How Would We Act
If We Took Climate Change Seriously?

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Distinguished Scholar Seminar

Co-Sponsored by
the UF Department of Biology
and the Florida Climate Institute

Tuesday, March 22, 2011, at 3:30pm
122 Frazier Rogers Hall, University of Florida

Fukushima #1 in better times

Source*: "After the Deluge: Short and Medium-term Impacts of the Reactor Damage Caused by the Japan Earthquake and Tsunami." Nautilus Institute for Security and Sustainability, March 17, 2011**. ***Figure 4 **: Fukushima Number 1 Nuclear Power Plant**

After-heat: A fire you can't put out.

Percent of pre-shutdown power

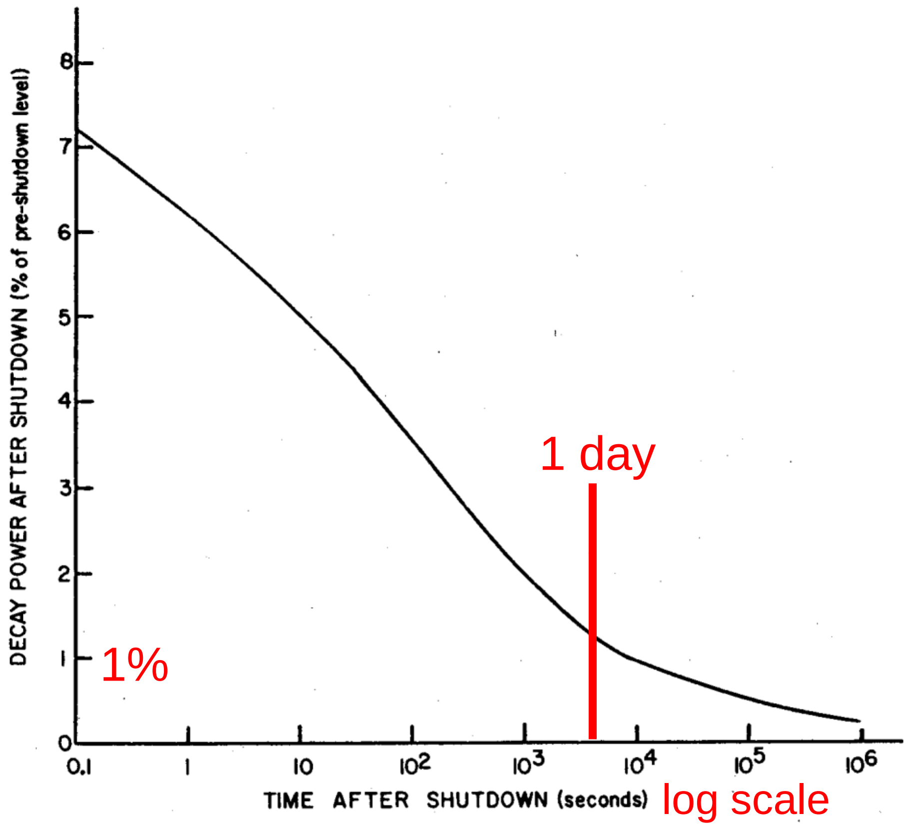

Figure 4-1. THERMAL POWER AFTER REACTOR SHUTDOWN.
After the nuclear chain reaction ceases, radioactivity remaining in the fuel will generate heat as a result of radioactive decay. Assuming that the reactor had been operating for a substantial period, the power generated immediately after shutdown will be approximately 7% of the level before shutdown. For a 3000 MWth reactor, with 1000 MWe capacity, this implies an initial decay power level of about 200 MWth. Due to the rapid decay of short-lived species, this decay heat level decreases rapidly, but is is this heat that imposes the requirement that, in a light-water reactor, cooling water remain available to prevent damage to the fuel.

Source: A. Nero. Jr., *The Guidebook to Nuclear Reactors*, p. 54

The Deutsche Bank Carbon Counter

Penn Station, New York City
June 18, 2009, about 9:15 a.m.
Real time: www.dbcca.com

The Deutsche Bank Carbon Counter

The number shown, about 3.6 trillion tons, is the mass of CO_2 that would provide as much warming (“forcing”) as is provided by *all* the current long-lived gases (Kyoto and Montreal gases).

The mass of CO_2 in the atmosphere is about 3.0 trillion tons.

The number climbs 750 ton/second, or two-thirds of one percent per year.

Penn Station, New York City
June 18, 2009, about 9:15 a.m.
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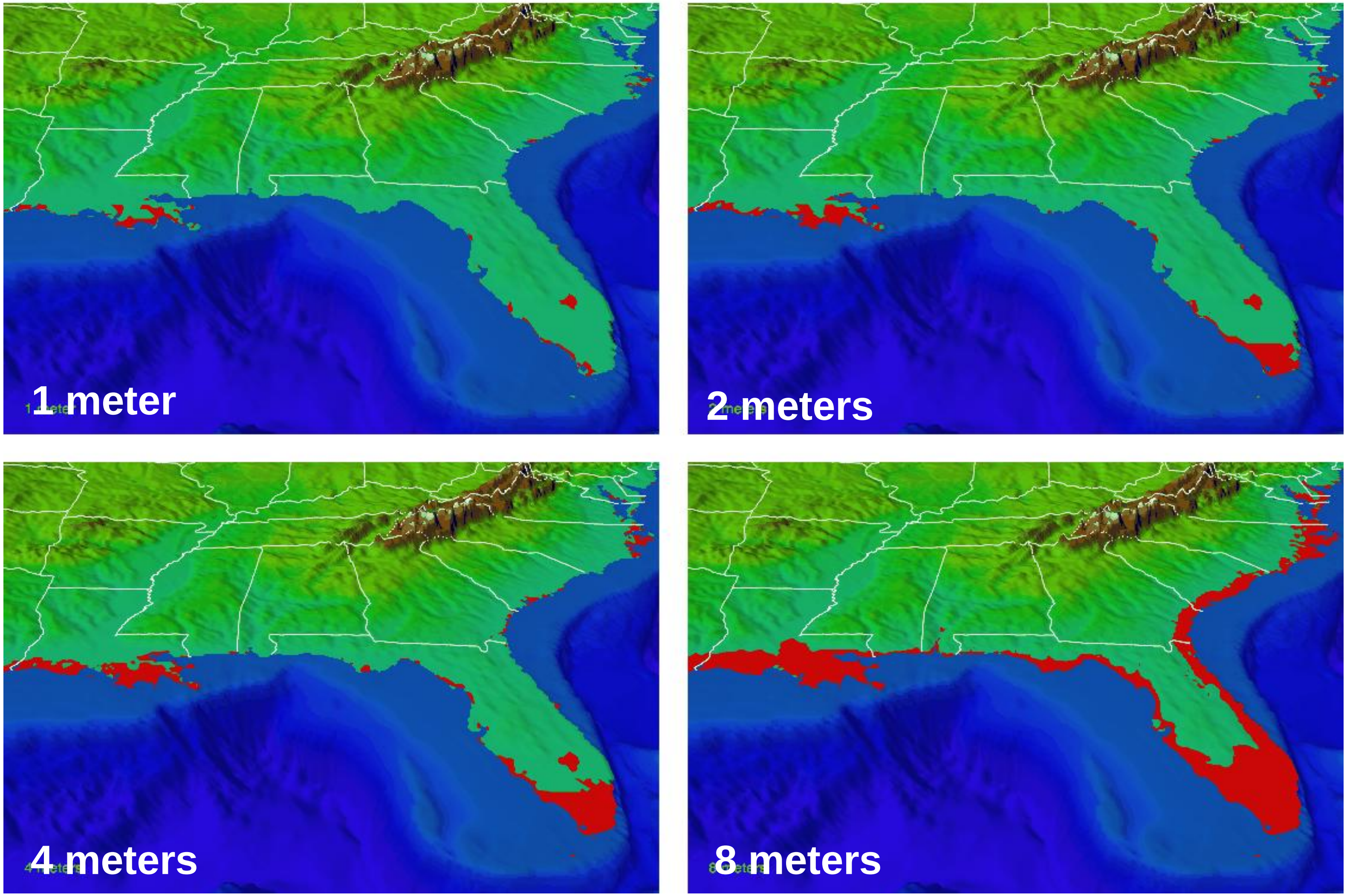
Sea Level Rise



Greenland ice sheet: 7 meters
West Antarctic Ice Sheet: 5 meters

Source: T. Knutson, Geophysical Fluid Dynamics Laboratory, NOAA. See:
http://www.gfdl.noaa.gov/~tk/climate_dynamics/climate_impact_webpage.html#section4

