Low-Carbon Energy

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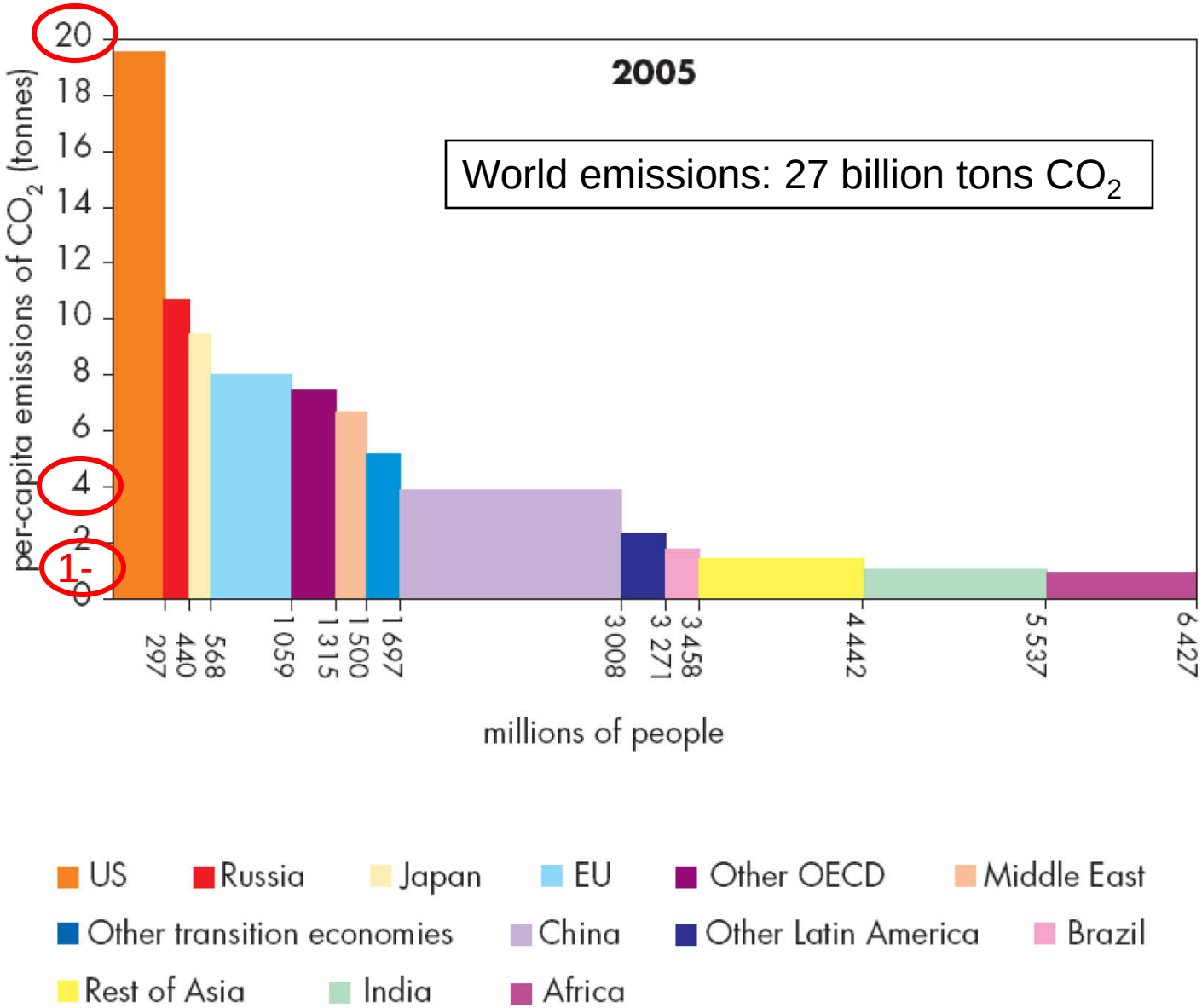
Summit on America's Climate Choices:

Developing the Framework
for a National Response to Climate Change

Keynote Perspectives on Climate Change

March 30, 2009

Per-capita fossil-fuel CO_2 emissions, 2005



Source: IEA WEO 2007

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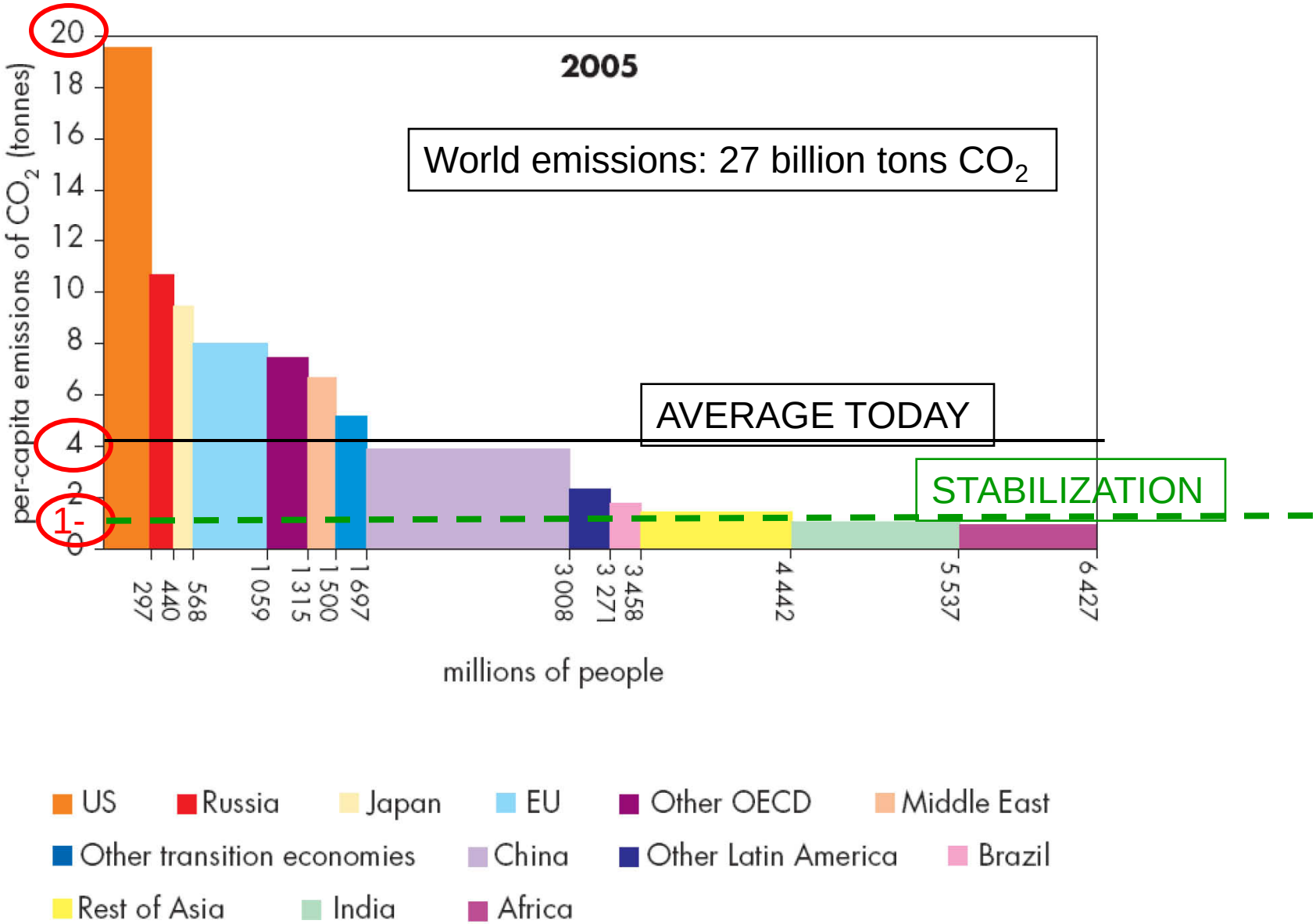


Source: IEA WEO 2007

“Stabilization”: 1 ton CO_2/yr per capita

It is *not* sufficient to limit emissions in the prosperous parts of the world and allow the less fortunate to catch up. Such an outcome would overwhelm the planet.

The emissions of the future rich must eventually equal the emissions of today’s poor, …

…not the other way around.

