Place-based Mitigation of Climate Change

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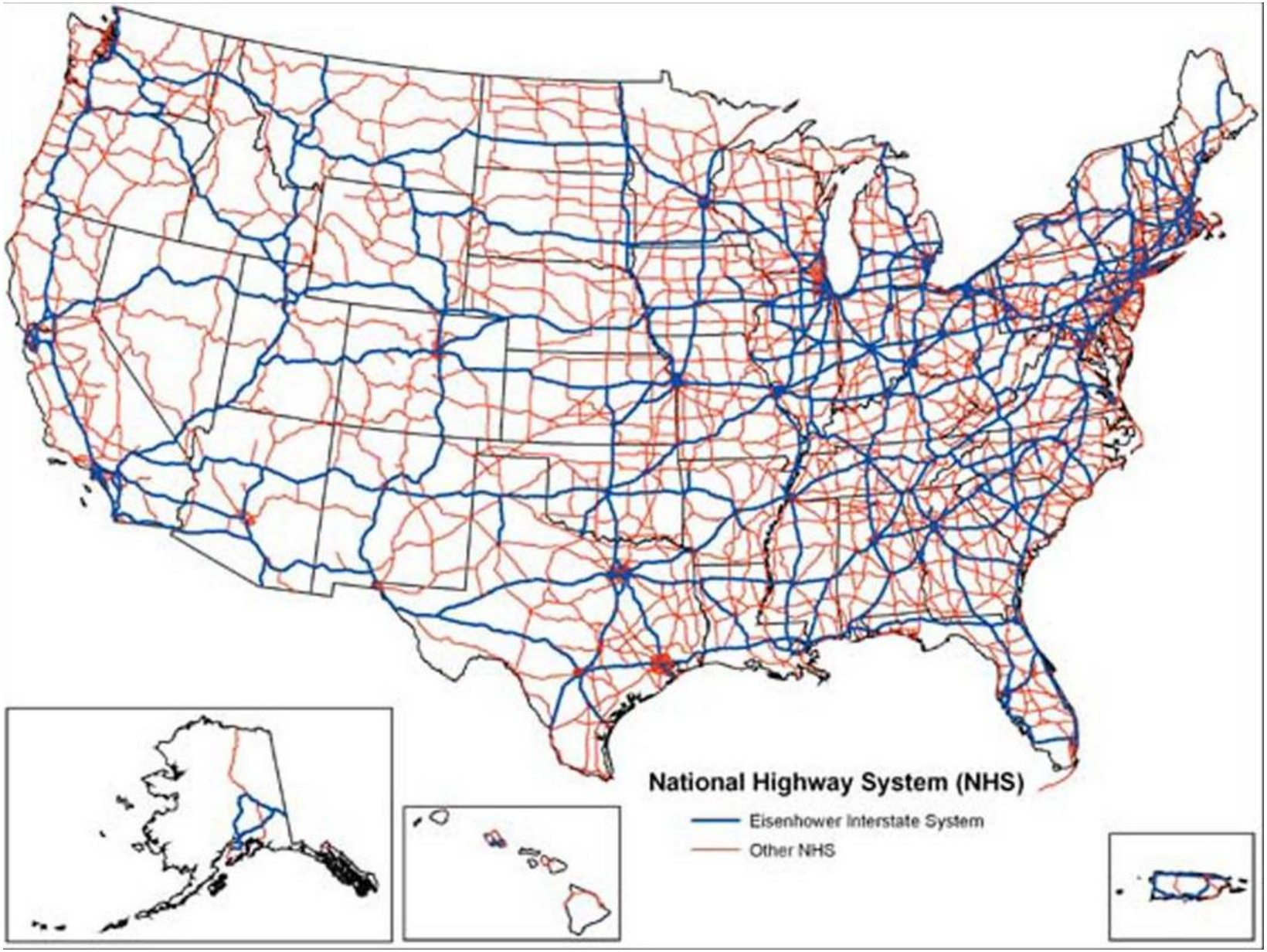
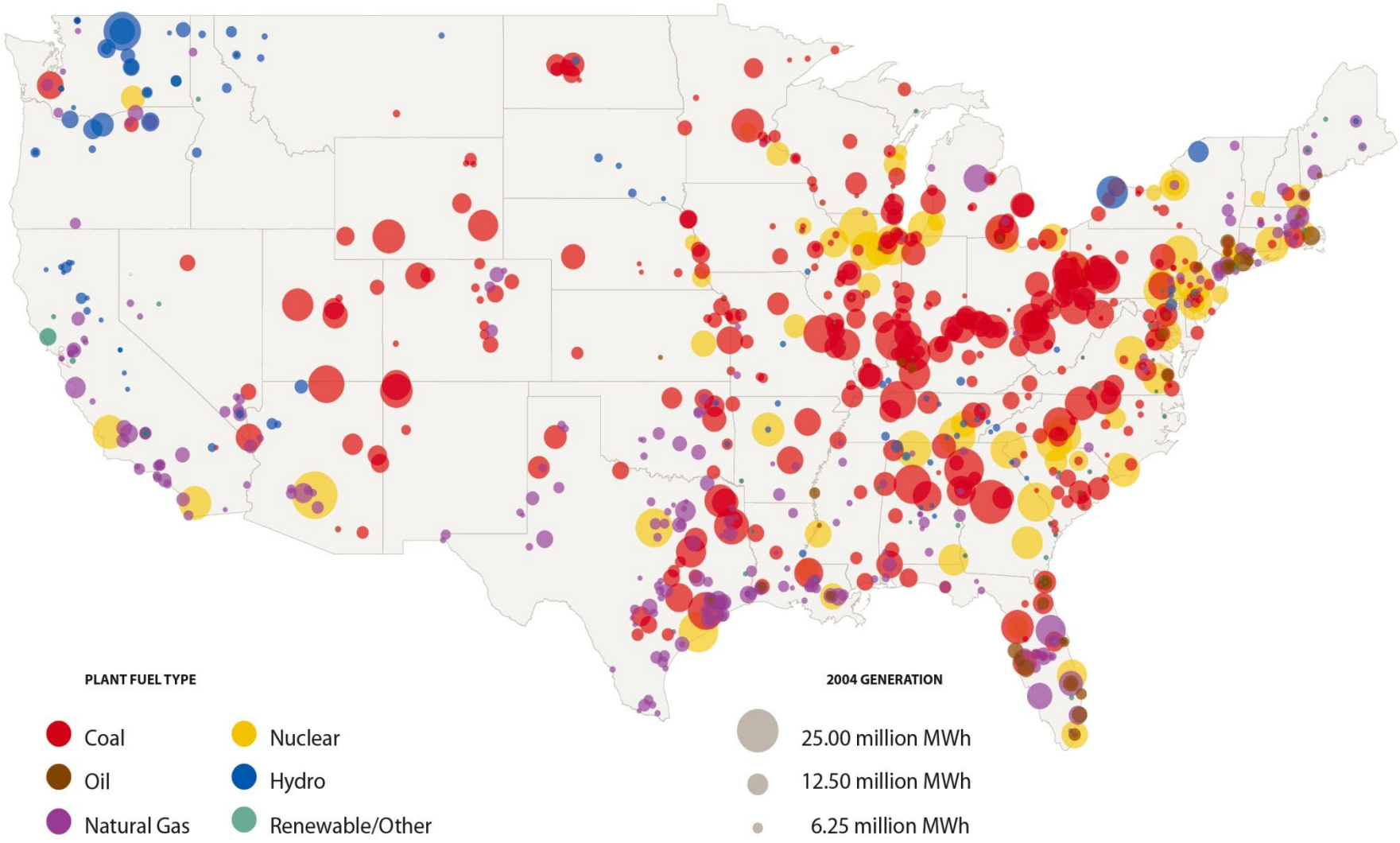
Re-imagining Cities: Urban Design After the Age of Oil

