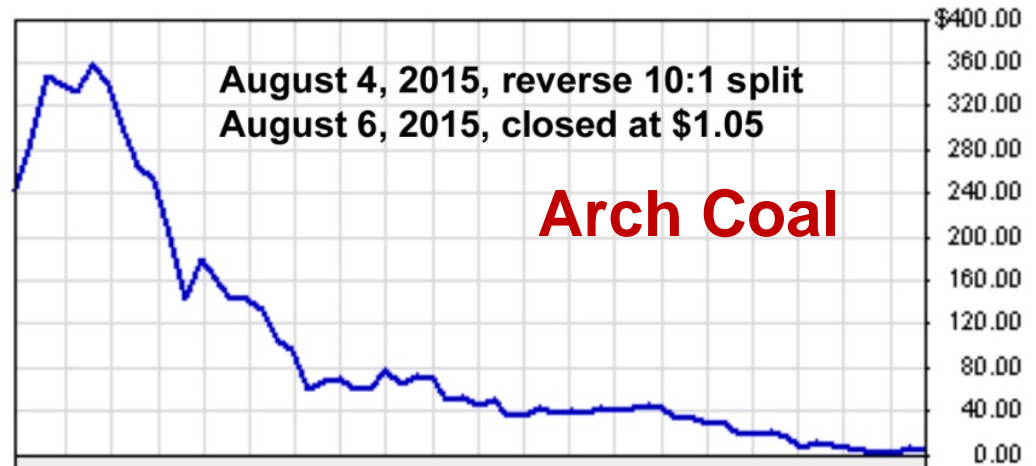


Wall Street and Coal

Whose War Is It?

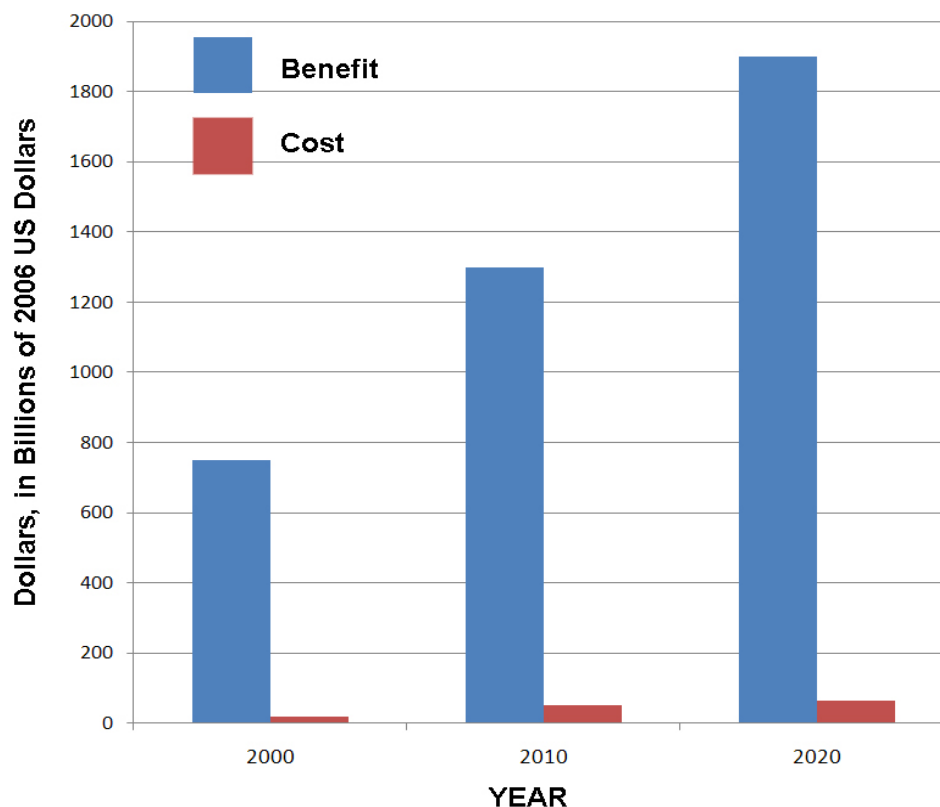
Alpha Natural Resources (bought Massey for \$7.1 billion 4 years ago), Walter Energy, Patriot Coal, many smaller companies, all have filed for bankruptcy.

But, domestic coal consumption rose by 4% between 2012 and 2015.



