Setting the Stage

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The Future of Nuclear Energy

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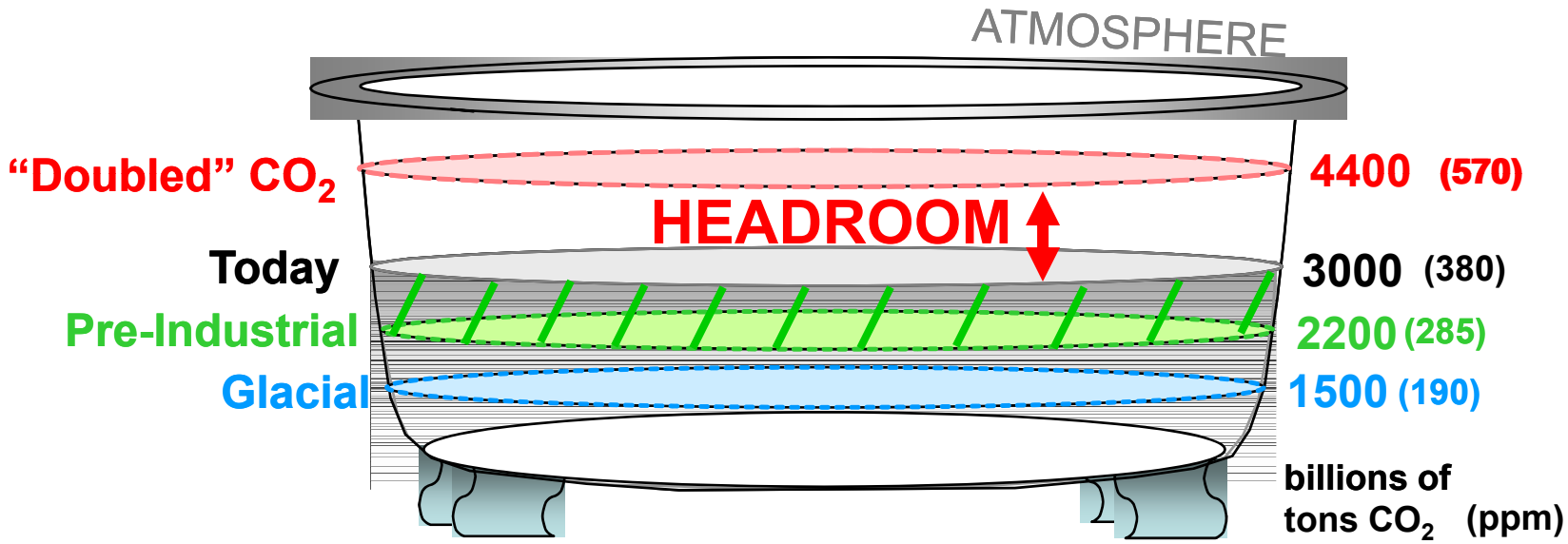
Outline

1. Carbon math for the planet
2. Nuclear wedges and competing wedges
3. The promise and the perils of global nuclear power

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



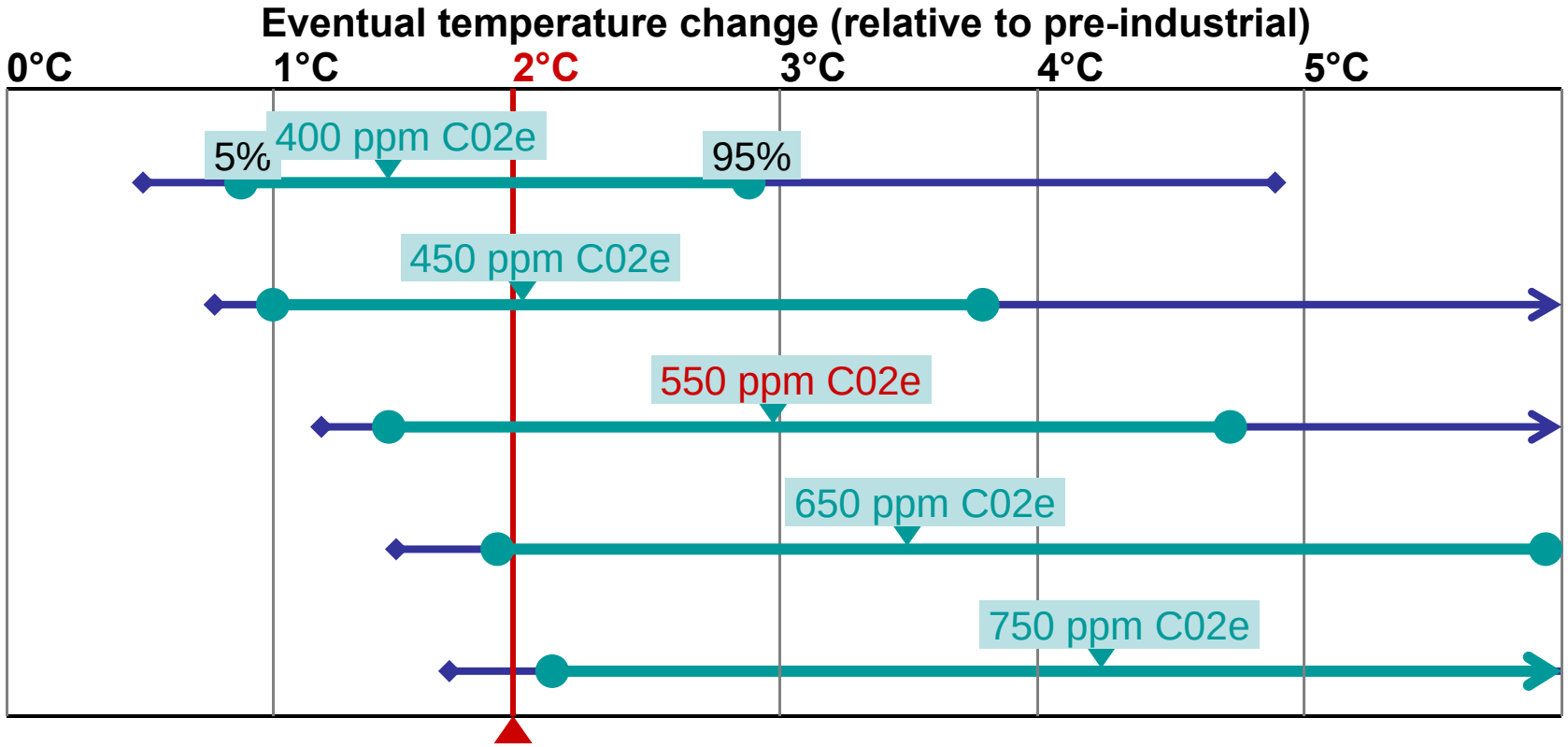
Rosetta Stone: To raise the concentration of CO_2 in the atmosphere by **one part per million:**