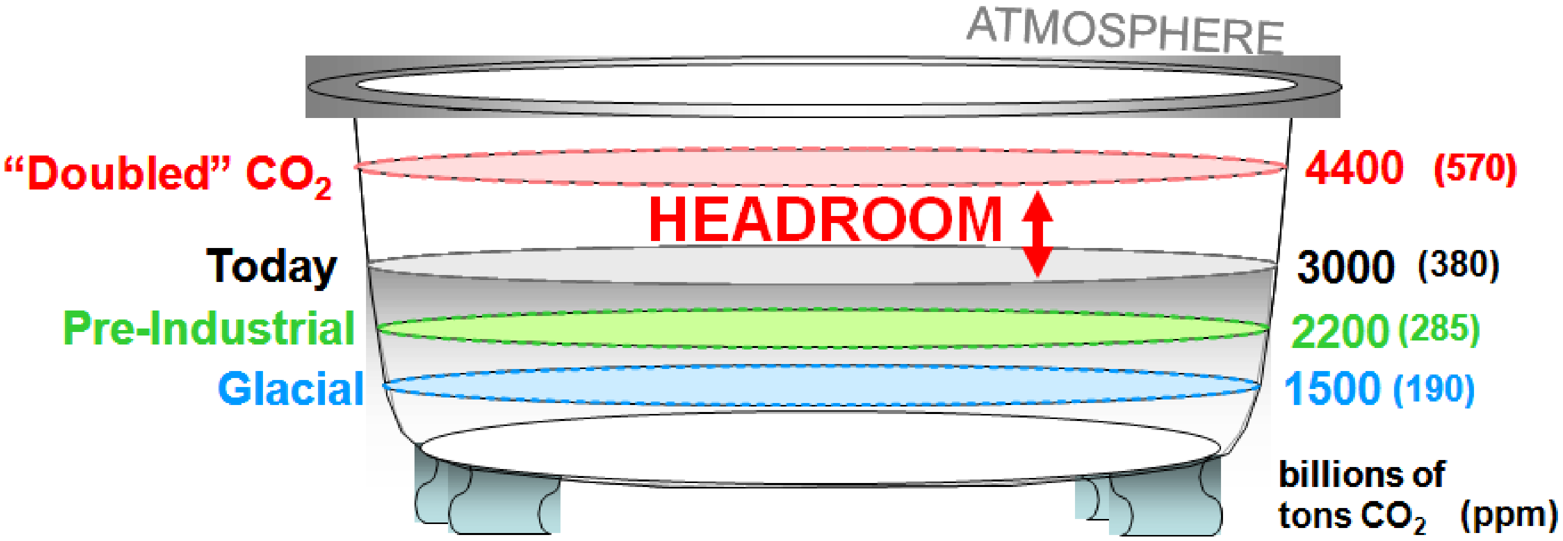
Our current climate is privileged

We planted crops where the rain fell and built our cities near rivers and coasts. So, we will grow different crops and move inland and perhaps abandon some very warm places. (A *falling* sea level would have required much dredging of harbors.)

Much disruption lies ahead.

Carbon Math

Past, present, and potential future levels of CO_2 in the atmosphere

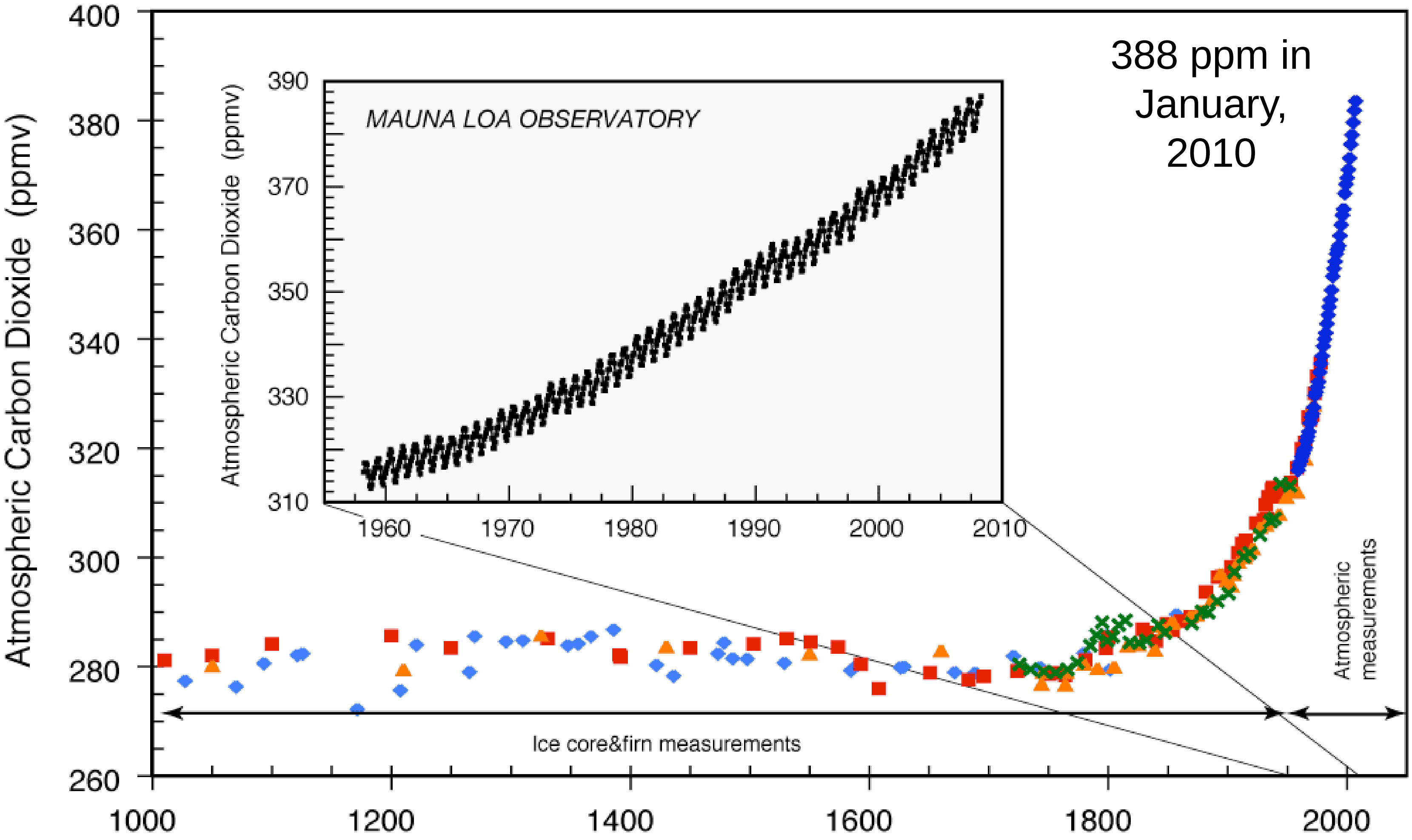


Rosetta Stone: To raise the concentration of CO_2 in the atmosphere by **one part per million:**

add **7.8 billion tons of CO_2,**

in which are **2.1 billon tons of carbon.**

Atmospheric CO_2 since 1000 AD



Source: Sarmiento. Ice core data from Barnola, 1999; Mauna Loa data from D. Keeling & T. Whorf, 2000

50 Years Forward and Back

550 ppm

Double the pre-industrial concentration

"3°C"

4000 $GtCO_2$

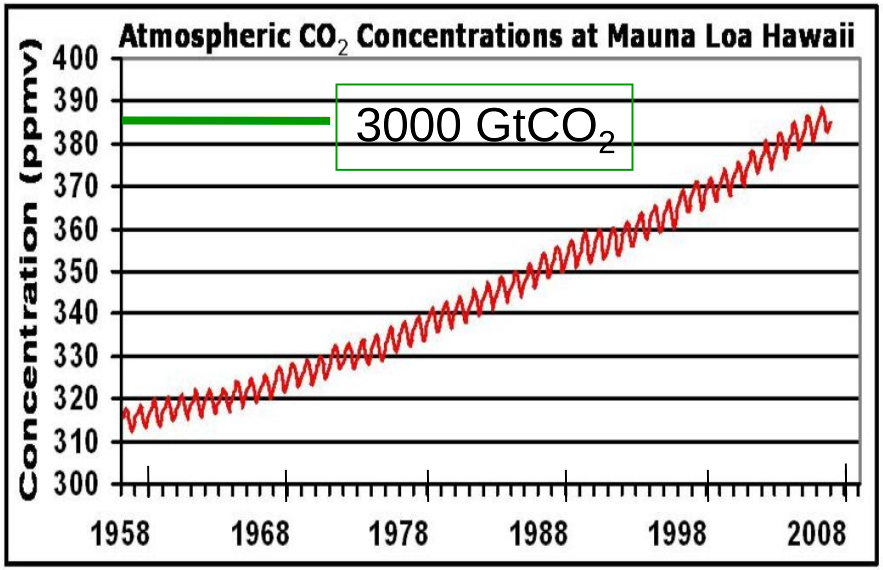
500 ppm

?