Penn Institute for Urban Research
U. Pennsylvania
November 6, 2008

Legacy: National Highway System

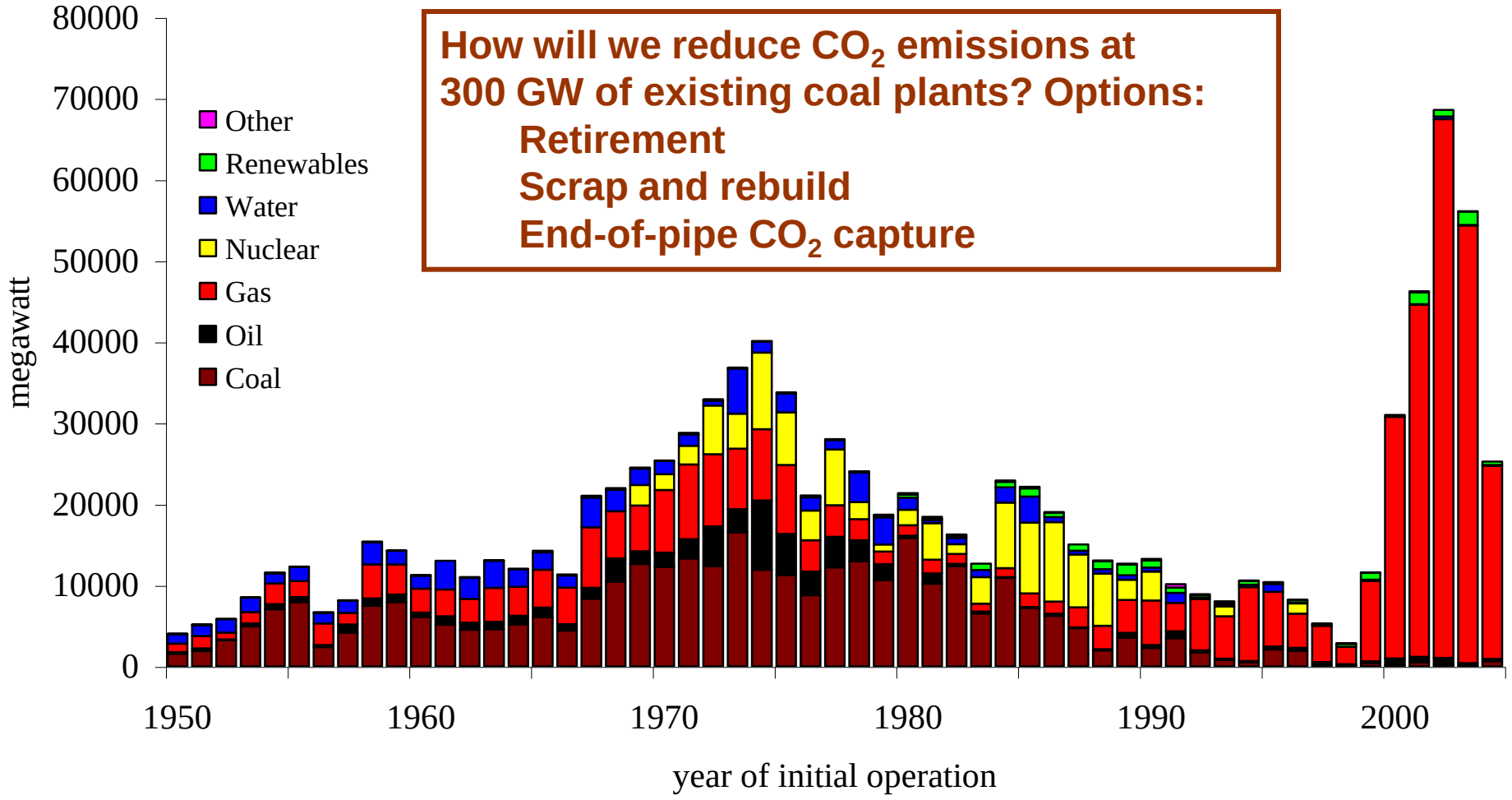


Legacy: U.S. Power Plants



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

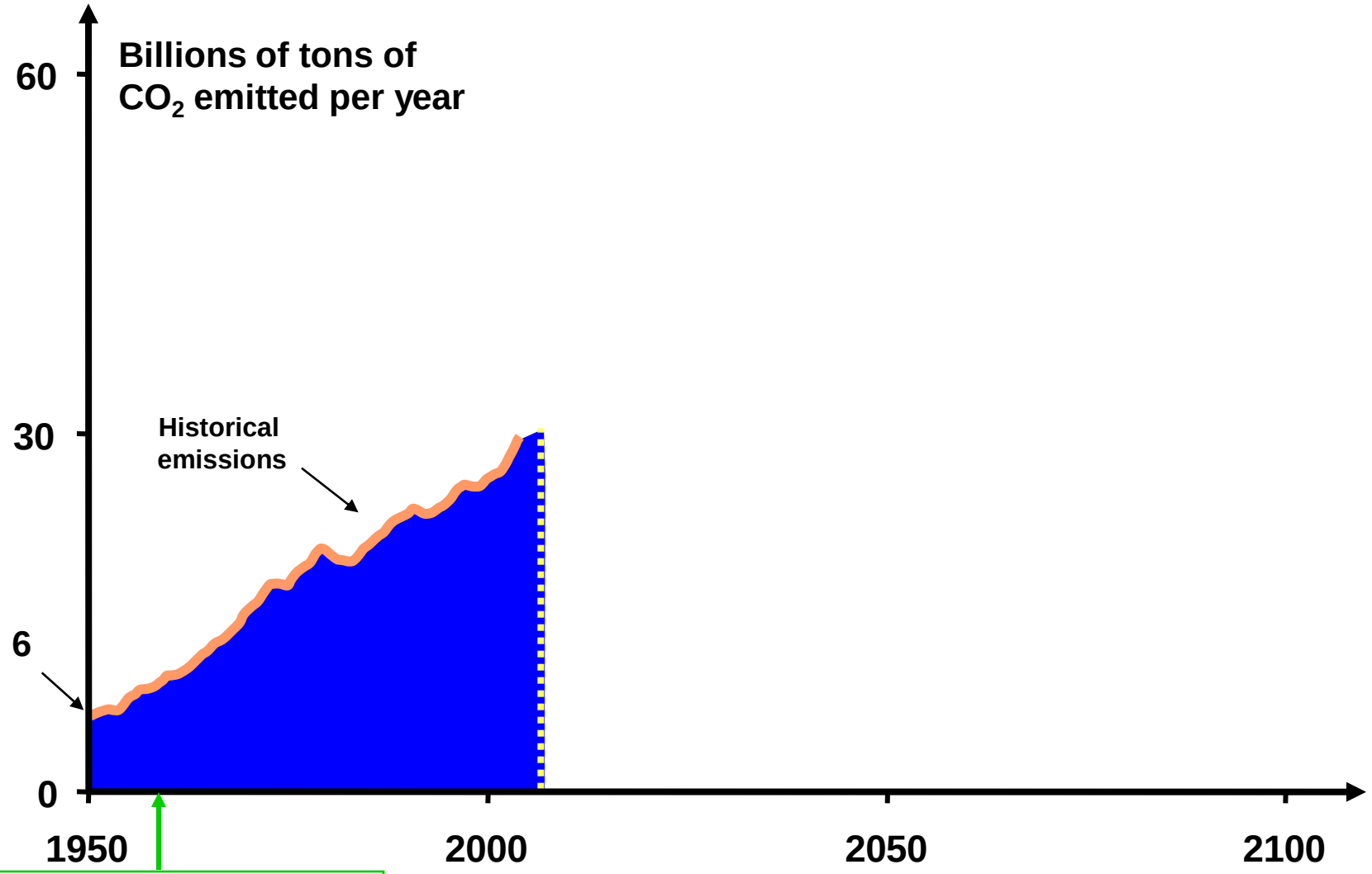
U.S. Power Plant Capacity, by Vintage



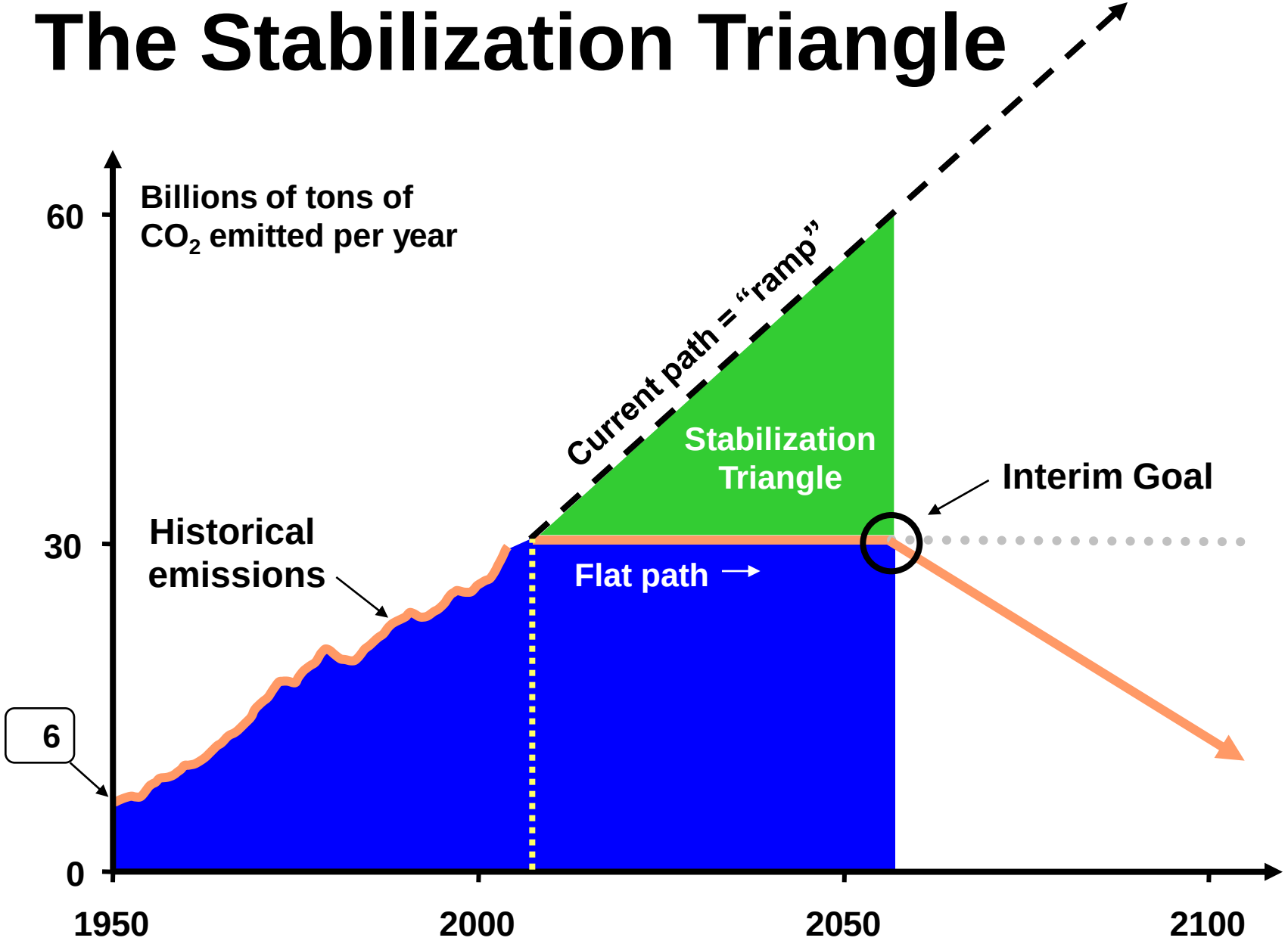
If we push hard on end-use efficiency, will our current fleet suffice for >20 yrs?

Source: EIA

Historical Global CO_2 Emissions



The Stabilization Triangle