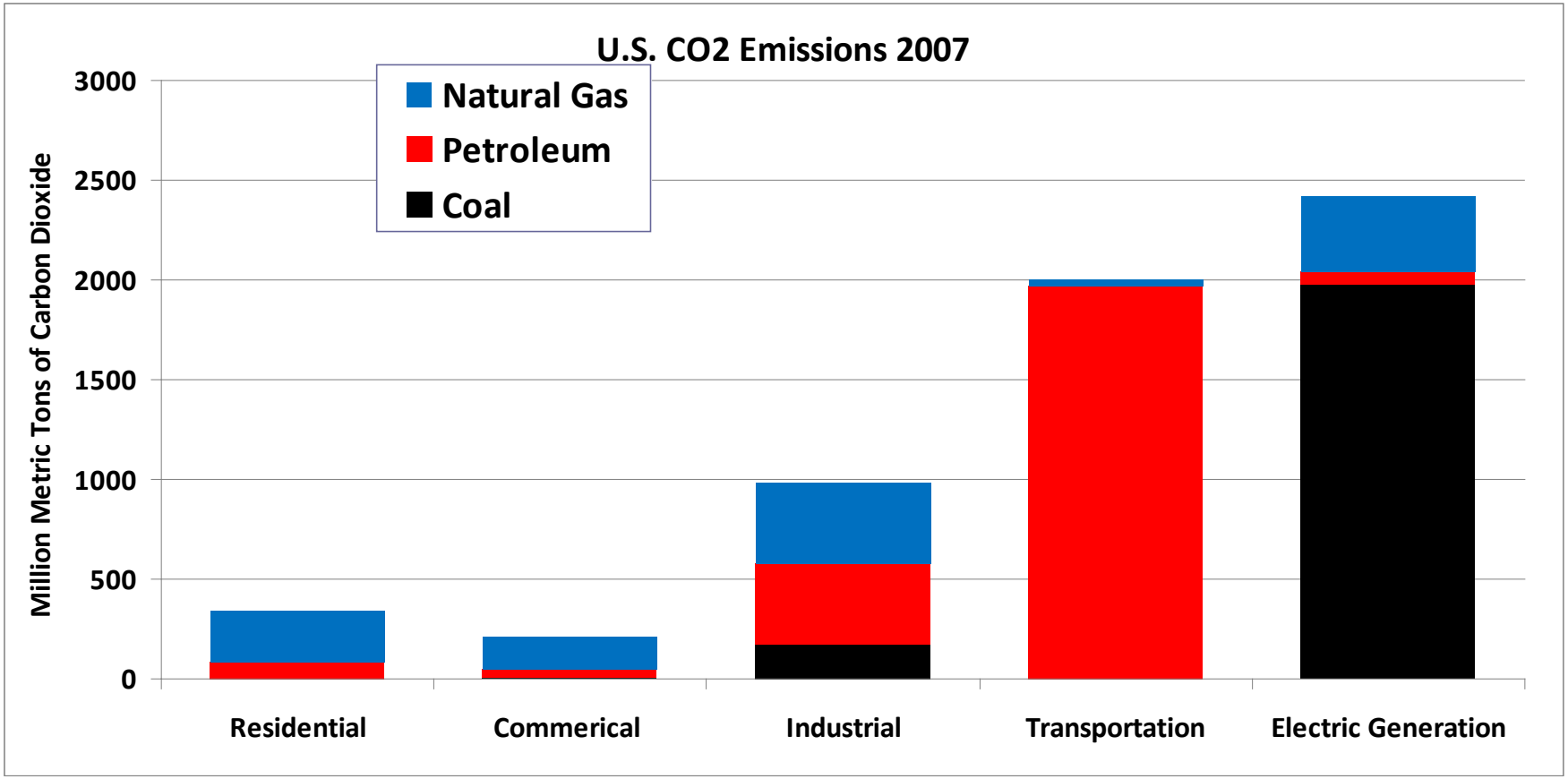
Four ways to emit 4 tons CO_2/yr (today's global per-capita average)

Activity	**Amount producing 4 ton CO_2/yr emissions**
a) Drive	10,000 miles/yr, 30 miles per gallon
b) Fly	10,000 miles/yr
c) Heat home	Natural gas, average house, average climate
d) Lights	300 kWh/month when all coal-power (600 kWh/month, natural-gas-power)

Grounds for optimism

- The world today has a terribly inefficient energy system.
- Carbon emissions have just begun to be priced.
- Most of the 2059 physical plant is not yet built.