450 ppm

"2°C"

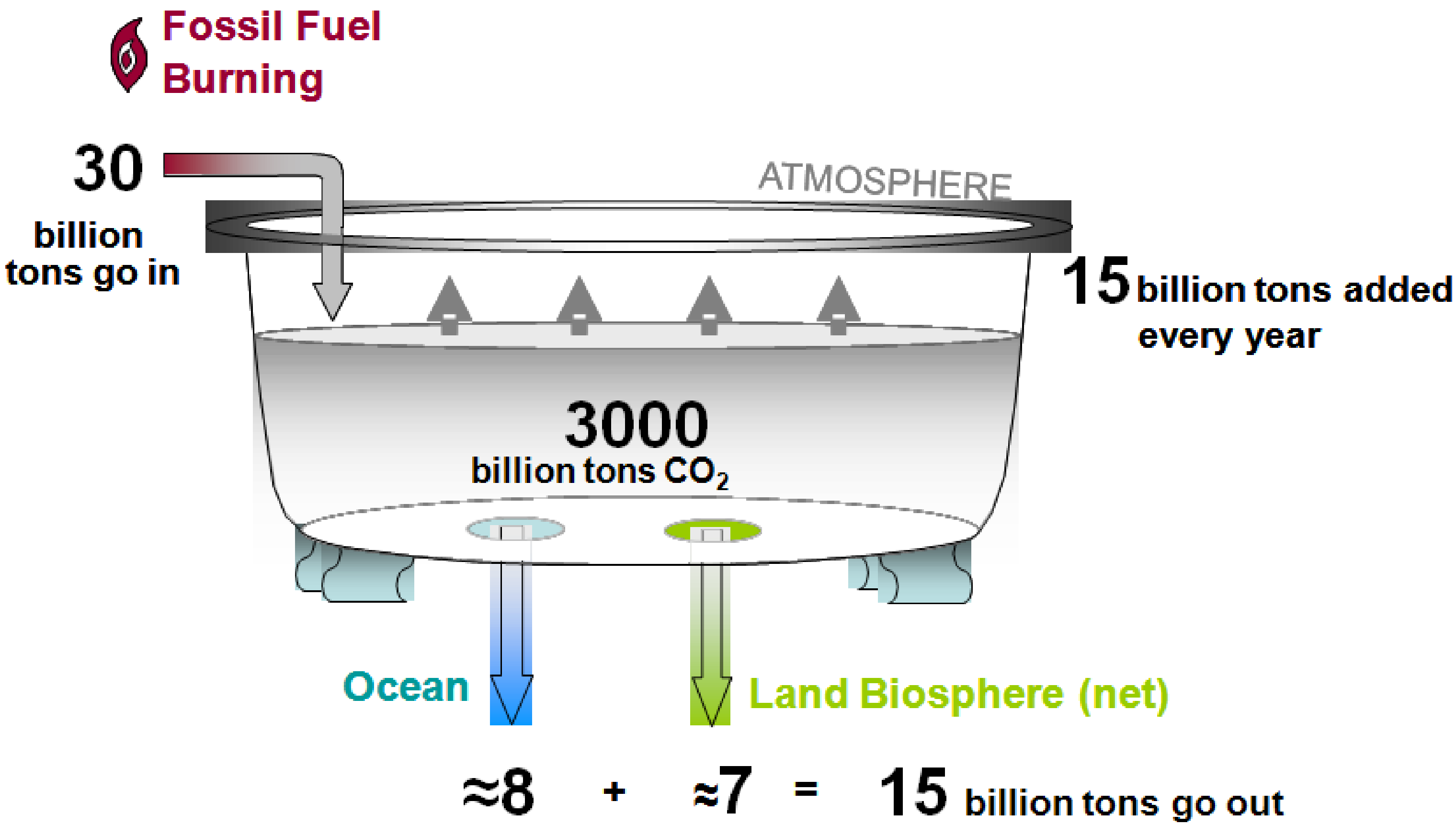
Up 2 ppm/yr



2061

http://cdiac.ornl.gov/trends/co2/sio-mlo.html

Yearly, fossil fuel burning adds 30 billion tons of CO_2 to the atmosphere, and half stays in.



Today, global per-capita emissions are ≈ 4 tCO_2/yr.

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

Activity	**Amount producing 4 ton CO_2/yr emissions**
a) Drive	24,000 km/yr, 5 liters/100km (45 mpg)
b) Fly	24,000 km/yr
c) Heat home	Natural gas, average house, average climate
d) Lights	300 kWh/month if all coal-power (1000 gCO_2/kWh) 600 kWh/month, natural-gas-power (500 gCO_2/kWh)

Florida 2008 electricity: 550 gCO_2/kWh (220 TWh, 120 $MtCO_2$); 50% of all Florida CO_2 is from electricity.

Princeton University CO_2 in 2007

University emissions*	112,000 tCO_2
12,500 participants**	
Per-capita emissions	9 tCO_2

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

What about UF?

Some messages for biologists

1. Fossil and biological carbon are the same, isotopes aside.
2. Augmentation of biocarbon stock is a greenhouse strategy: afforestation, soil management, (ocean uptake?).
3. Augmentation of bioenergy use is a greenhouse strategy: biofuels, biopower.
4. Values that biologists understand better than most others need to be protected: notably, food supply, ecosystem services, biodiversity.