Today and for the interim goal, global per-capita emissions are ≈ 4 to 5 tCO_2/yr.

Four ways to emit 4 tonCO_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)

Princeton University CO_2 in 2007

University emissions*	112,000 tCO2
12,500 participants**	
Per-capita emissions	9 tCO2

*On-site cogeneration plant, purchased electricity, fuel for University fleet.
**7,100 students and 5,400 employees

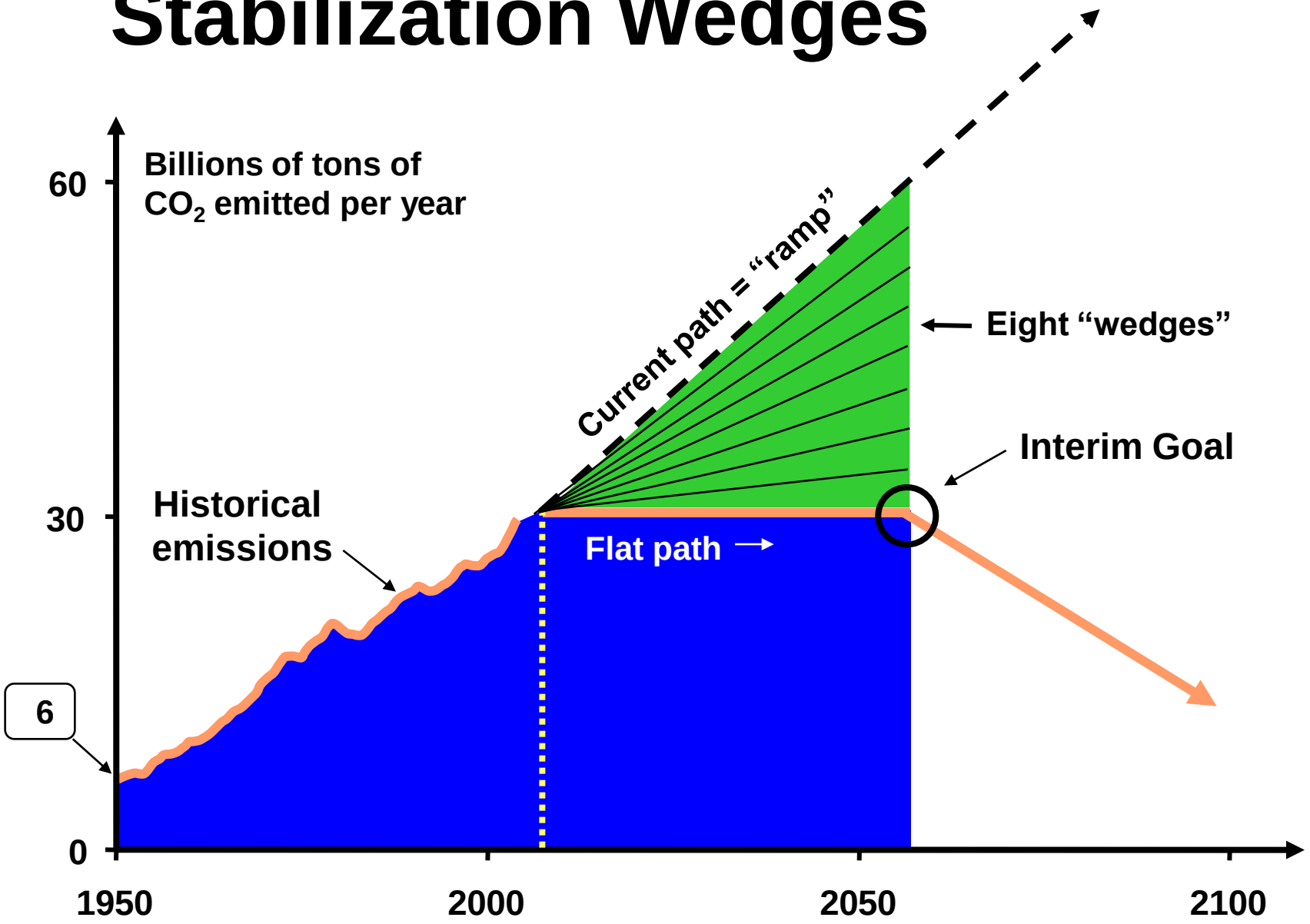
What about *your* workplace, church, hospital, town?