U.S. Fossil-fuel CO_2 emissions

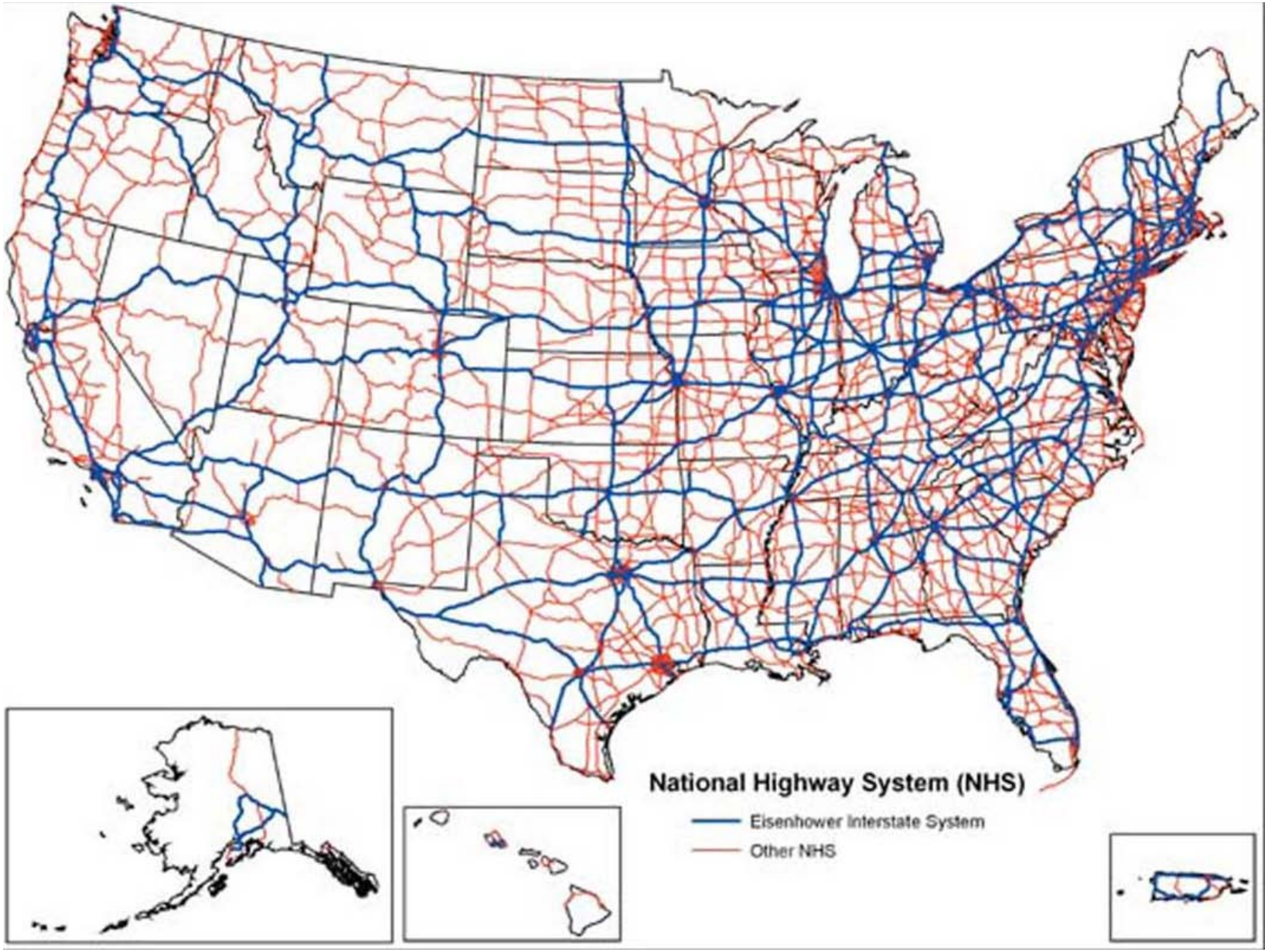


U.S. total emissions: 6.0 billion tons CO_2

Source: J. Sweeney, 2009

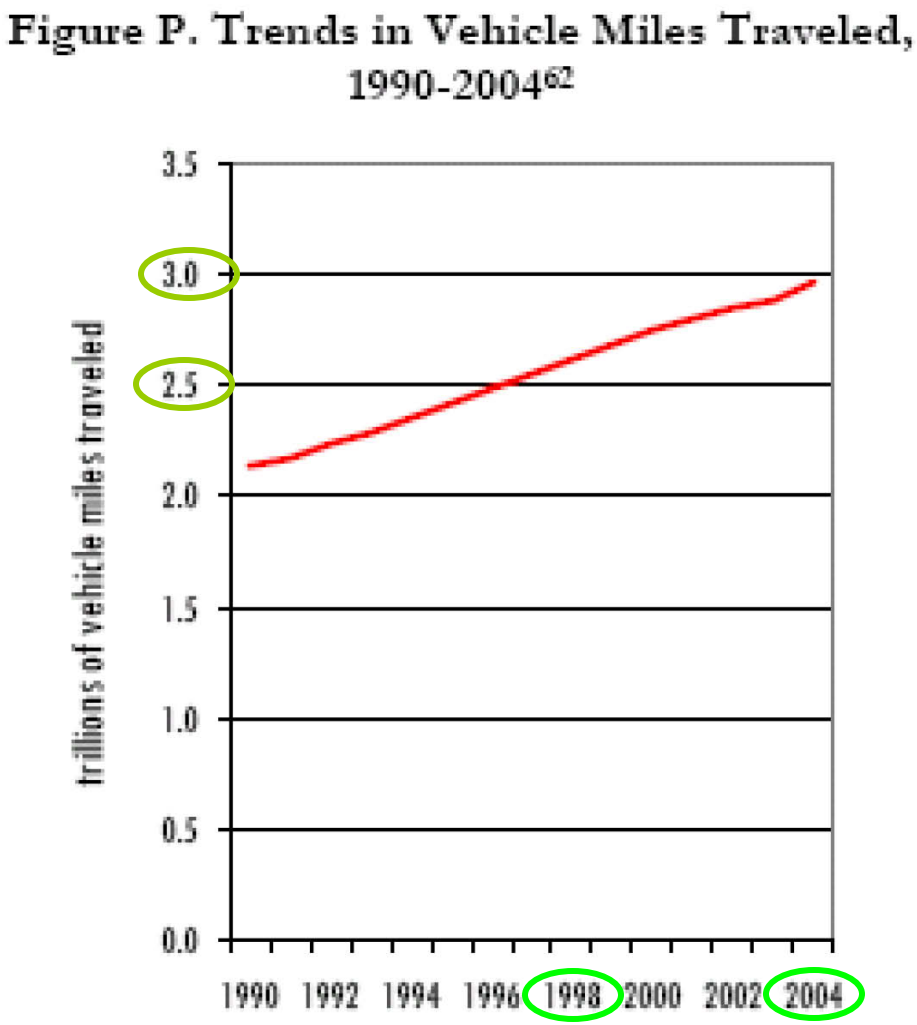
Energy Efficiency:
Our most salient option

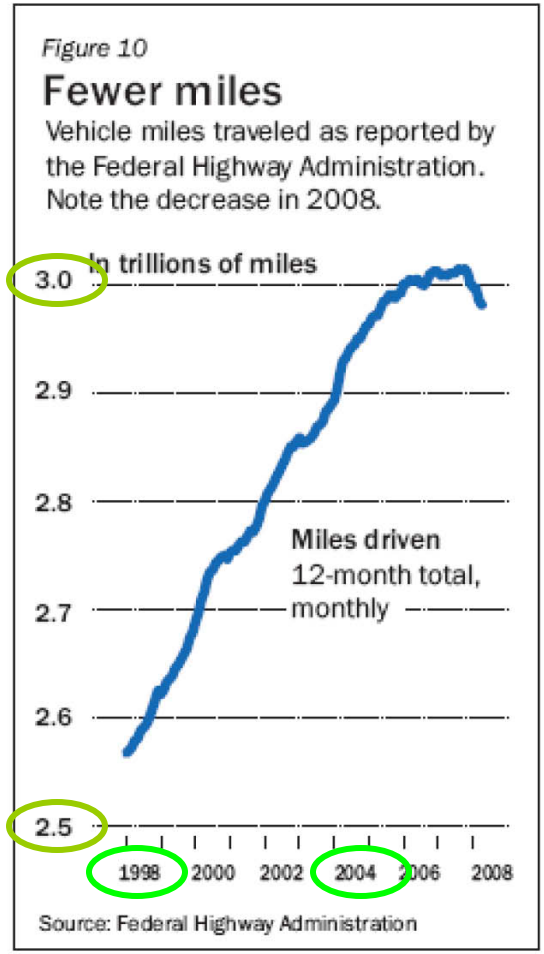
Legacy: National Highway System



Efficient Use of Fuel

U.S. vehicle-miles traveled, two views

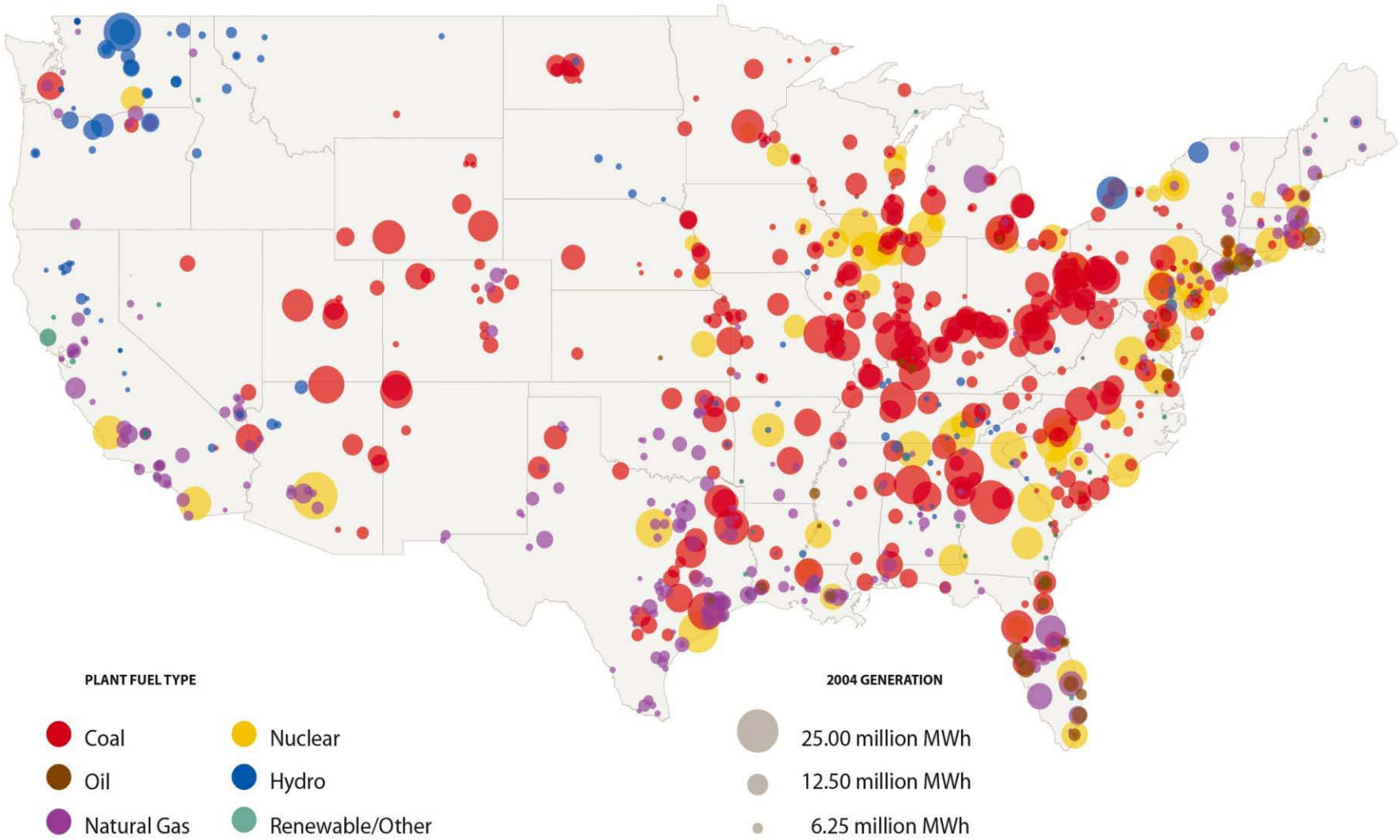




The New York Times (used with permission)