The Global Carbon Cycle

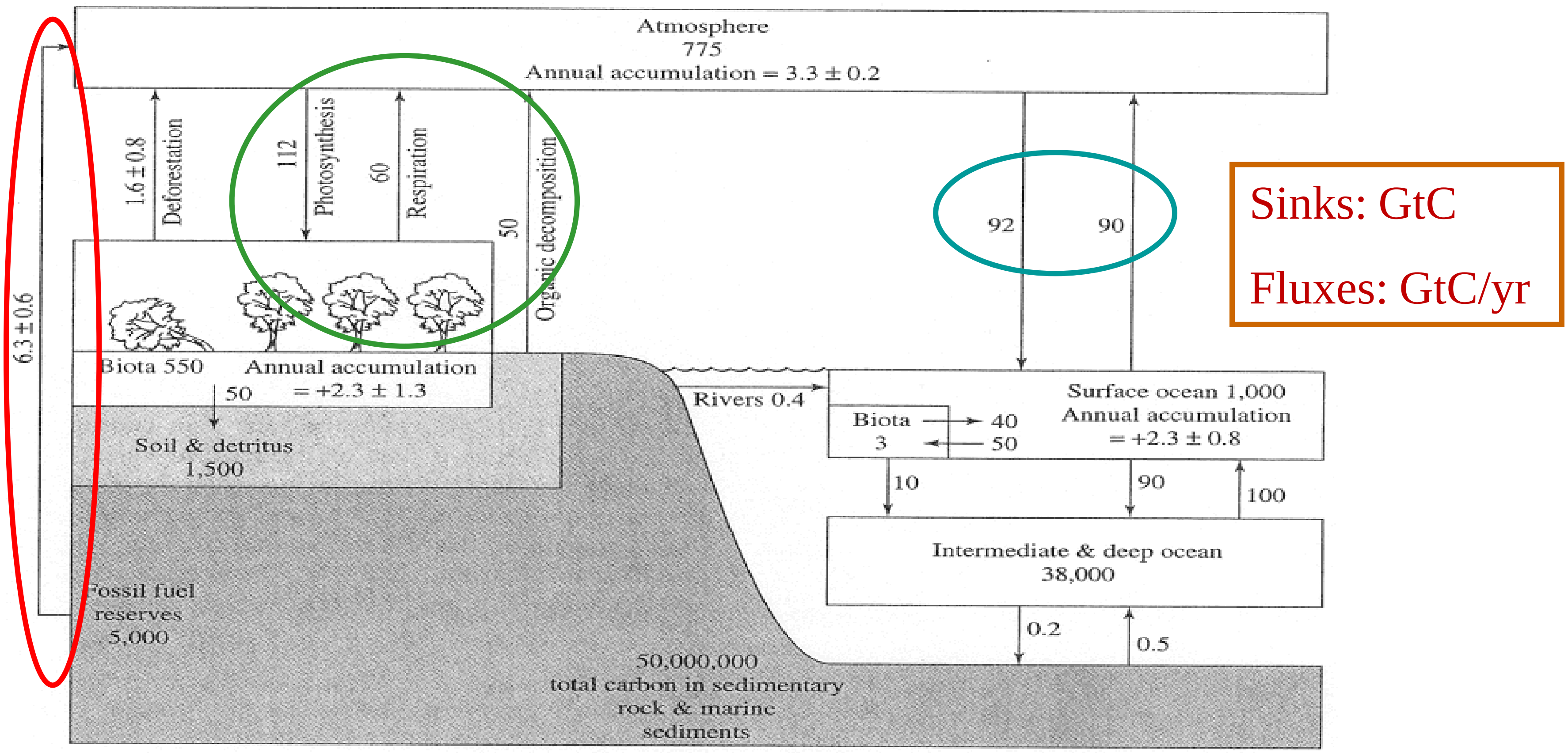
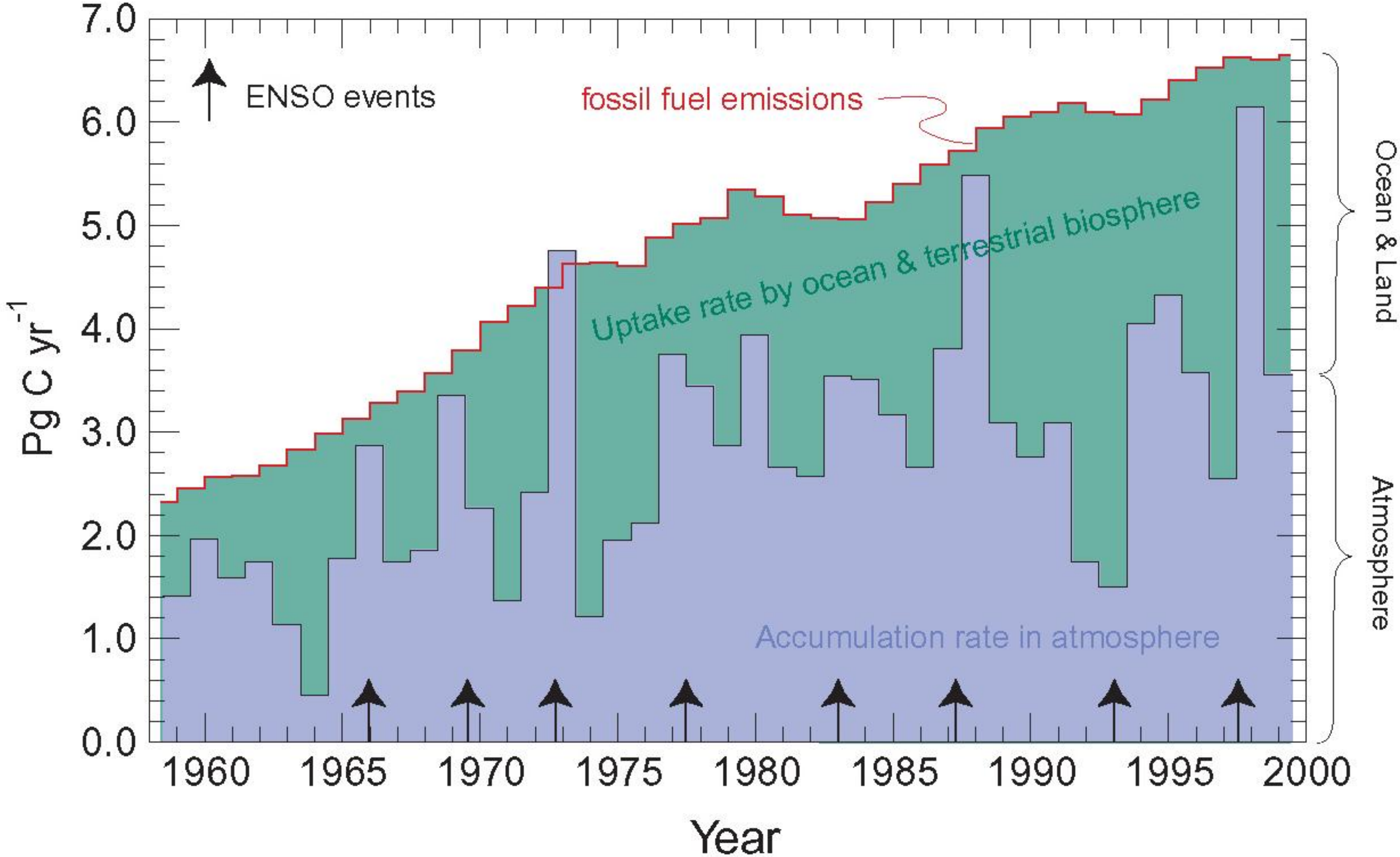


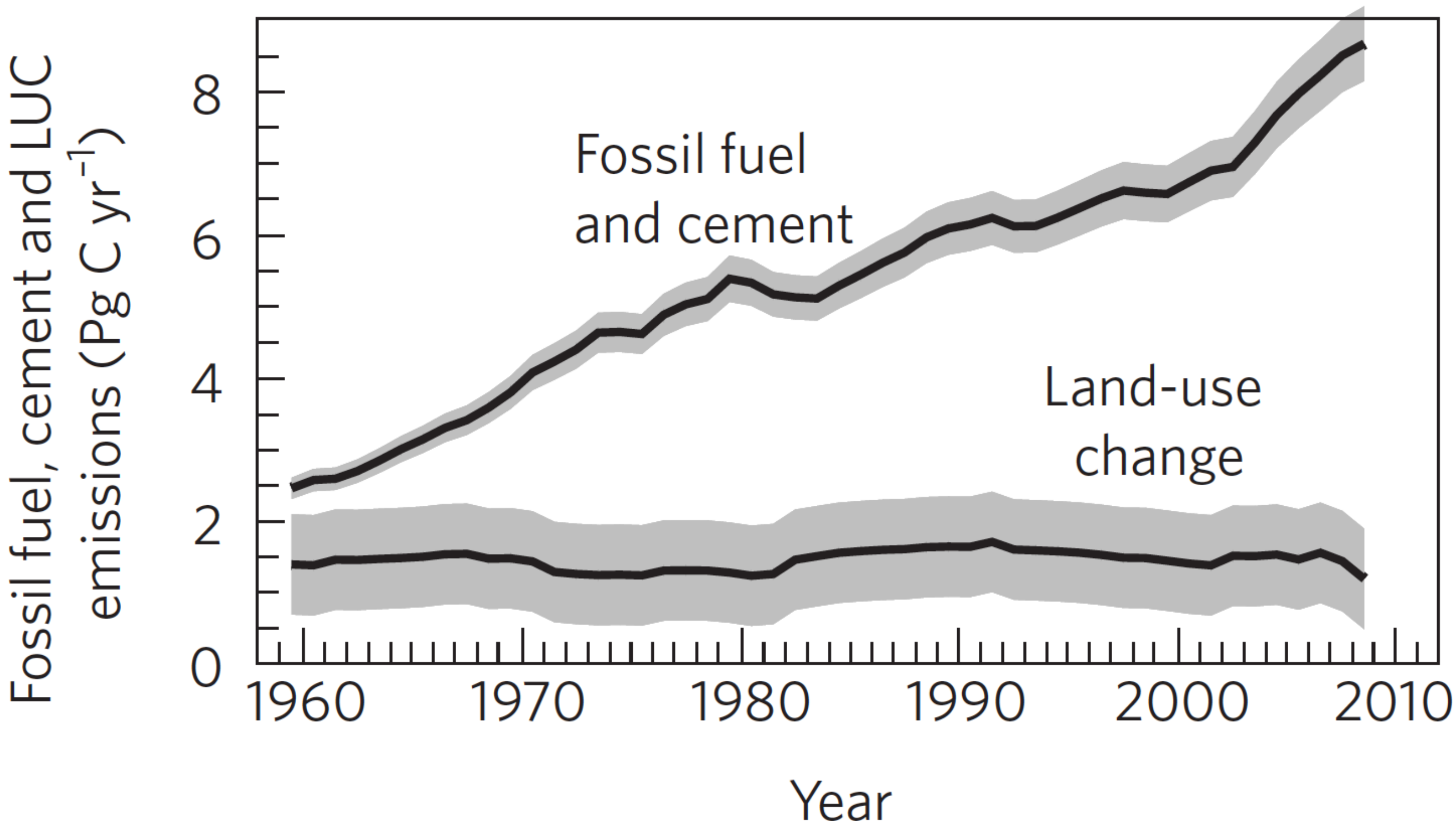
Figure 6.18 The carbon cycle (in Gt C for pools; Gt C/yr for fluxes). Net annual accumulation in biota is the difference between enhanced biomass accumulation (2.3 ± 1.3 Gt C/yr) and deforestation (1.6 ± 0.8 Gt C/yr), which equals about +0.7 Gt C/yr. *Sources:* Adapted from the Carbon Dioxide Information Analysis Center (2000). *Global Carbon Cycle (1992–1997)* (Oak Ridge National Laboratory, U.S. Department of Energy) (http://cdiac.esd.ornl.gov); Intergovernmental Panel on Climate Change (IPCC) (2000). *Summary for Policymakers, Land Use, Land-Use Change, and Forestry* (Geneva, Switzerland: World Meteorological Organization/United Nations Environment Programme).