Costs *versus* Benefits, Clean Air Act

Source:
US EPA

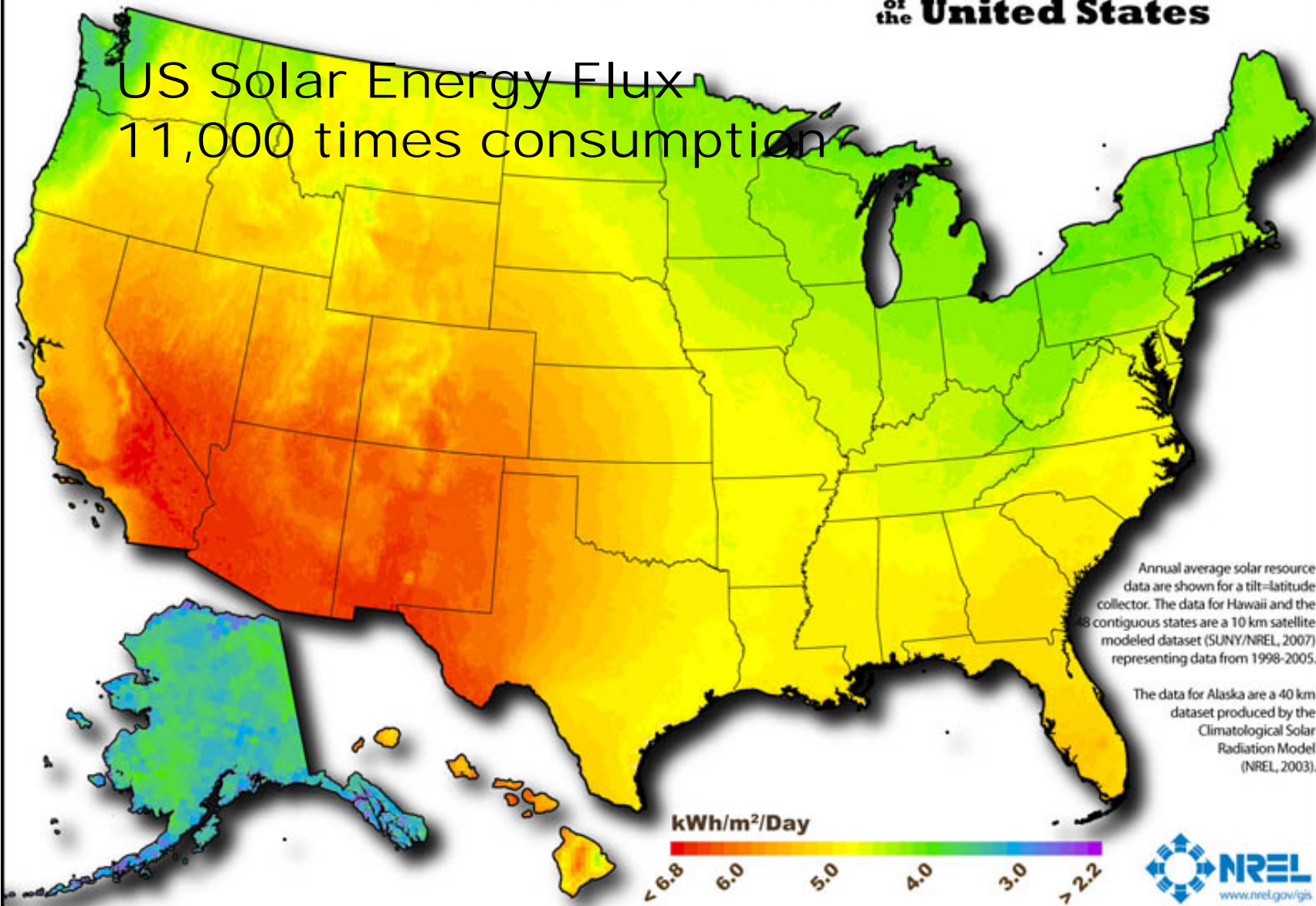


Sustainable Energy Future

- **Improve efficiency**
- **Use more renewables**
- **More Wind Energy**
- **More solar**
 - Photovoltaic
 - Sun-powered boilers
 - Now-experimental
 - Artificial photosynthesis
 - Hydrolysis to generate hydrogen
- **Federal support for R&D and Education**