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

Nonetheless, grounds for optimism:

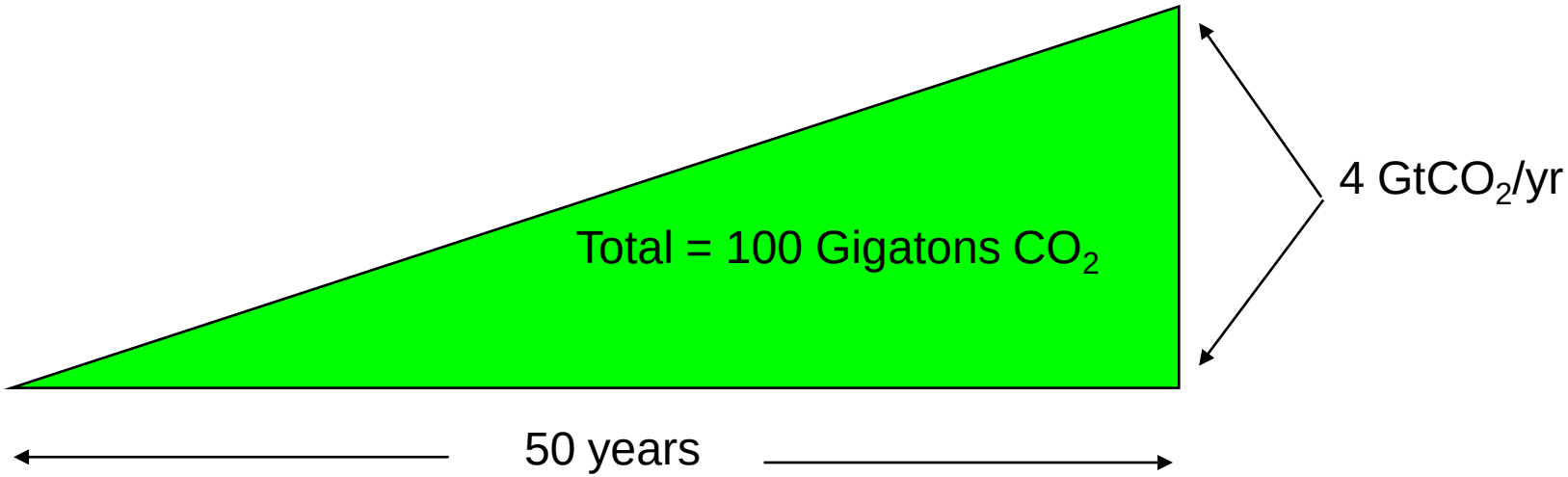
- The world today has a terribly inefficient energy system.
- Carbon emissions have just begun to be priced.
- Most of the 2058 physical plant is not yet built.

Stabilization Wedges



What is a “Wedge”?

A “wedge” is a strategy to reduce carbon emissions that grows in 50 years from zero to 4 $GtCO_2$/yr. The strategy has already been commercialized at scale somewhere.



Cumulatively, a wedge redirects the flow of 100 $GtCO_2$ in its first 50 years. This is **six trillion dollars** at \$60/tCO_2.

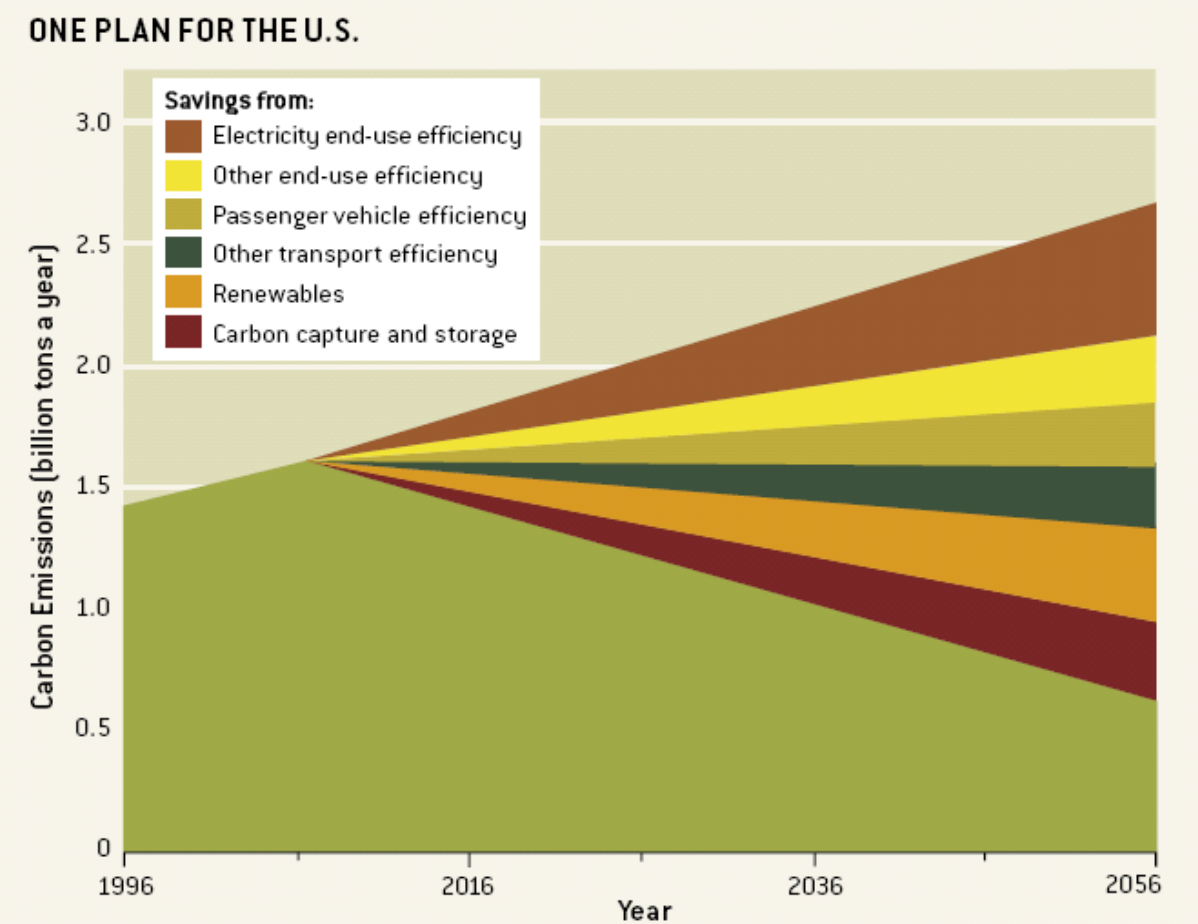
A “solution” to the CO_2 problem should provide at least one wedge.

“The Wedge Model is the iPod of climate change: You fill it with your favorite things.”

David Hawkins, NRDC, 2007.

Therefore, prepare to negotiate with others, who have different favorite things.

U.S. Wedges

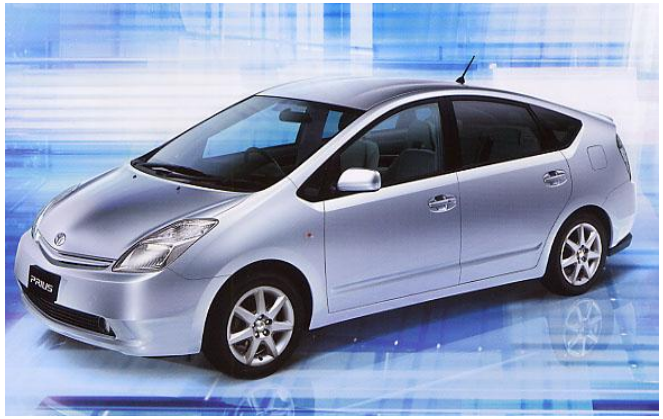


Source: Lashof and Hawkins, NRDC, *in* Socolow and Pacala, *Scientific American*, September 2006, p. 57

Priority #1: Invent a smart-carbon post-industrial society

The post-industrial age features unprecedented private consumption. In industrialized countries more than 60% of oil is used in vehicles, more than 60% of electricity in buildings.

Efficient Use of Fuel



Effort needed by 2055 for 1 wedge:

Note: 1 car driven 10,000 miles at 30 mpg emits 4 tons of CO_2.