Spiro & Stigliani, p. 171

Growth Rate of Carbon Reservoirs

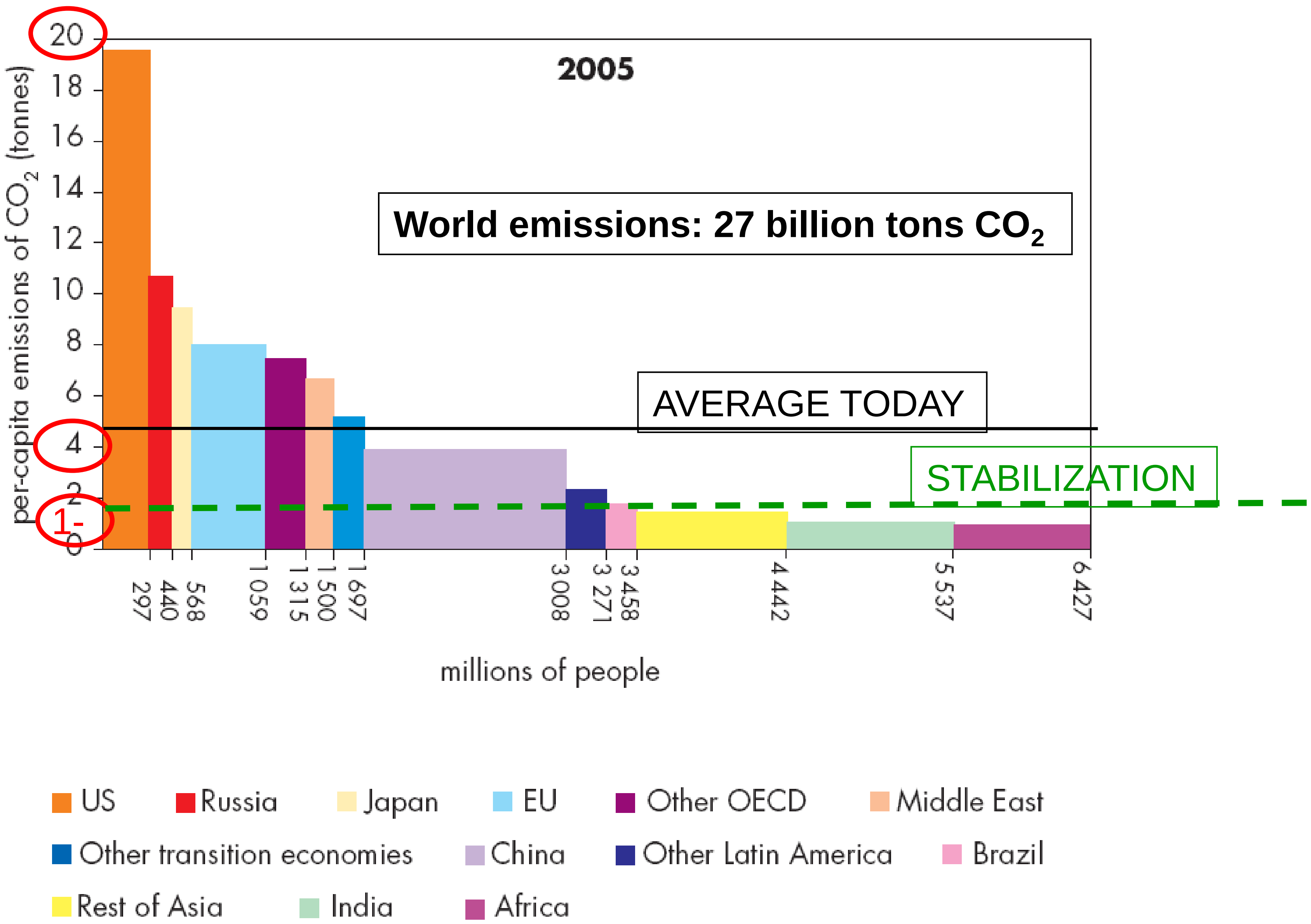


Land use change emissions have remained relatively constant over time



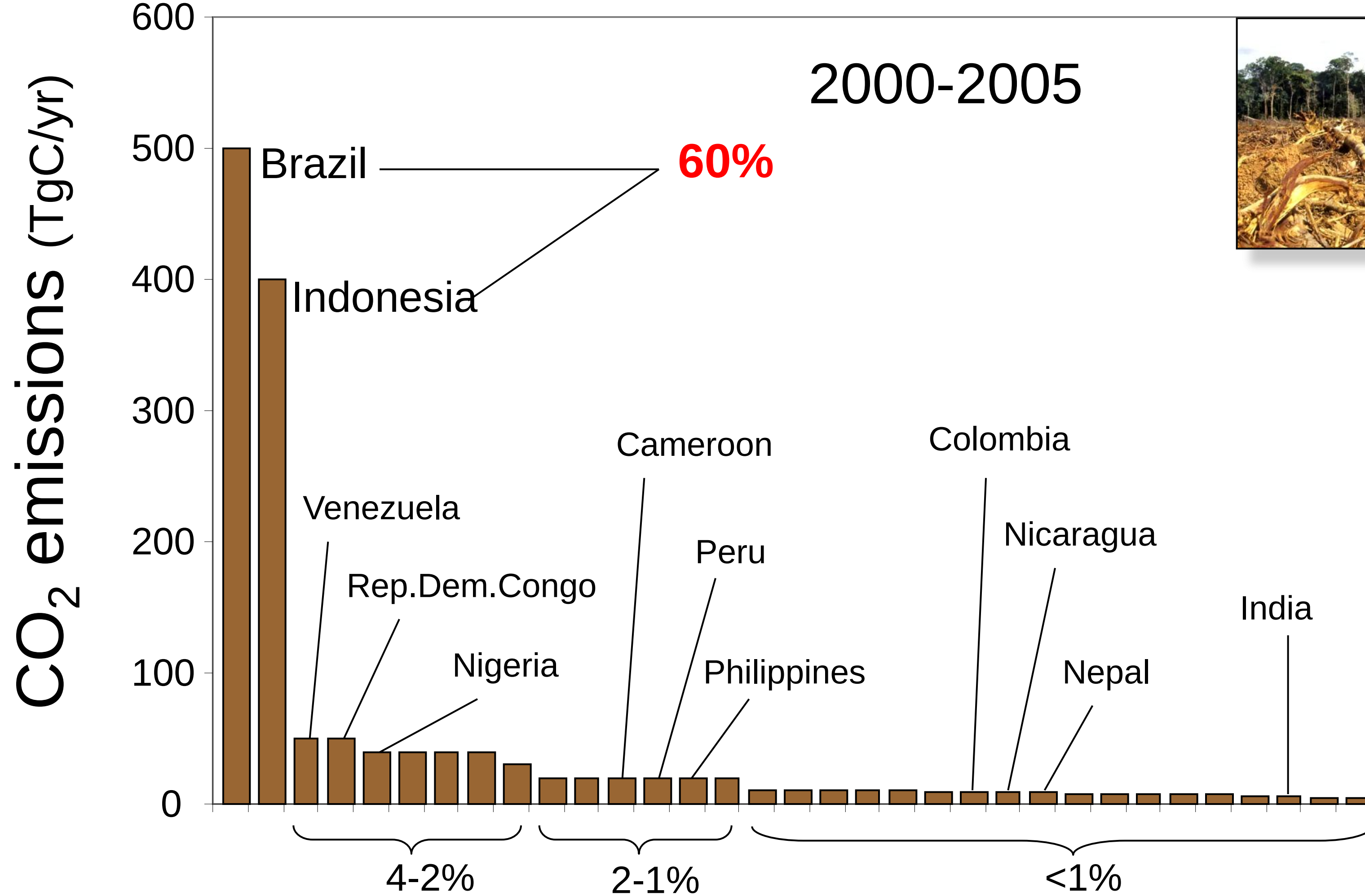
Le Quéré et al. (2009)