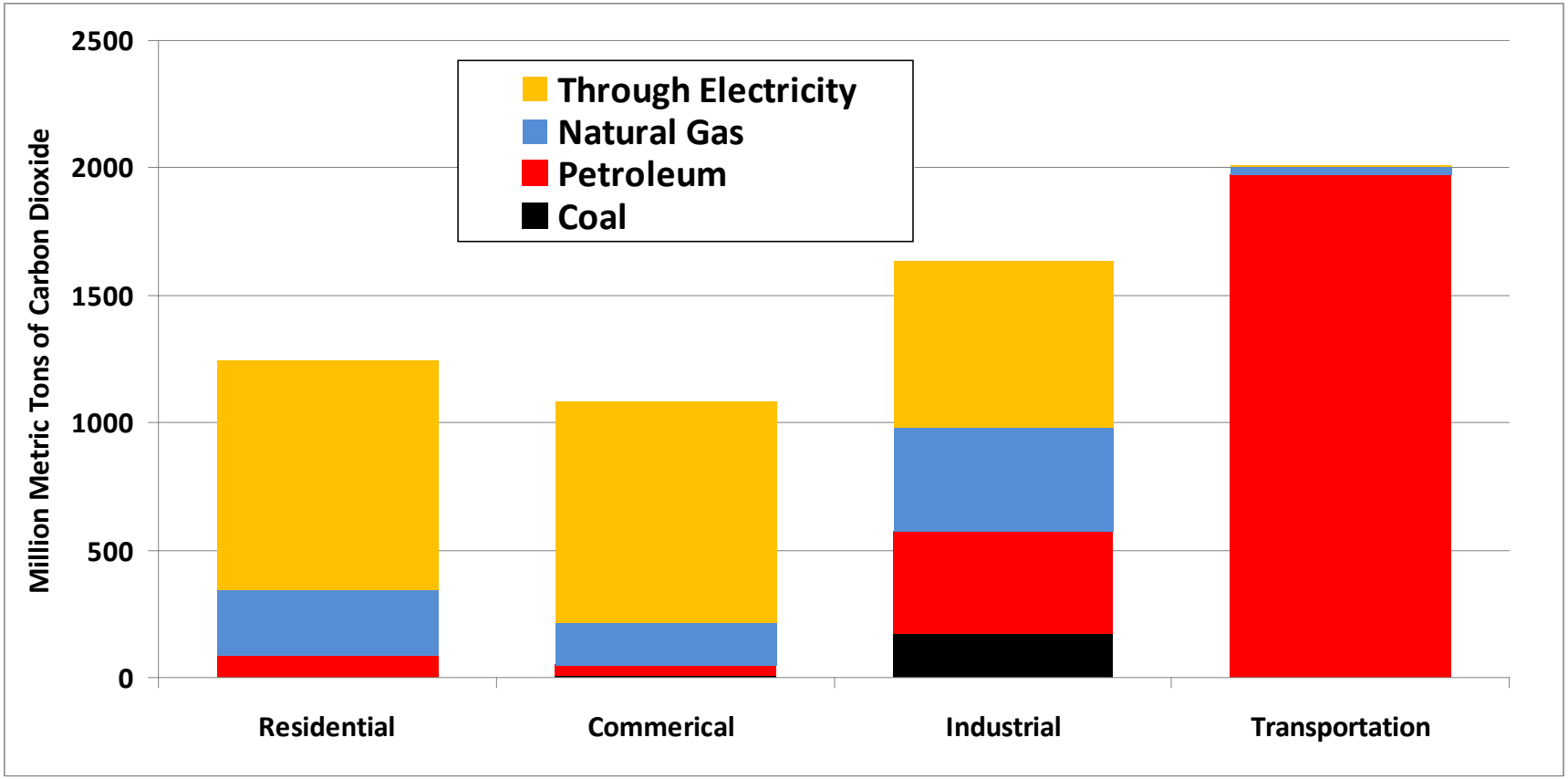
Sources: *Left*: U.S. PIRG Education Fund, 2007. *The Carbon Boom: State and National Trends in Carbon Dioxide Emissions Since 1990, April 2007* (44 pp.), p. 27. *Right*: American Physical Society, 2008. *Energy Future: Think Efficiency.*

Legacy: U.S. Power Plants



Source: *Benchmarking Air Emissions*, April 2006. The report was co-sponsored by CERES, NRDC and PSEG.

At the power plant, CO_2 heads for the sky, most electrons head for buildings!



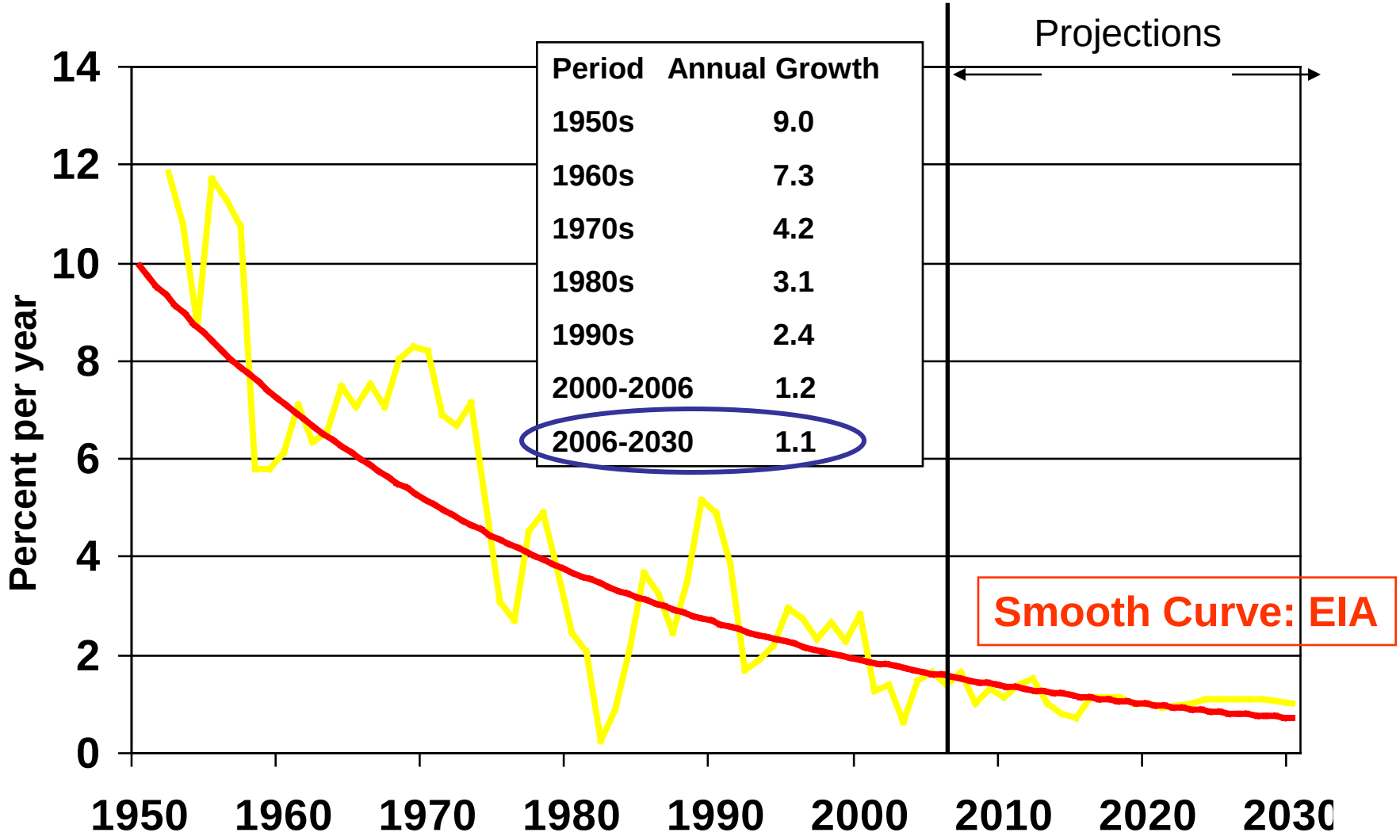
U.S. CO2 emissions, 2007, electricity allocated. *Source*: J. Sweeney, 2009.

Efficient Use of Electricity

Measure, measure, measure!