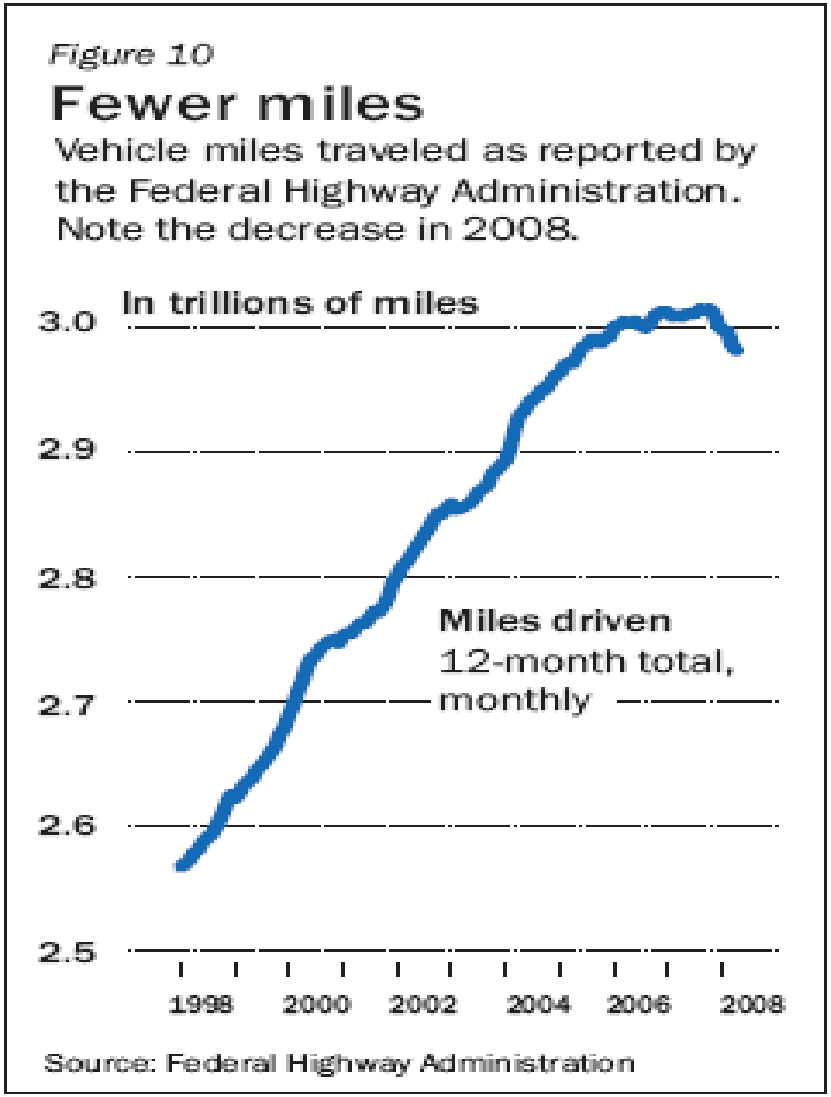
2 billion cars driven 10,000 miles per year at 60 mpg instead of 30 mpg.

2 billion cars driven, at 30 mpg, 5,000 instead of 10,000 miles per year.

Property-tax systems that reinvigorate cities and discourage sprawl

Video-conferencing

U.S. vehicle-miles traveled



Source: American Physical Society, 2008. *Energy Future: Think Efficiency.*

Efficient Use of Electricity

motors

lighting

cogeneration

Effort needed by 2055 for 1 wedge:

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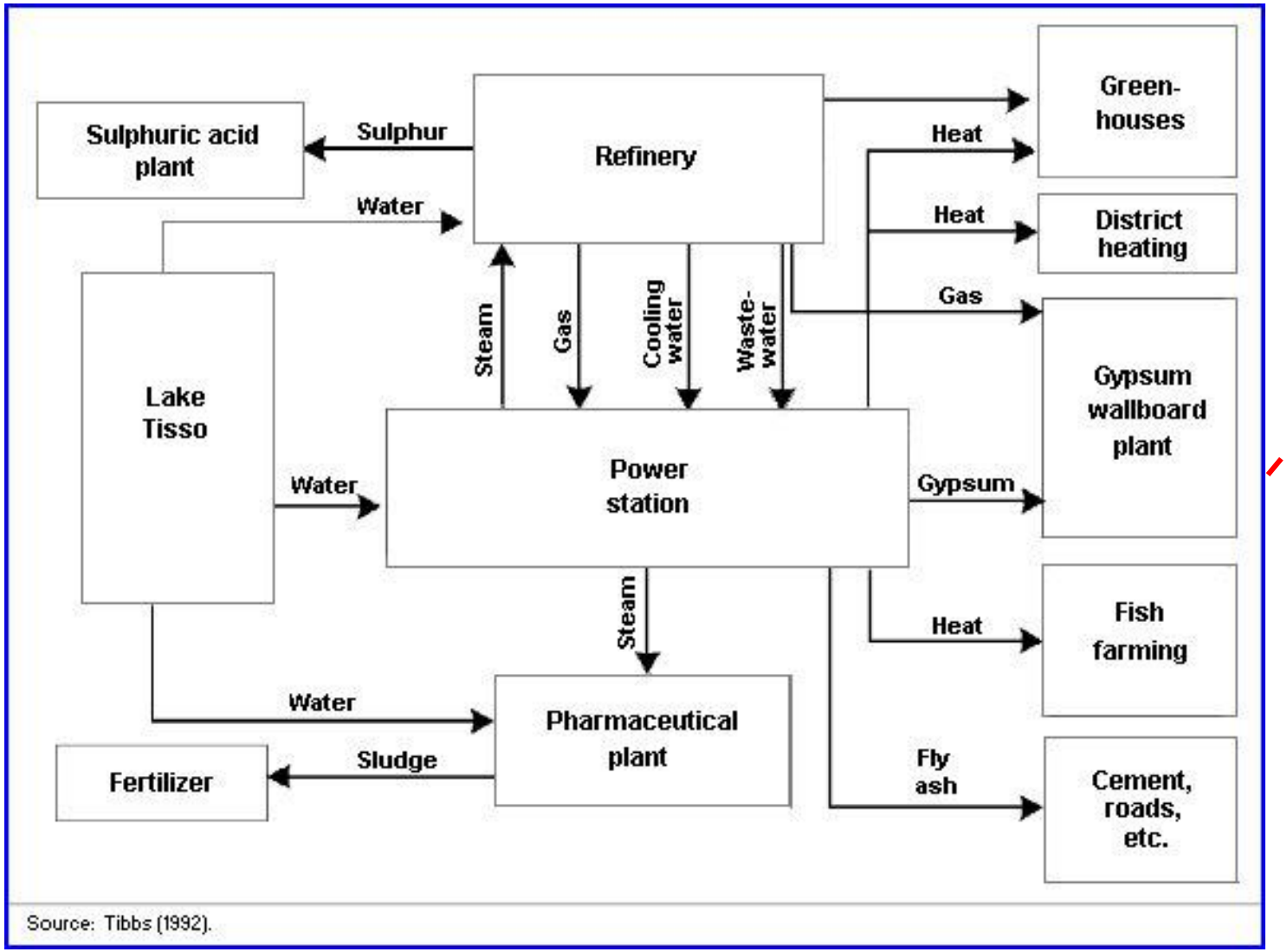
25% reduction in expected 2055 electricity use in commercial and residential buildings

Target: Commercial and multifamily buildings as well as single-family homes

Industrial Symbiosis: Kalundborg, Denmark



Source: http://www.ec.gc.ca/soer-ree/English/SOER/1996report/Doc/1-7-4-10-5-3-1.cfm. Accessed 11/1/08.

Ways to drive efficiency investments

Measure, measure, measure: “Trust, but verify”
Focus attention on performance: construction detail, secondary decisions (interior design), operation and maintenance.

Set tough performance standards
Examples: appliance efficiency, interior temperature, light levels

Use price (spot-market, time-of-day) to flatten loads
Stimulate load management and storage technology, behavioral change.

Address poverty via lifeline rates (e.g., for the first 300 kWh/month)
Subsidize retrofit of highly inefficient older buildings of the urban core.

Wind farms out of sight

Last month, the right to construct 96 wind turbines *16 to 20 miles off the coast* of Atlantic and Ocean counties was granted by the New Jersey Board on Public Utilities to Garden State Offshore Energy.