Per-capita fossil-fuel CO_2 emissions, 2005



Source: IEA WEO 2007

Net CO_2 emissions from land use change in tropical countries



Source: Sarmiento (privately), from RA Houghton 2009, unpublished, based on FAO land use change statistics

Global CO_2 budget

	2000-2008	
Sources (Pg C/yr)		
Fossil fuel + cement	7.7	0.4 (85%)
Land use	1.4	0.7 (15%)
Sinks (Pg C y^{-1})		
Atmospheric growth	4.1	0.1 (45%)
Ocean sink (models)	2.3	0.4 (26%)
Land sink (models)	3.0	0.9 (29%)
Residual (imbalance)	-0.3	1.3

Source: Sarmiento, from Le Quéré et al. (2009)

What would we do
if we took climate change seriously?
Set One

Frame the problem honestly

Admit that the news is unwelcome.

Admit that the job is hard and requires sustained focus.

Admit that we don’t know how large a problem we face.

A big new idea

Science has introduced a big, counterintuitive idea: *Human beings are able to change the planet at global scale.*

Forests have been cleared and fisheries have been depleted on a global scale. Most of the low-cost oil has been found. The surface oceans are already more acidic.

That we are changing the climate is just another example.

An unwelcome idea.

We would much rather live on a larger planet, where all our actions mattered less.

Our new assignment: "*Fitting on Earth.*"

Don't shoot the messenger

The messenger has been shot before.

Galileo argued that the earth wasn't at the center of the universe and was excommunicated.

Darwin argued that human beings were part of the animal kingdom and was cruelly mocked.

The idea that humans can't change our planet is as out-of-date and wrong as the earth-centered universe.

The job is hard

"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.

We are deciding only how fast to get there.

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

The "few" are today's climate science researchers.

The "many" are the rest of us.

We are asked to reduce our emissions.

Climate science today sends a difficult message

1. Neither mild nor severe climate change can be ruled out, given our poor understanding of feedbacks.
2. The probability of very bad outcomes is poorly known.
3. Breakthroughs are not imminent. We are not only flying blind, but the fog is not about to lift.

Grounds for optimism

1. The world today has a terribly inefficient energy system.
2. Carbon emissions have just begun to be priced.
3. Most of the 2061 physical plant is not yet built.
4. Very smart scientists and engineers now find energy problems exciting.

What would we do if we took climate change seriously? *Set Two*

Confront prosperity:

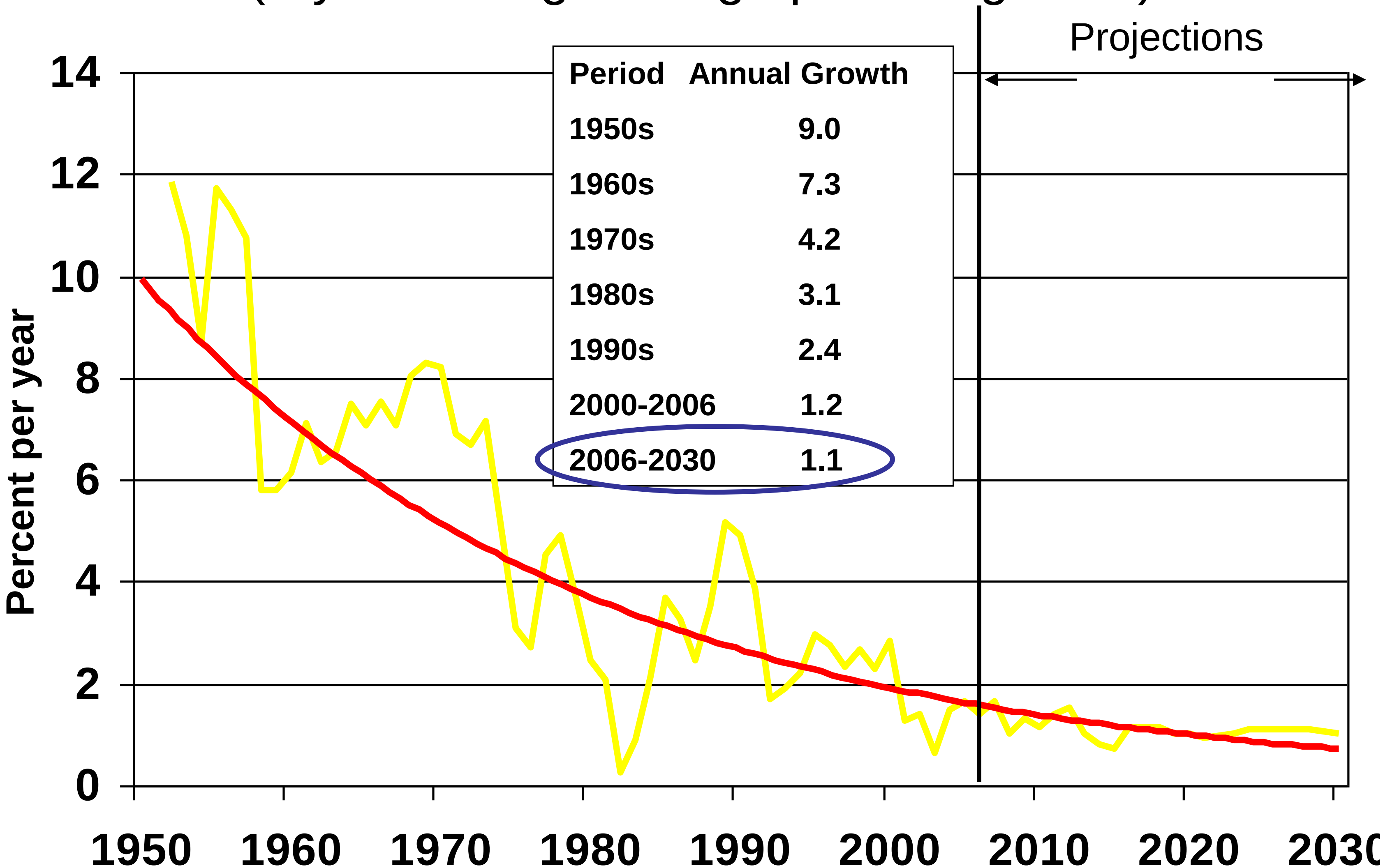
Assure that peak demand is behind us.

Measure, measure, measure.

Displace conventional coal plants.