U.S. Electricity Growth Continues to Slow

(3-year rolling average percent growth)



Period	Annual Growth
1950s	9.0
1960s	7.3
1970s	4.2
1980s	3.1
1990s	2.4
2000-2006	1.2
2006-2030	1.1

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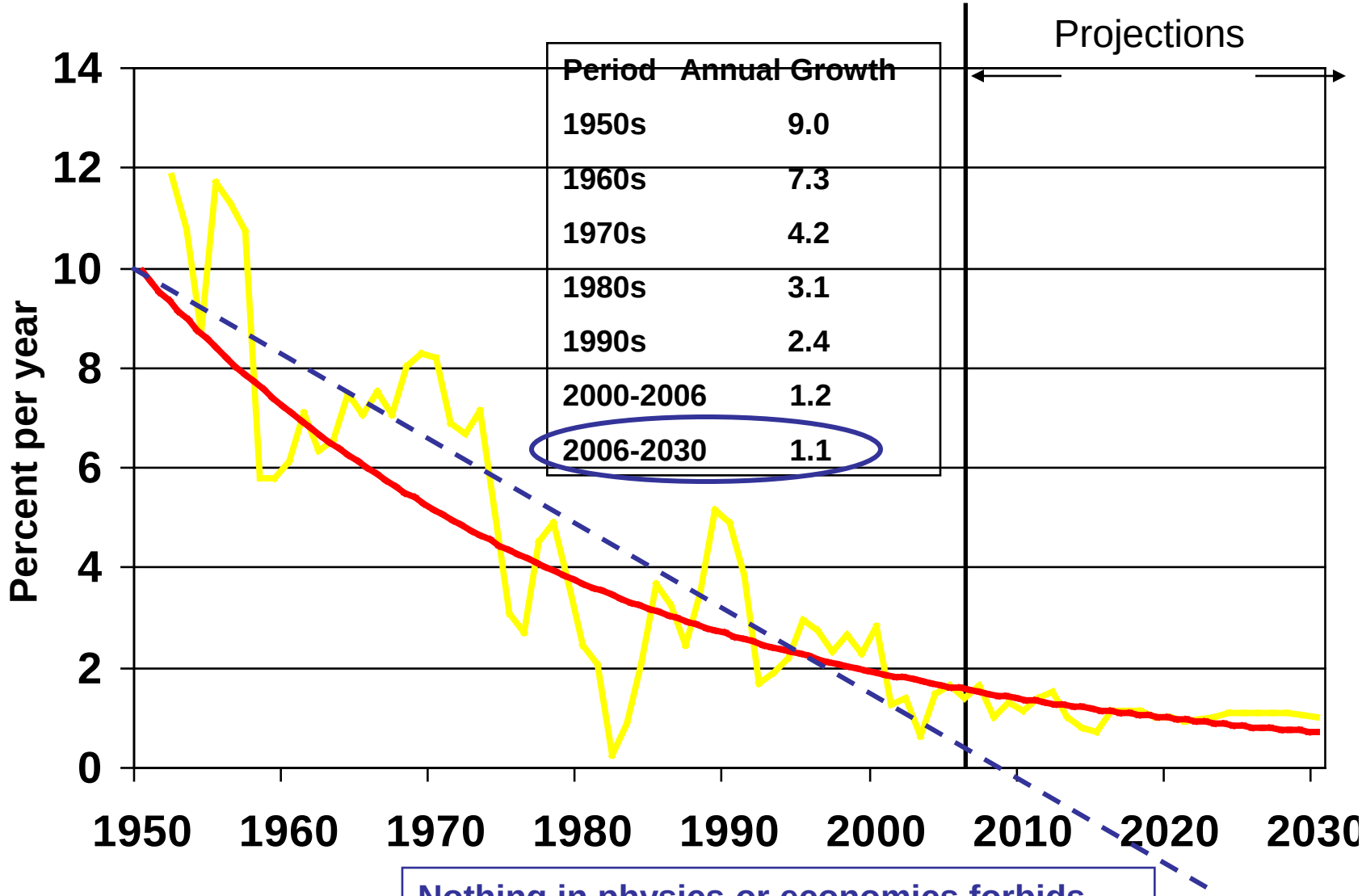

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Nothing in physics or economics forbids negative values! Blue dashed line: RHS.

Is peak energy demand behind us?

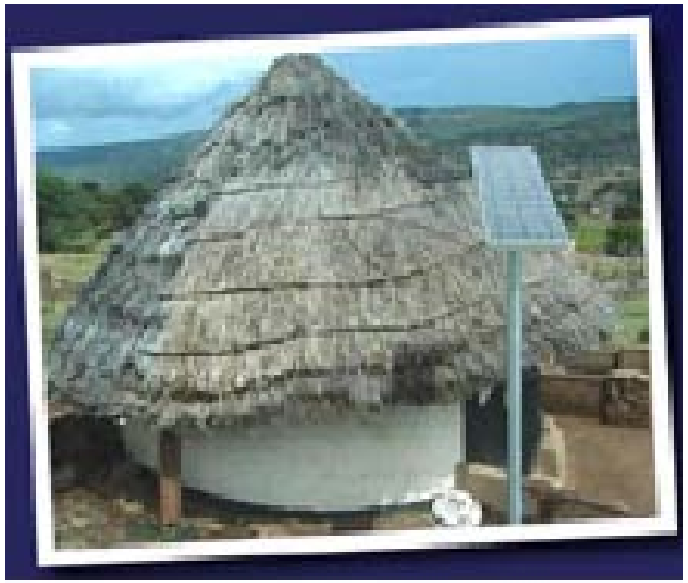
If the U.S. takes efficiency seriously, annual consumption from now on could be less than in any past year – for both:

- U.S. oil consumption
- U.S. electric power consumption

This could be a goal of the U.S. Economic Recovery and Reinvestment Plan.

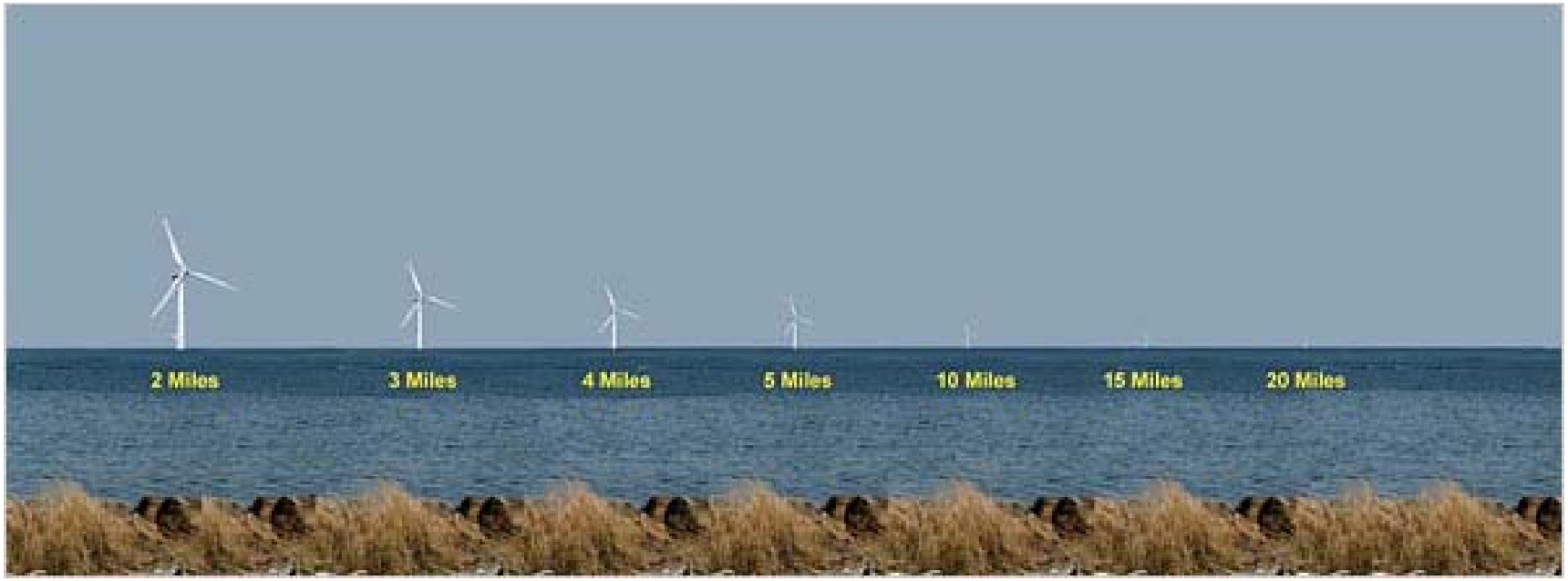
Low-carbon Electricity Supply
An abundance of alternatives