Photovoltaic Solar Resource of the United States

US Solar Energy Flux
11,000 times consumption

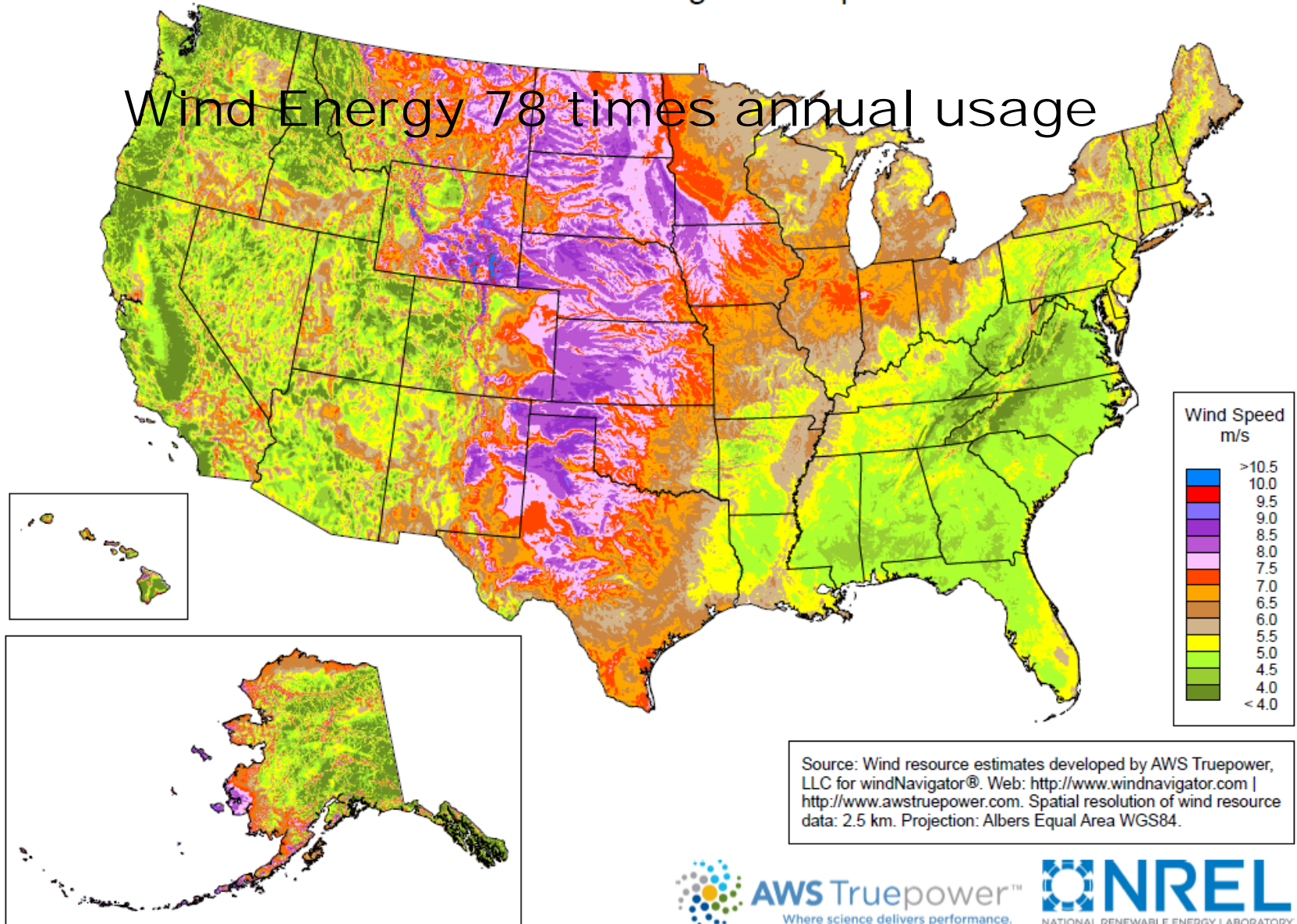


Author: Billy Roberts - October 20, 2008

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.

United States - Annual Average Wind Speed at 80 m

Wind Energy 78 times annual usage



AWS Truepower™
Where science delivers performance.



NREL
NATIONAL RENEWABLE ENERGY LABORATORY

01.APRIL.2011 2:11



University at Buffalo
The State University of New York

PSR®



**Physicians
for Social
Responsibility**

Photocatalytic Splitting of H₂O

- Catalysts added to cell
- Illuminated by artificial sunlight
- Bubbles: oxygen, front of cell; hydrogen, back of cell
- Reference: Concepcion, et al, Chemical approaches to artificial photosynthesis, PNAS, Sept 25, 2012, 109:15560-15564



R Valentine, Wikipedia

Everyone Can Do Something It's Your Professional Responsibility

- Ask your candidates if they support EPA's current clean air and carbon dioxide emission standards.
- Speak to your friends, family, and colleagues about the importance of clean air and protecting our health.
- Join Physicians for Social Responsibility
go to: www.psr.org

Here is Some of What We Do, Thanks!



Lockwood home, Buffalo, NY, 4,400 Watt PV Array



**We replace
CFLs With
LEDs**