U.S. electricity growth rate is falling

(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

Exponential curve (20 years for rate to fall by half): EIA

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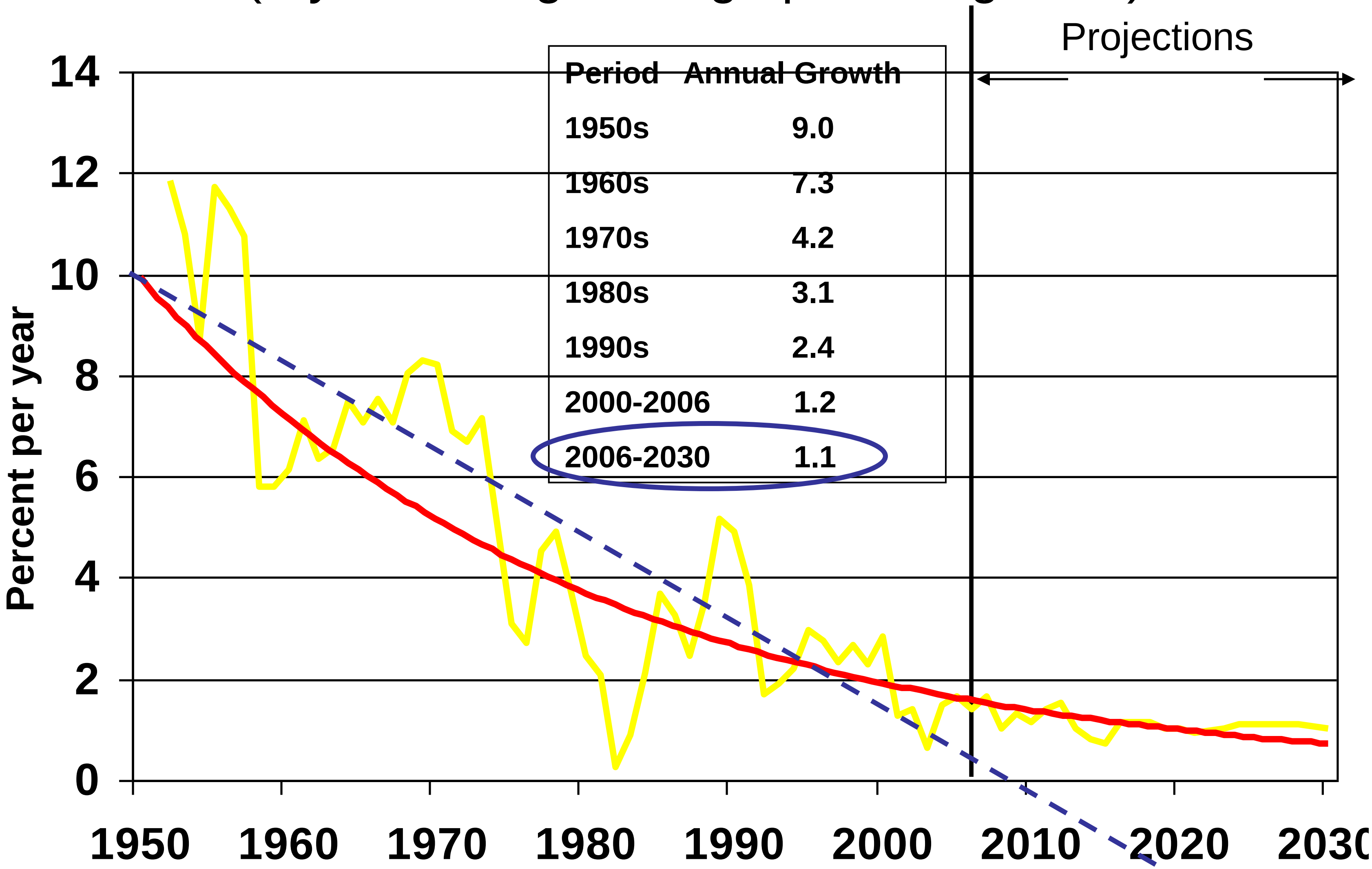

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Nothing in physics or economics forbids negative values! Blue dashed line: RHS.

Is peak energy demand behind us?

Annual US and OECD consumption from now on could be less than in any past year – for both:

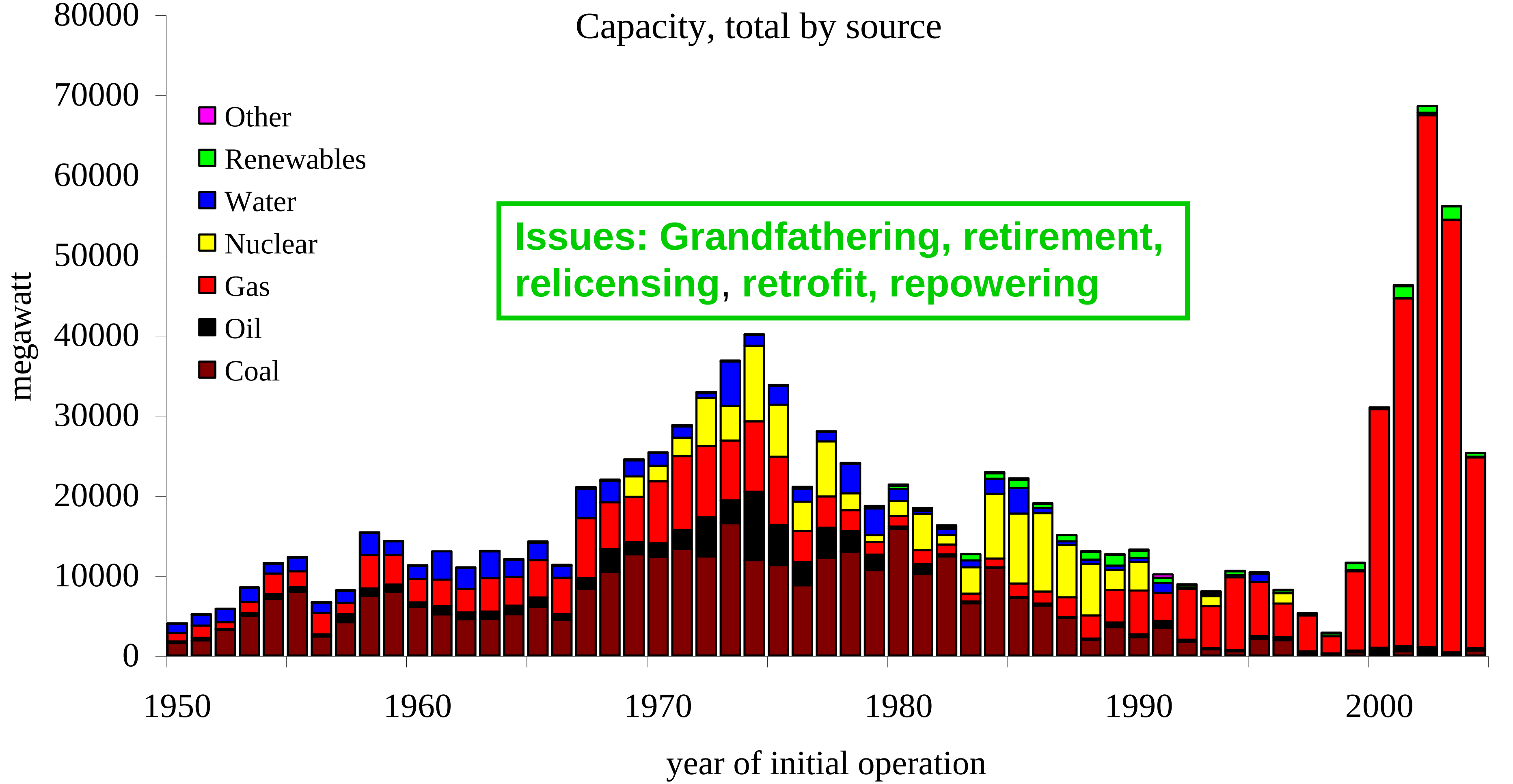
- oil consumption
- electric power consumption

Efficiency: Measure, measure, measure

Give architecture prizes for performance, not only for design.

Trust, but verify.

U.S. power plant capacity, by vintage



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

Zero minus zero equals zero

Where there is no load growth and there are no retirements, nothing new needs to be built.

Note: Demand can grow in some regions, fall in others.