Photovoltaic Power



Graphics courtesy of DOE Photovoltaics Program

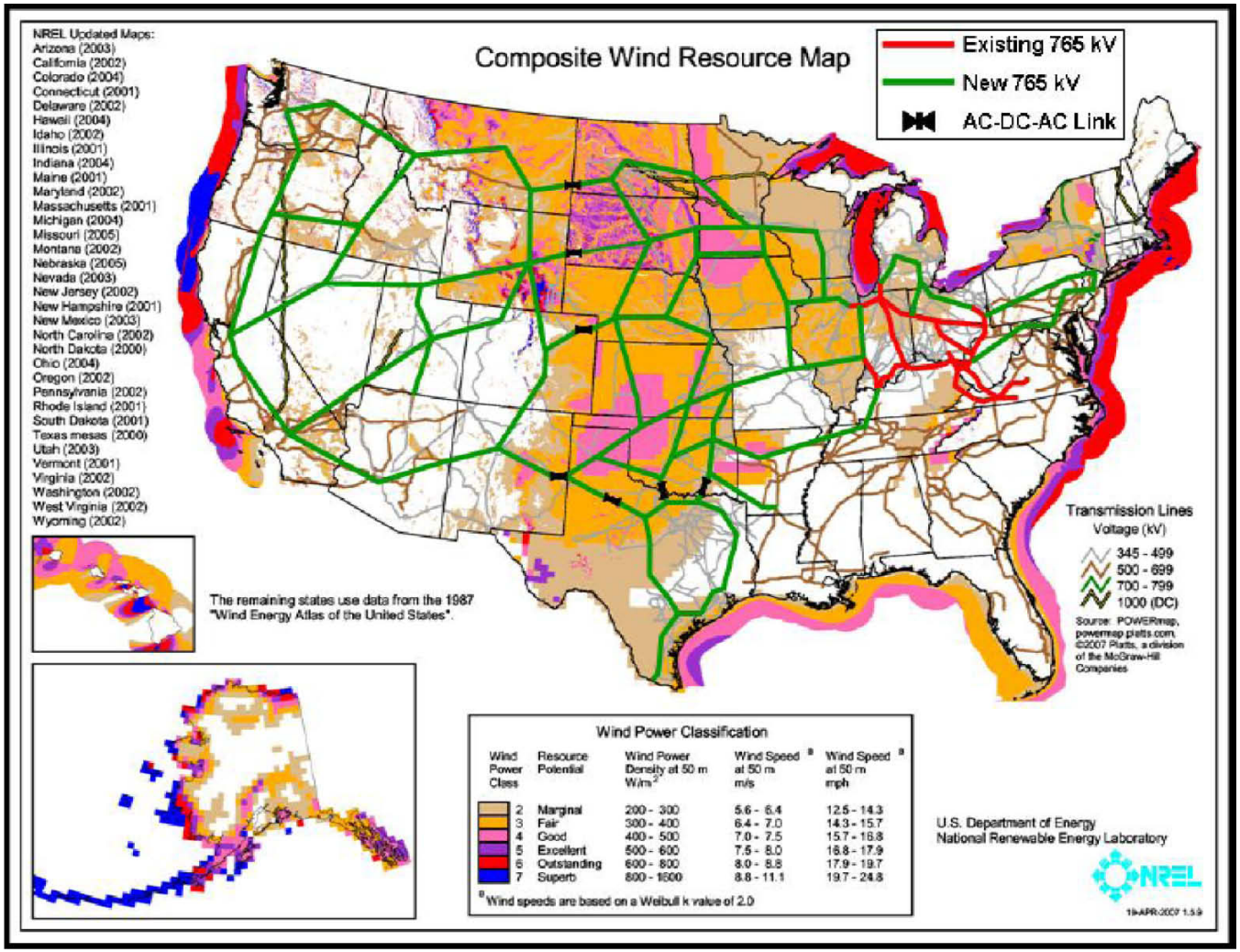
Wind Farms – Out of Sight



Offshore New Jersey: 96 turbines, 346 MW, ½ by 1/3 mile rectangle, 16 to 20 miles from coast. 1 billion dollar project. Power "starting in 2013."

Source: http://www.nytimes.com/2008/10/04/nyregion/04wind.html?ref=nyregion, *New York Times*, October 3, 2008.

765 kV backbone for 350 GW wind



19,000 miles of new 765 kV line.

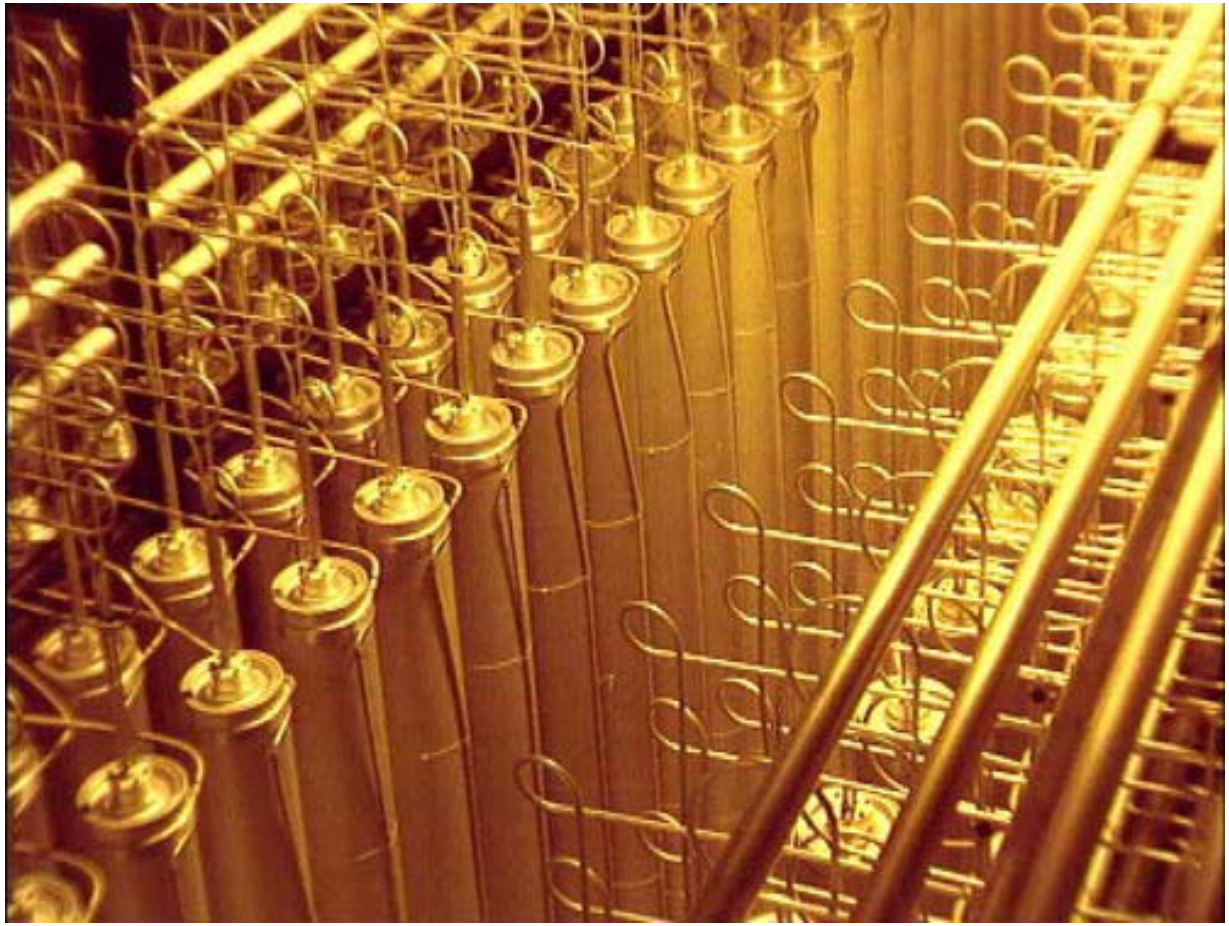
$60 billion.

Source: American Electric Power, 2007.
http://www.aep.com/about/i765project/docs/WindTransmissionVisionWhitePaper.pdf.

Fission Power – with Dry Cask Storage

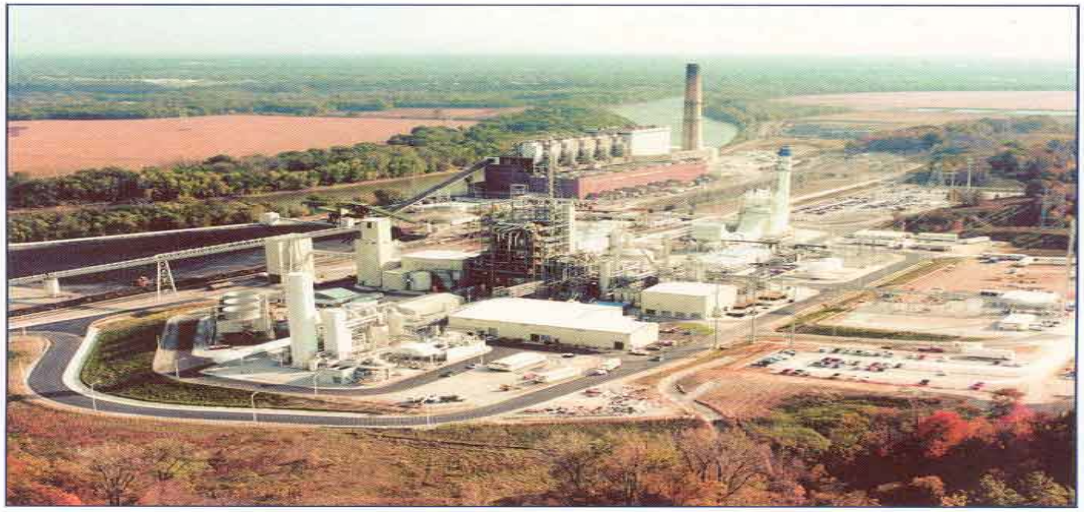
Site: Surry station, James River, VA; 1625 MW since 1972-73,. *Credit*: Dominion.