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

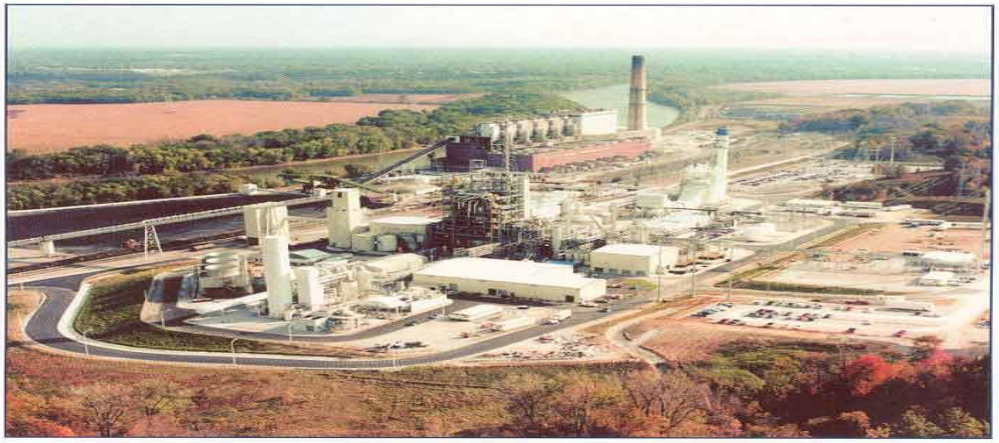
Nuclear Electricity

Effort needed by 2055 for 1 wedge: 700 GW (twice current capacity) displacing coal.

Phase out of nuclear power creates the need for another half wedge.

Dry cask storage, adequate for 100 yrs.

Coal with Carbon Capture and Storage



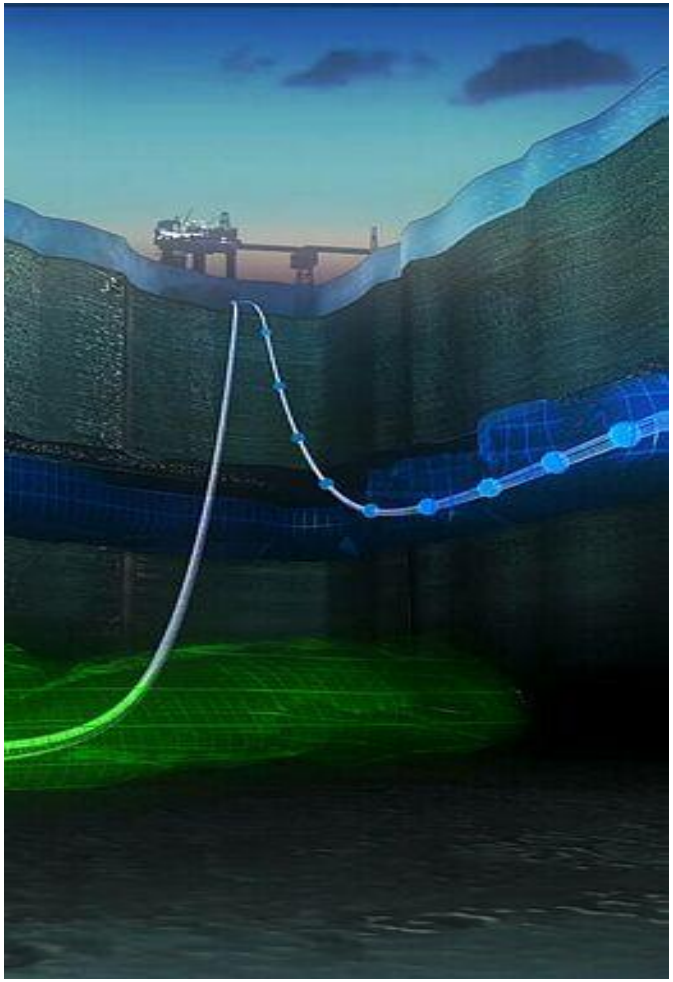
The Wabash River
Coal Gasification Repowering Project

Effort needed by 2055 for 1 wedge:

Carbon capture and storage (CCS) at 800 GW coal power plants.

CCS at “coal-to-liquids” plants producing 30 million barrels per day.

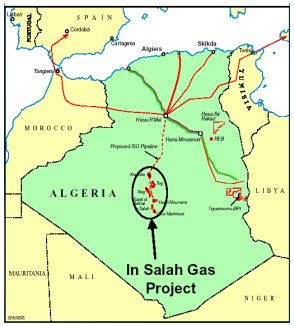
Which will happen first?



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

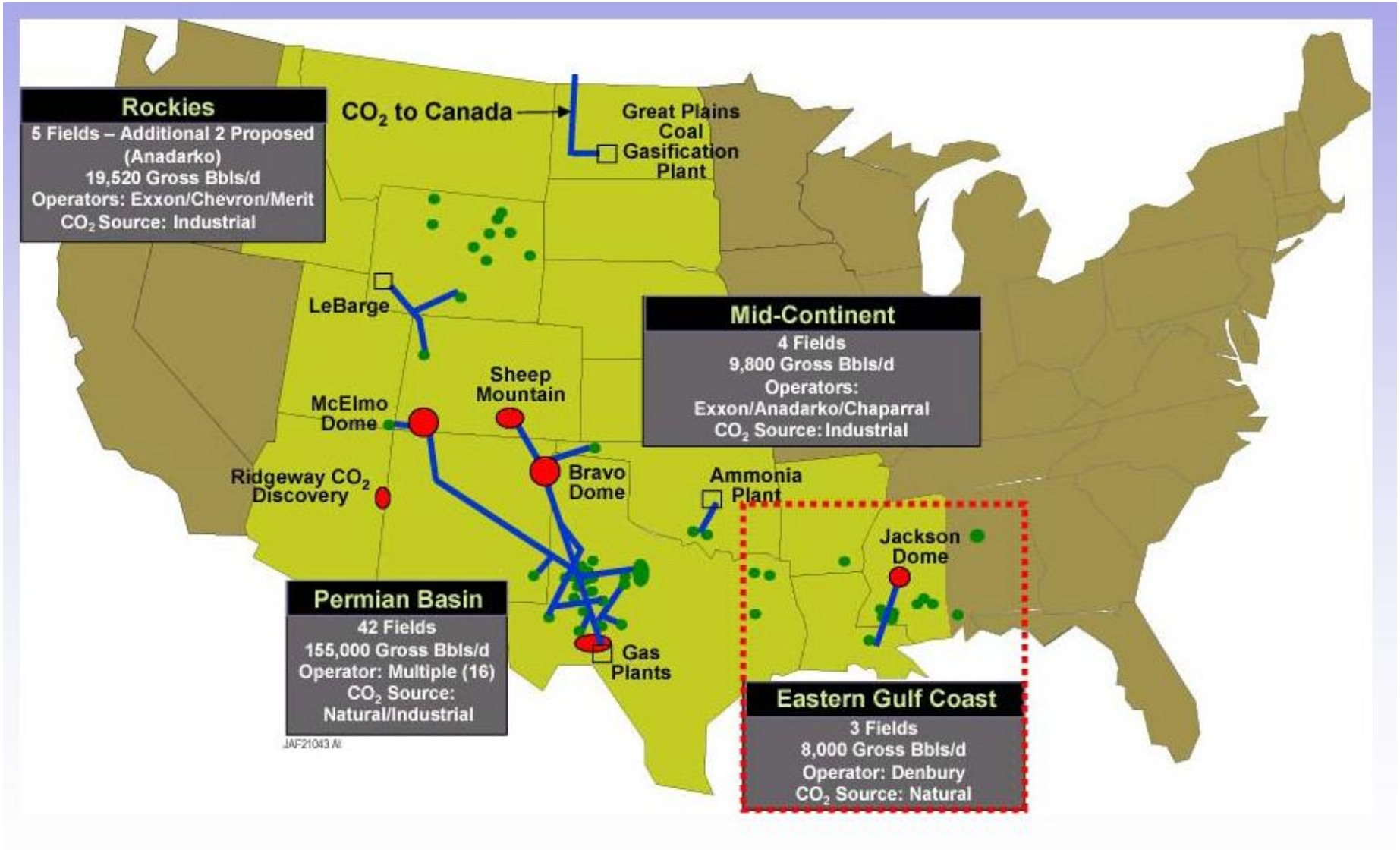
Already, in the middle of the Sahara!