The future coal power plant

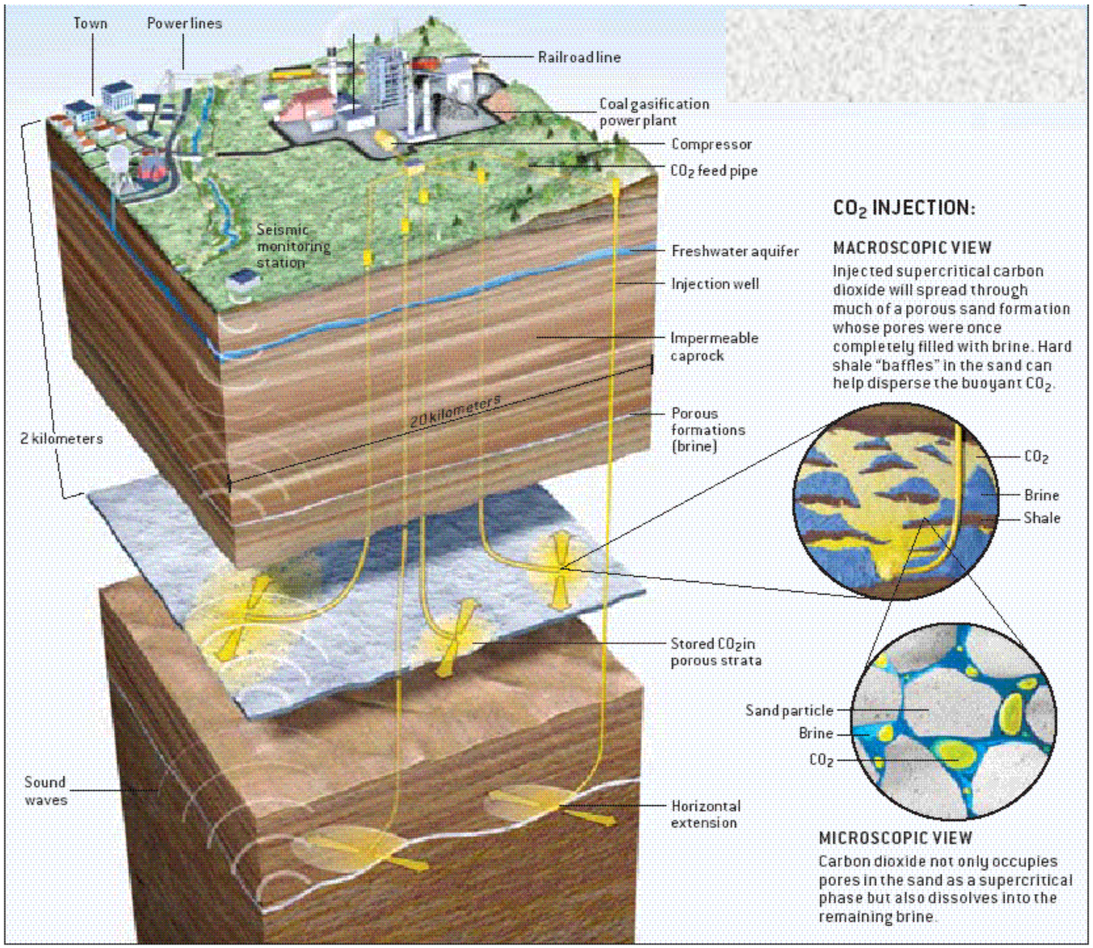


ILLUSTRATION BY DAVID FIERSTEIN; CONCEPT BY JULIO FRIEDMANN *Lawrence Livermore National Laboratories*

www.sciam.com SCIENTIFIC AMERICAN 51

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.

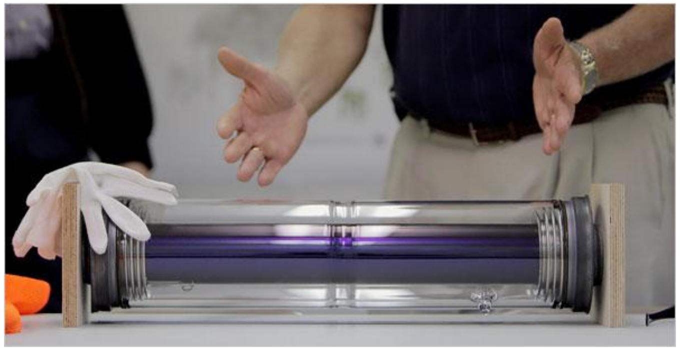
Injection rate is 150,000 bbl(CO_2)/day, or 300 million standard cubic feet/day (scfd). Lifetime injection: 3 billion barrels, or 6 trillion standard cubic feet, over 60 years.

An immense bet on renewables

Obama, Chu, Holdren, *et al.*: Use-inspired science will deliver new, competitive options – especially, renewables.

ARPA-E, Hubs, Centers,…

Concentrating Solar Power (CSP)



Florida Power and Light's "Next Generation Solar Energy Center," Martin County: 75 MW, 500 acres, 190,000 mirrors.

Photovoltaic Power

Graphics courtesy of DOE Photovoltaics Program

Every strategy can be implemented well or poorly

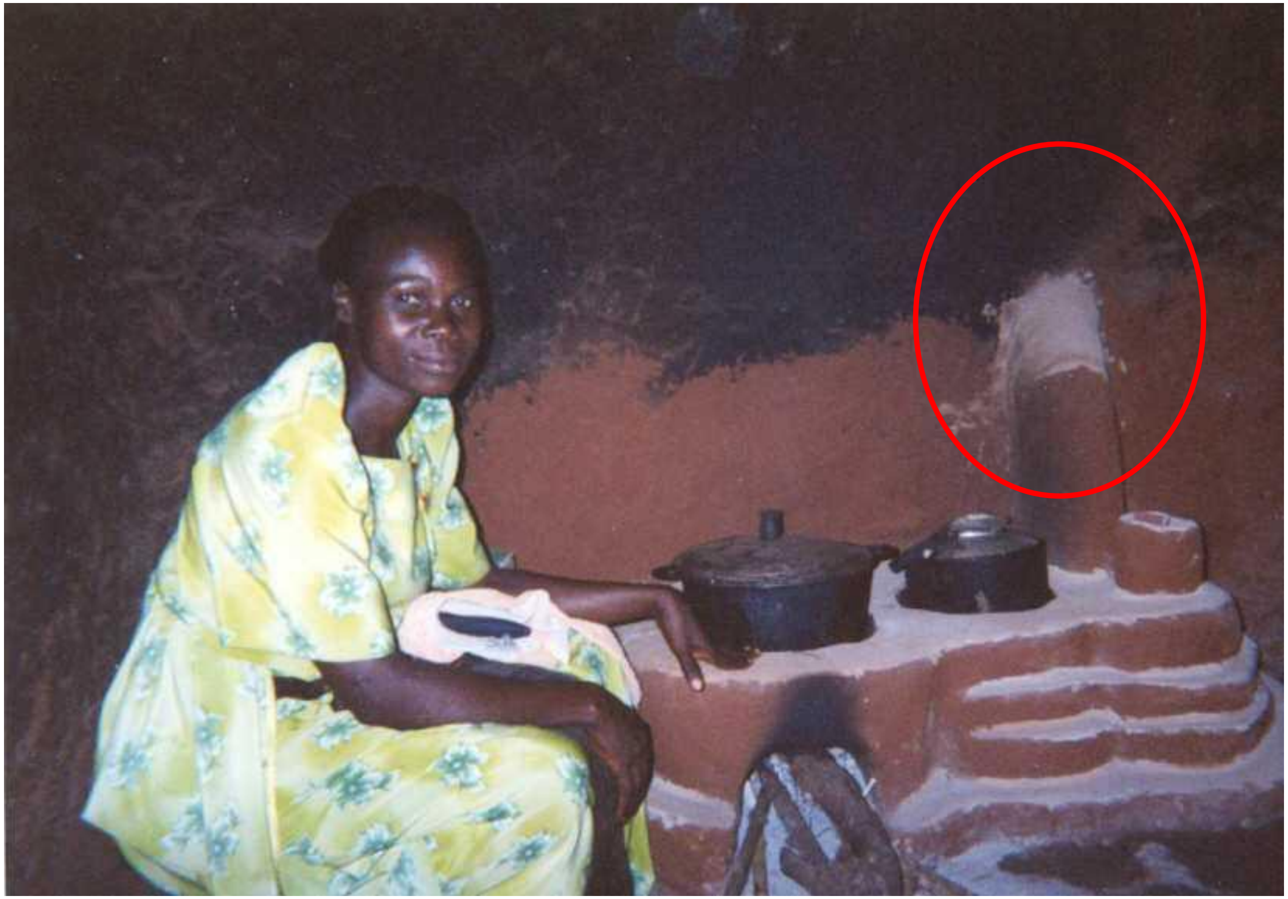
Every “solution” has a dark side.

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

Risk management: We must trade the risks of disruption from climate change against the risks of disruption from mitigation.

Concluding Thoughts

Indoor air pollution: No. 1 adverse health impact of energy



Here: a vented wood stove. Later, a gas stove – fueled by *either* biogas or fossil-gas (LPG, DME).

The developing world will decide what kind of planet we live on

For a while longer, the industrialized countries will lead.

The world can't solve the climate problem without moving beyond "per capita" – looking *inside* countries.

What if "common but differentiated responsibilities" refers to individuals instead of nations?

Cherish the scientific method

It's worth at least 0.1C.*

*At 2000 $GtCO_2/^oC$, 200 $GtCO_2$ (seven years of emissions).

Imagine dealing with climate change without it.

Prospicience

Prospicience: “The art [and science] of looking ahead.”

In the past 50 years we have become aware of 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 years and *vs.* 5000 years? Prospicience is needed to address planning horizons, infrastructure, waste management….

We have scarcely begun to ask: What are we on Earth to do?

Fitting on the 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.

Co-authors, recent papers

Wedges

Steve Pacala
Roberta Hotinski
Jeff Greenblatt (now, Lawrence Berkeley Laboratory)

Nuclear power

Alex Glaser

One-billion high emitters

Shoibal Chakravarty
Massimo Tavoni (FEEM, Milan)
Steve Pacala
Ananth Chikkatur (then, Harvard; now ICF in D.C.)
Heleen de Coninck (ECN, Netherlands)