Needed: A New International Regime

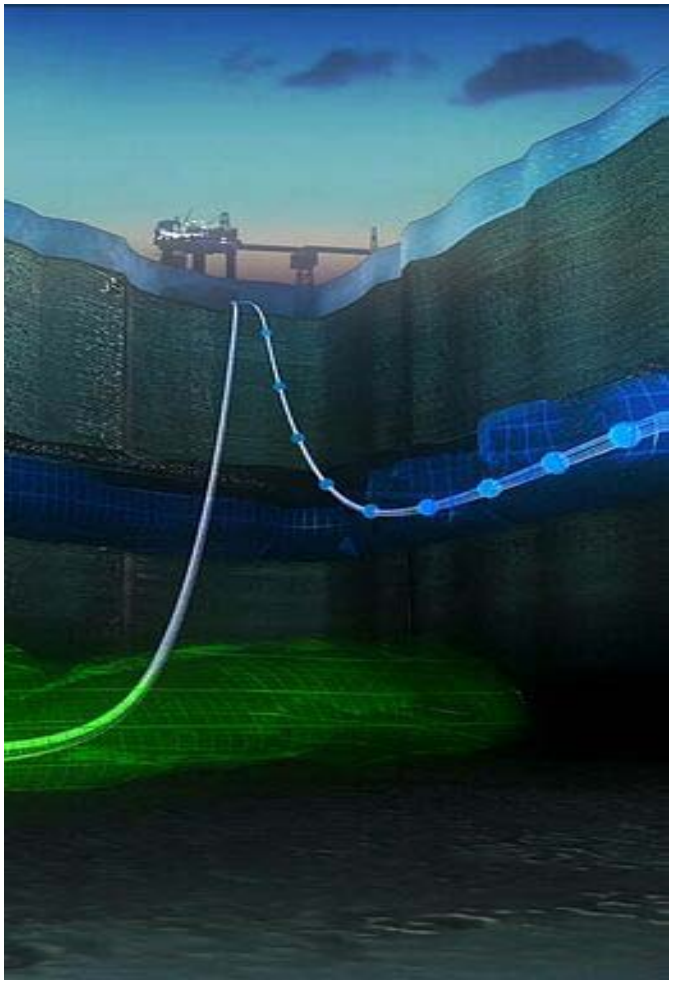


Pictured: A cascade of centrifuges
Challenge: A one-tier world for civilian nuclear power, not “suppliers and users.”

CO_2 Capture and Sequestration (CCS)



The Wabash River
Coal Gasification Repowering Project

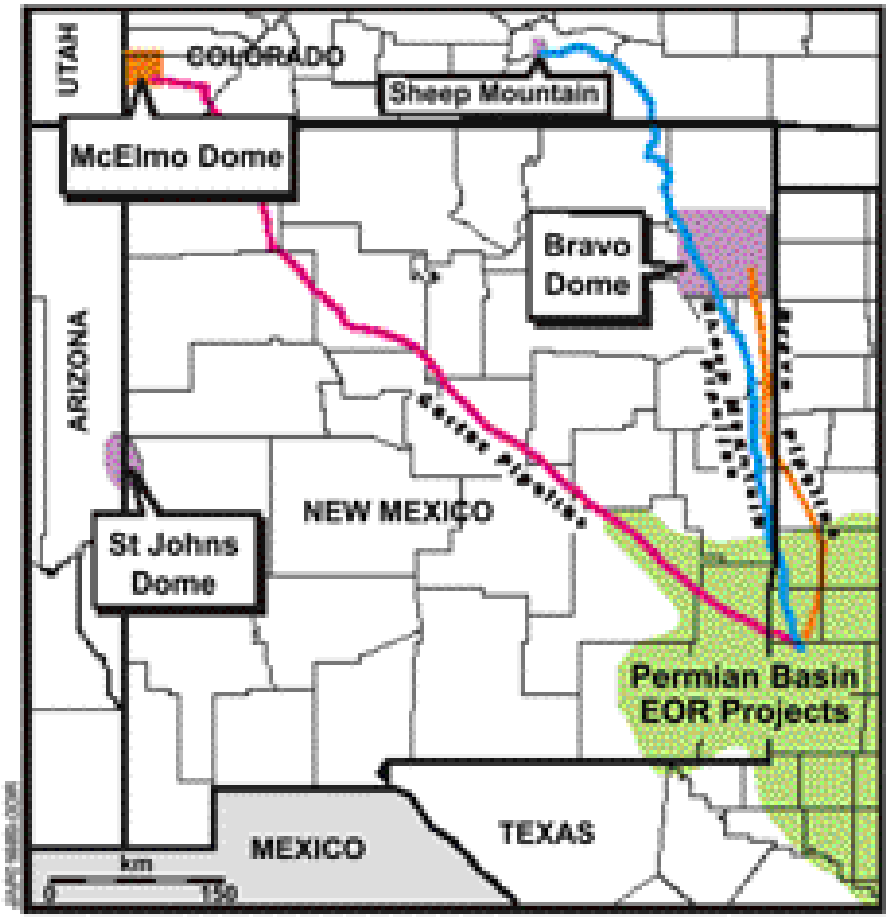


For power and synthetic fuels

Graphics courtesy of DOE Office of Fossil Energy and *Statoil ASA*

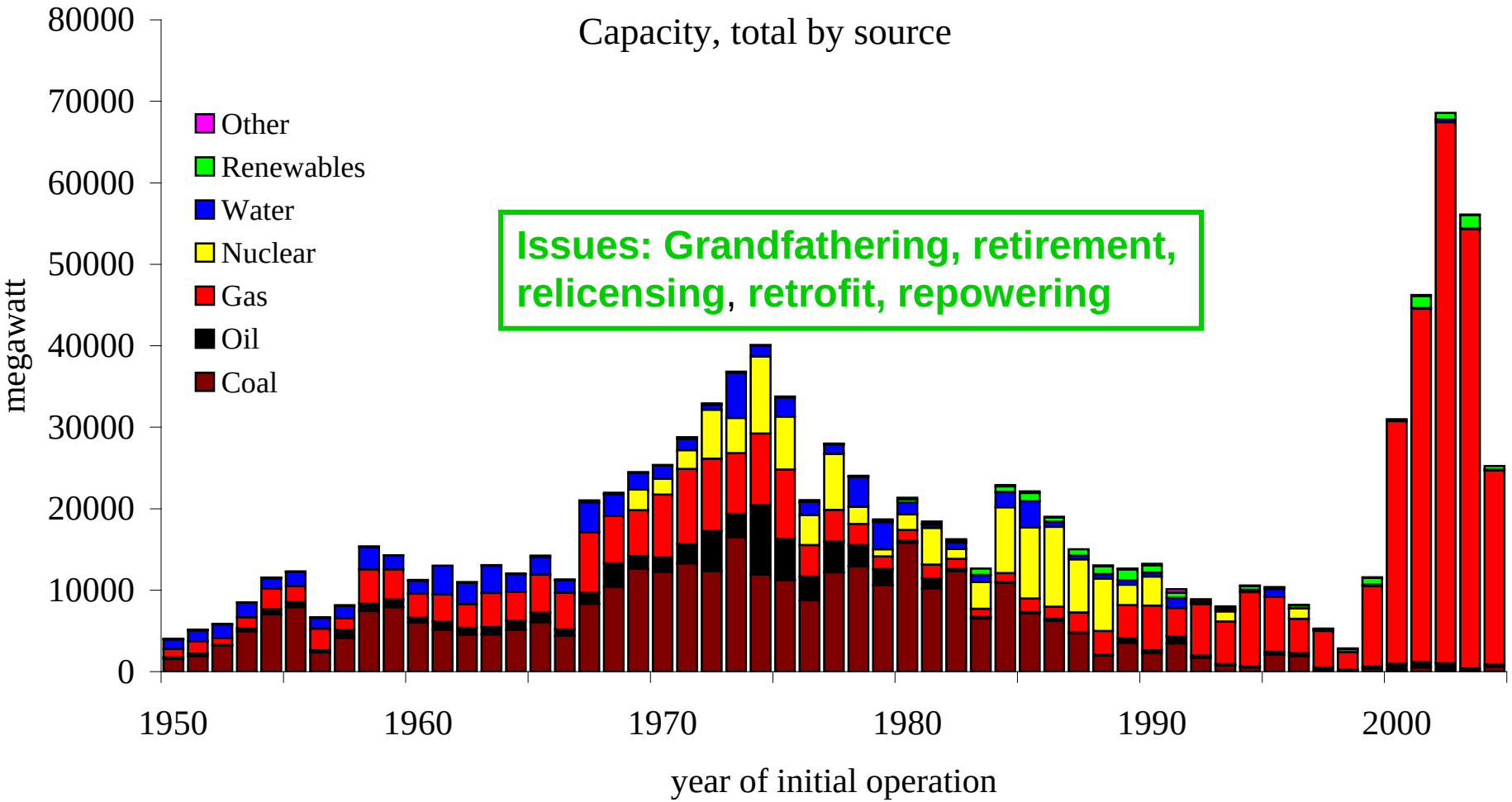
A 500-mile CO_2 pipeline built in the 1980s