At In Salah, Algeria, natural gas purification by CO_2 removal plus CO_2 pressurization for nearby injection



Separation at amine contactor towers

U.S. CO_2 pipelines: Another infrastructure



The Future Coal to Power + Fuels Plant

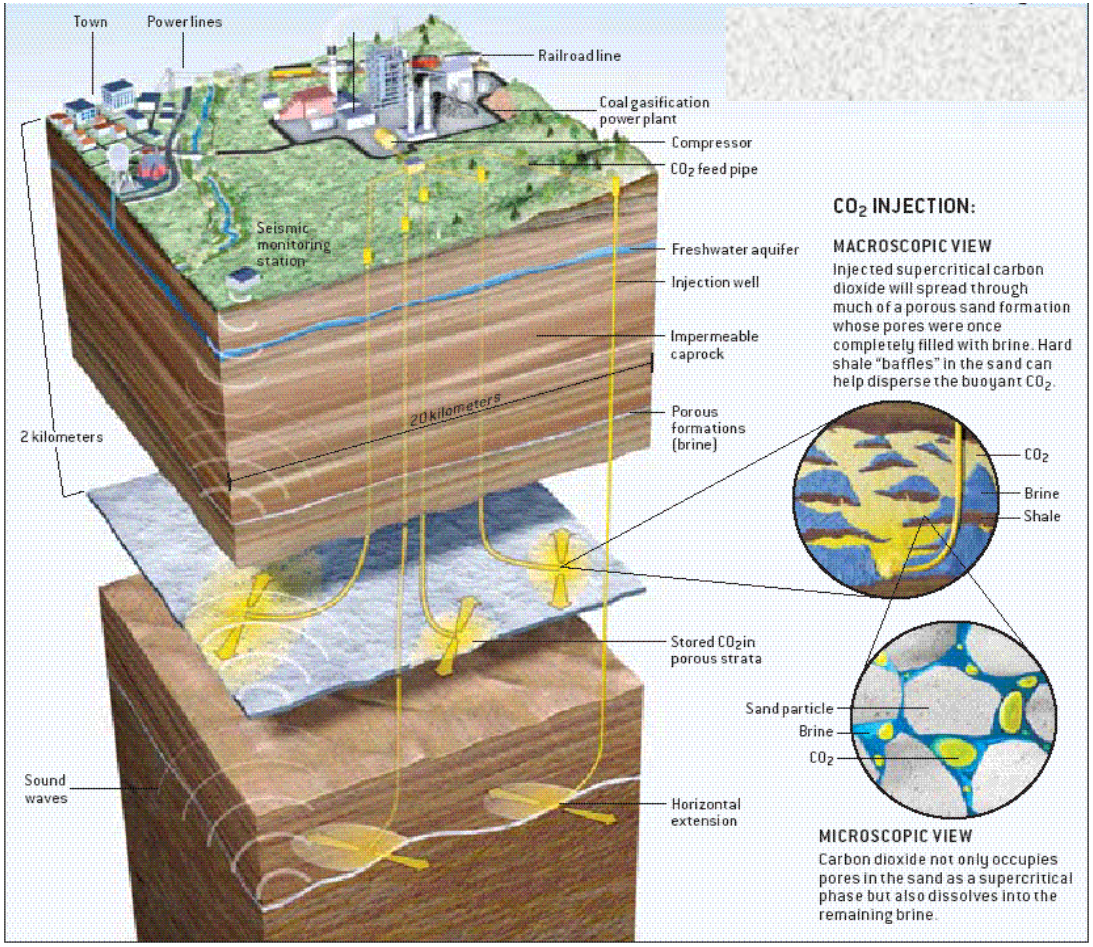


ILLUSTRATION BY DAVID FIERSTEIN; CONCEPT BY JULIO FRIEDMANN *Lawrence Livermore National Laboratories*

Shown here: After 10 years of operation of a 1000 MW coal plant, 60 Mt (90 Mm^3) of CO_2 have been injected, filling a horizontal area of 40 km^2 in each of two formations.

Assumptions:

- 10% porosity
- **1/3 of pore space accessed**
- 60 m total vertical height for the two formations.

- *Note:* Plant is still young.

Note: Injection rate is 150,000 bbl(CO_2)/day, 3 billion barrels over 60 years.

Every strategy can be implemented well or poorly

Every “solution” has a dark side, generating opposition that thwarts implementation.

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

Global equity

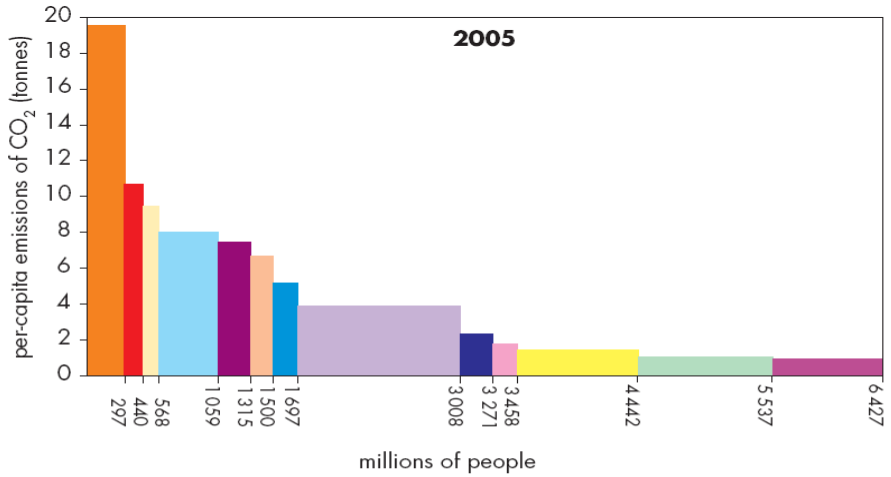
Two points:

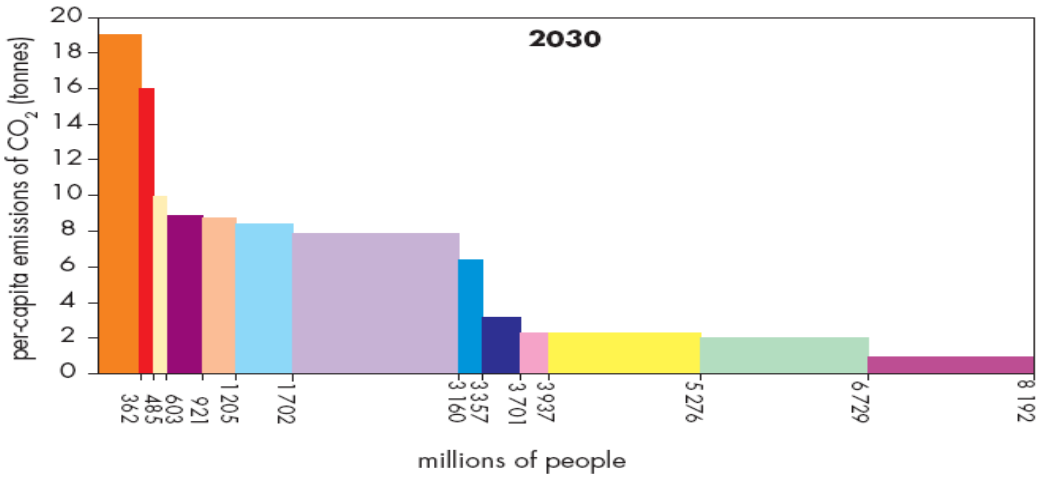
1. Climate change cannot be managed without the participation of the developing countries.

2. The CO_2 emissions of the *global poor* (40% of the world's population) are negligible, from the perspective of global warming.

Collaborators: Shoibal Chakravarty (PEI), Ananth Chikkatur (Harvard), Heleen DeConinck (Free University, Amsterdam), Steve Pacala (PEI), Massimo Tavoni (FEEM, Milan)

CO_2 emissions, 2005 and 2030, by region





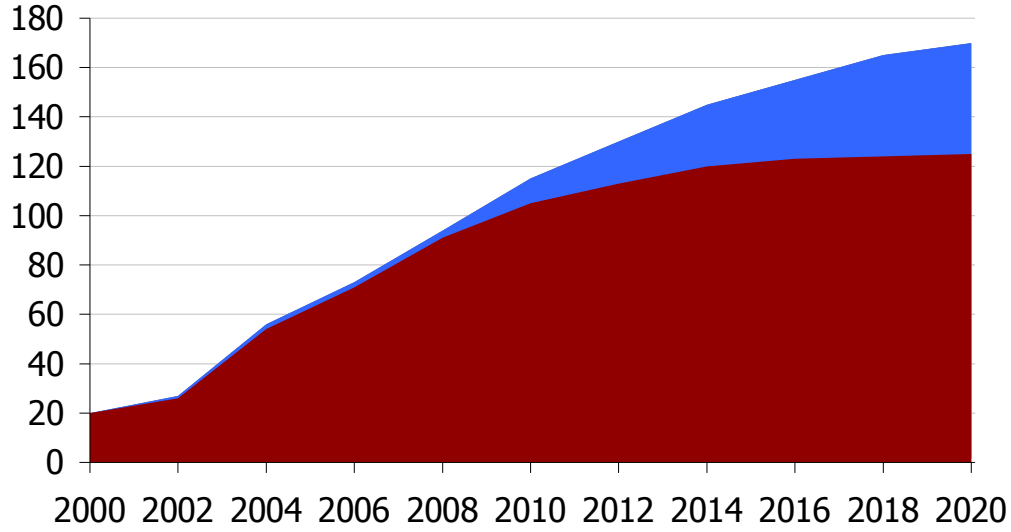
OECD: Less than 50% in 2005

Source: IEA, *WEO 2007*

China Appliance Standards

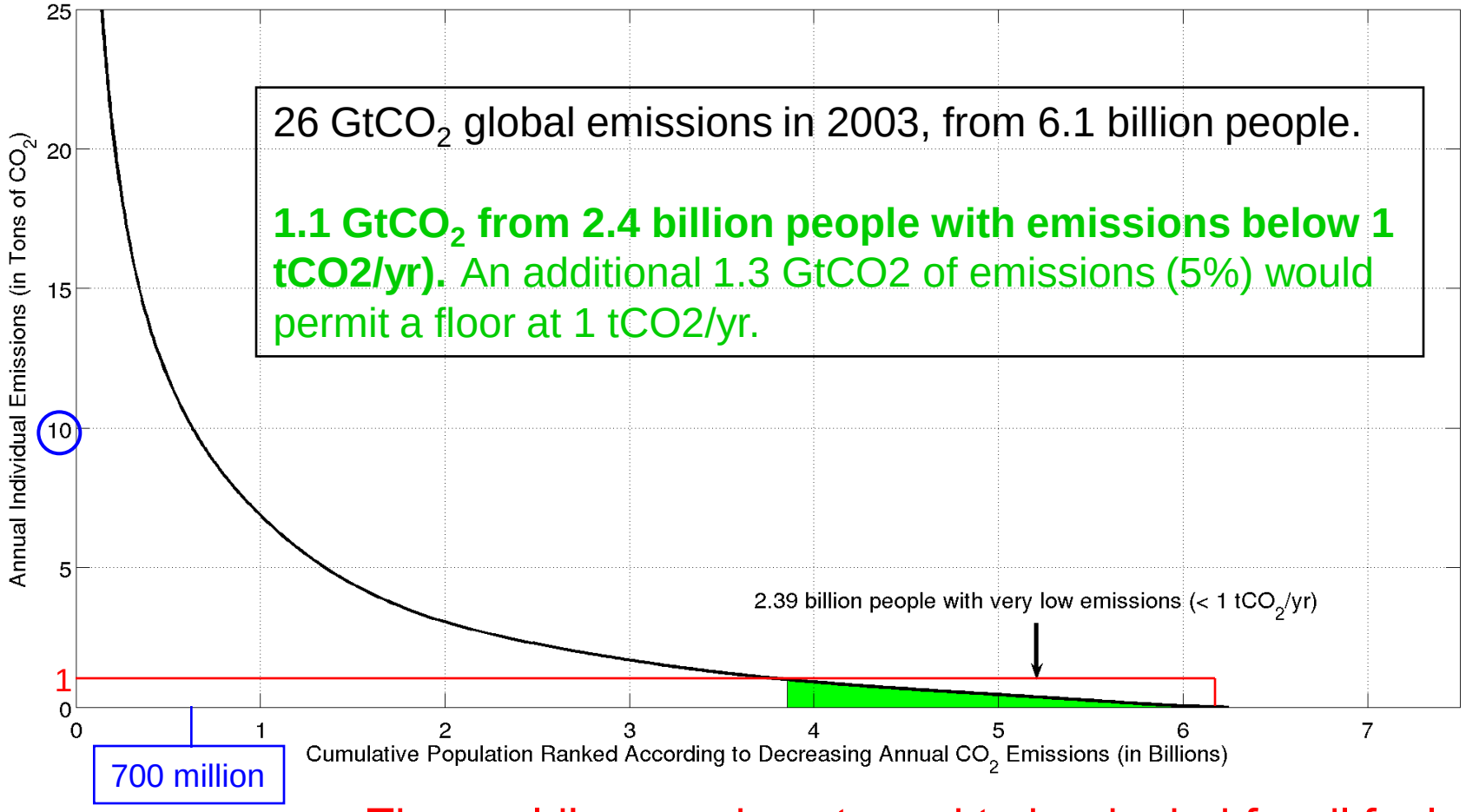
Business as Usual: CO_2 emissions from air conditioners in 2020 are 9x those in 2000.

New Air Conditioner Standard: Down 25% (45 $MtCO_2$/yr) in 2020.



50 million new, efficient air conditioners per year in 2020

The aggregate emissions of the world's poorest people are negligible



The world's poor do not need to be denied fossil fuels

What does 1 tCO_2/person-yr allow today?

Direct Energy Use	*Household rate of use (4.5 people)*	*Individual emissions ($kgCO_2$/yr)*
Cooking	1 LPG canister per month	120
Transport	70 km by bus, car, motorbike per day	220
Electricity	800 kWh per year	160
Total		*500*

1 tCO2/yr: Double the "direct" emissions to account for "indirect" emissions.

Planetary identity

In the process of taking climate change seriously, we develop a planetary identity. We augment our previous loyalties to family, to tribe, and to a nested set of political entities from the village to the nation. Every man's death diminishes us.

We also develop loyalties to future generations.

How do the world's norms change when large numbers feel an allegiance to the planet? Might one consequence be strengthened efforts to address global poverty and world peace – negating the claim that climate change is a distraction from assignments of greater urgency.

Prospicience

Prospicience: “The art [and science] of looking ahead.” We need a new word to describe a new intellectual domain.

In the past 50 years we have become aware of our deep history: the history of our Universe, our Earth, and life.

Can we achieve a comparable understanding of human civilization at various future times: 50 years ahead *vs.* 500 *vs.* 5000 *vs.* longer?

Prospicience

Prospicience is needed to guide decisions about infrastructure design, natural resources, wilderness preservation, reinsurance, endowment management ...and our understanding of what we are on Earth to do!

We have scarcely begun to ask: What are we on this planet to do? What are our goals? What are our responsibilities?

Imagine spending as much effort on our collective destiny on Earth as we spend on our personal destiny in the afterlife!

Can We Do It?

People (we!) are becoming increasingly determined to lower the risk that we and our children will experience major social dislocation and environmental havoc as a result of rising CO_2 in the atmosphere

…and we are learning that there are many ways of changing how we live, what we buy, and how we spend our time, that will make a difference.

We are in the midst of a discontinuity:

What once seemed too hard has become what simply must be done.

Precedents include abolishing child labor, addressing the needs of the disabled, and mitigating air pollution.