McElmo Dome:
In place: 1500 $MtCO_2$
Production: 15-20 $MtCO_2$/yr



Rule of thumb: 2 to 5 bbl incremental oil per tCO_2 injected.

U.S. Power Plant Capacity, by Vintage



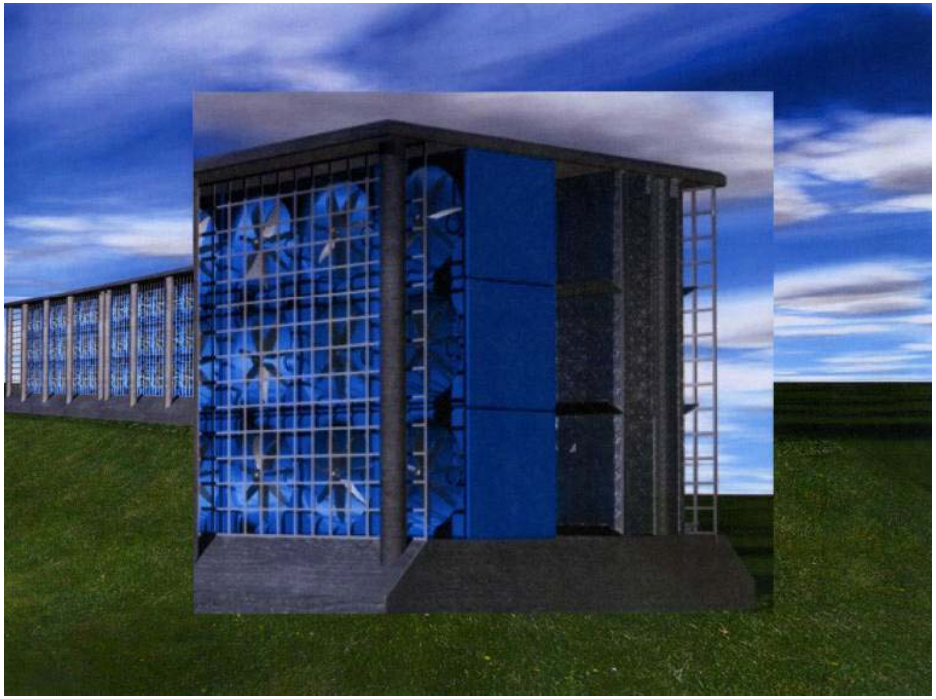
Source: EIA. Joseph.Beamon@eia.doe.gov

Some Far-out Ideas

Needed urgently:

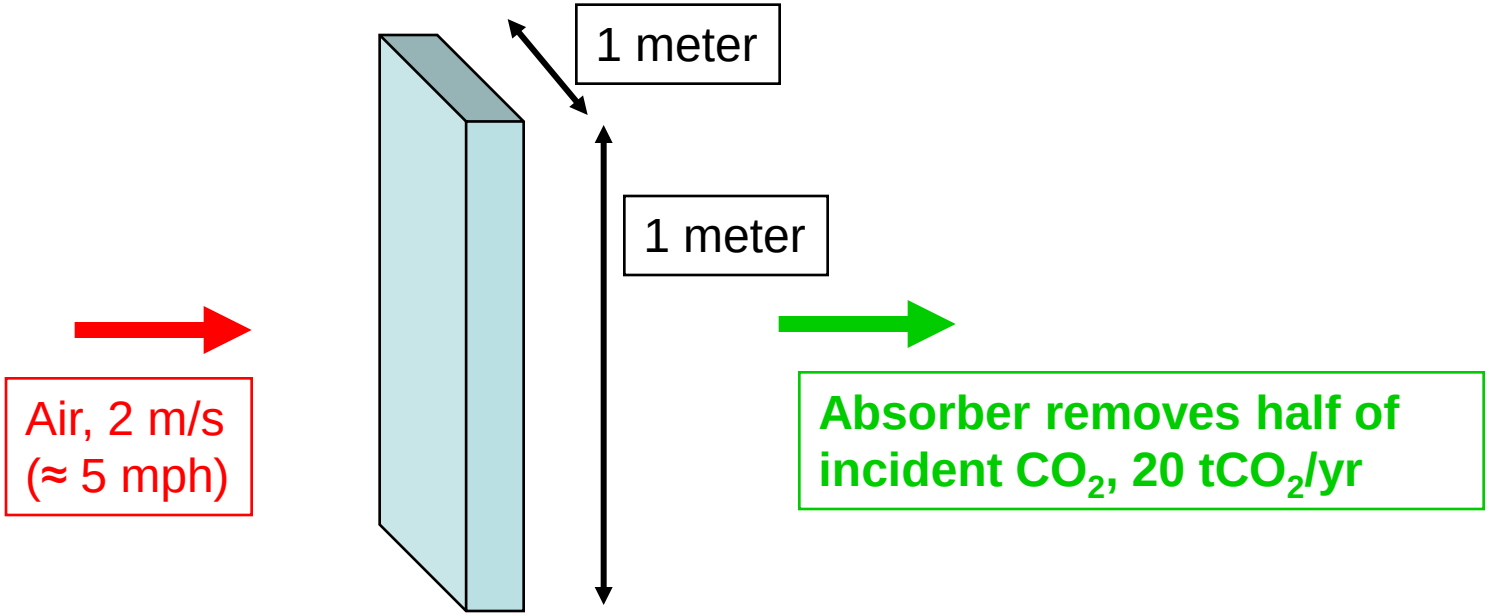
Contributions of sense and sensibility from many disciplines

Direct capture of CO_2 from air



Source: David Keith, MIT talk, Sept. 16, 2008

Window Absorber scaled to the emissions of the average American



1.5 billion window absorbers, plus long-term storage, would cancel today's global emissions.

Geoengineering

On June 15, 1991 (three days after this photo) , Mt. Pinatubo. injected 10 million tons of sulfur into the stratosphere.

The Earth's average surface temperature was 0.5^{o}C cooler six months later, then rebounded.

Sulfur injection: Epinephrine

We may someday need “fast geoengineering,” matched to the sudden onset of a crisis. S injection acts quickly.

The analogy here is to the use of epinephrine to treat an acute allergic reaction. It is considered irresponsible for a doctor not to have epinephrine in his or her medicine cabinet.

But geoengineering today is “comparable with 19th century medicine.” (James Lovelock).

**Novim study group*: Steve Koonin (head), David Battisti, Jason Blackstock, Ken Caldeira, Doug Eardley, Jonathan Katz, David Keith, Ari Patrino, Dan Schrag, Robert Socolow.

Every strategy can be implemented well or poorly

Every “solution” has a dark side:

Conservation	Regimentation
Renewables	Competing uses of land
Nuclear power	Nuclear war
“Clean coal”	Mining: worker and land impacts
Geoengineering	Technological hegemony

Never in history has the work of so few led to so much being asked of so many!

The “few” are the climate science researchers.

They are persuaded that our planet can change abruptly and produce major disruptions of human civilization.

They have singled out carbon dioxide as a particularly powerful agent of change.

The “many” are the rest of us.

Understandably, we wish we lived on a larger planet, with a larger atmosphere so that our emissions would be less significant –

and also a planet with larger fisheries, bigger forests, more abundant ground water, so that *all* our actions mattered less.

Can We Do It?

But the planet we have is Earth.

Fortunately:

- Our science has discovered threats fairly early;
- We can identify a myriad of helpful technologies;
- We have a moral compass that tells us to care not only about those alive today but also about the collective future of our species.

What has seemed too hard becomes what simply must be done.