add **7.7 billion tons of CO_2,**

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

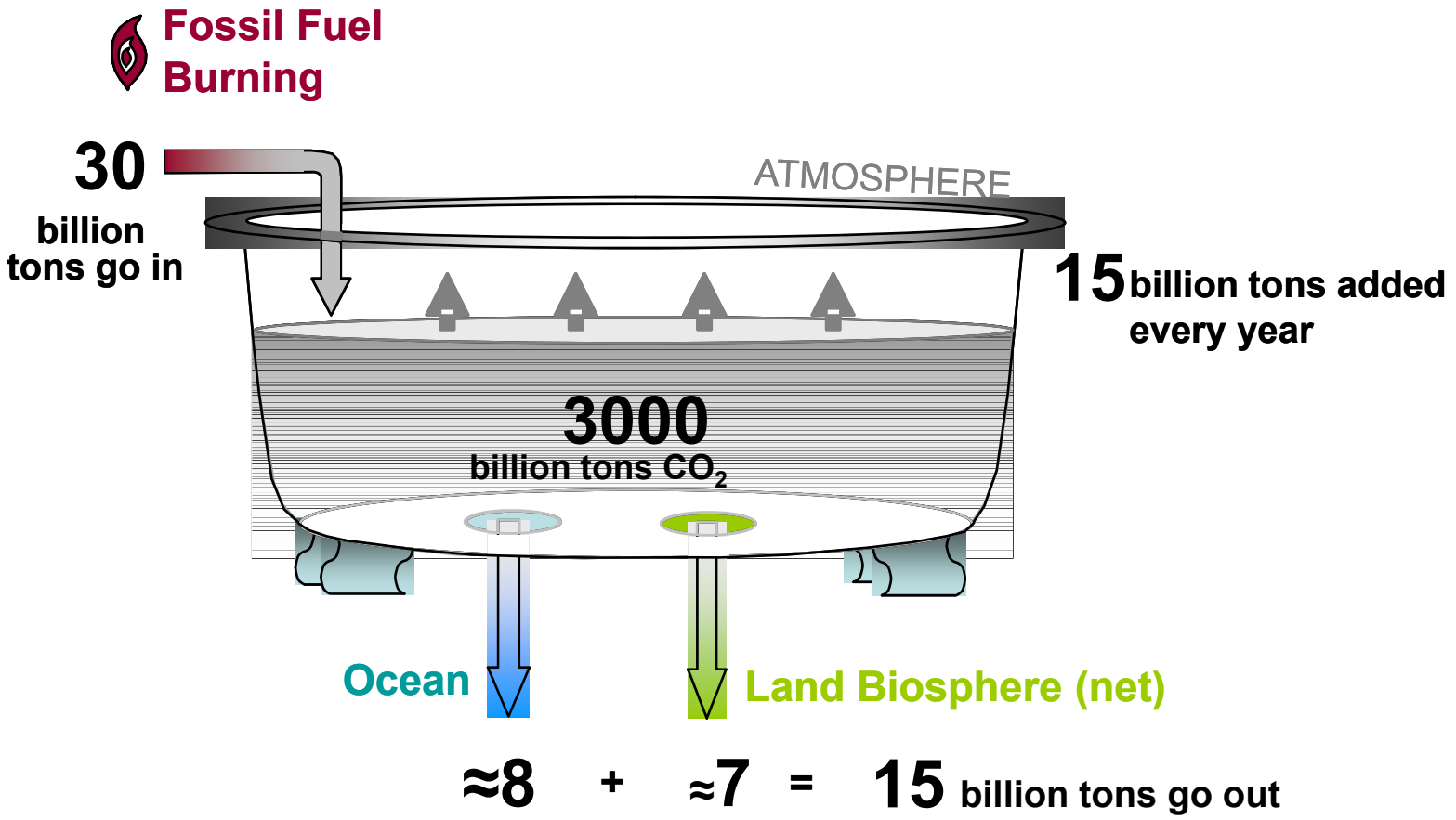
When we choose a target (with its headroom), we are buying insurance, managing risk.

The worst and the best outcomes compatible with today's science are entirely different. There is no line in the sand, with safety on one side and disaster on the other.



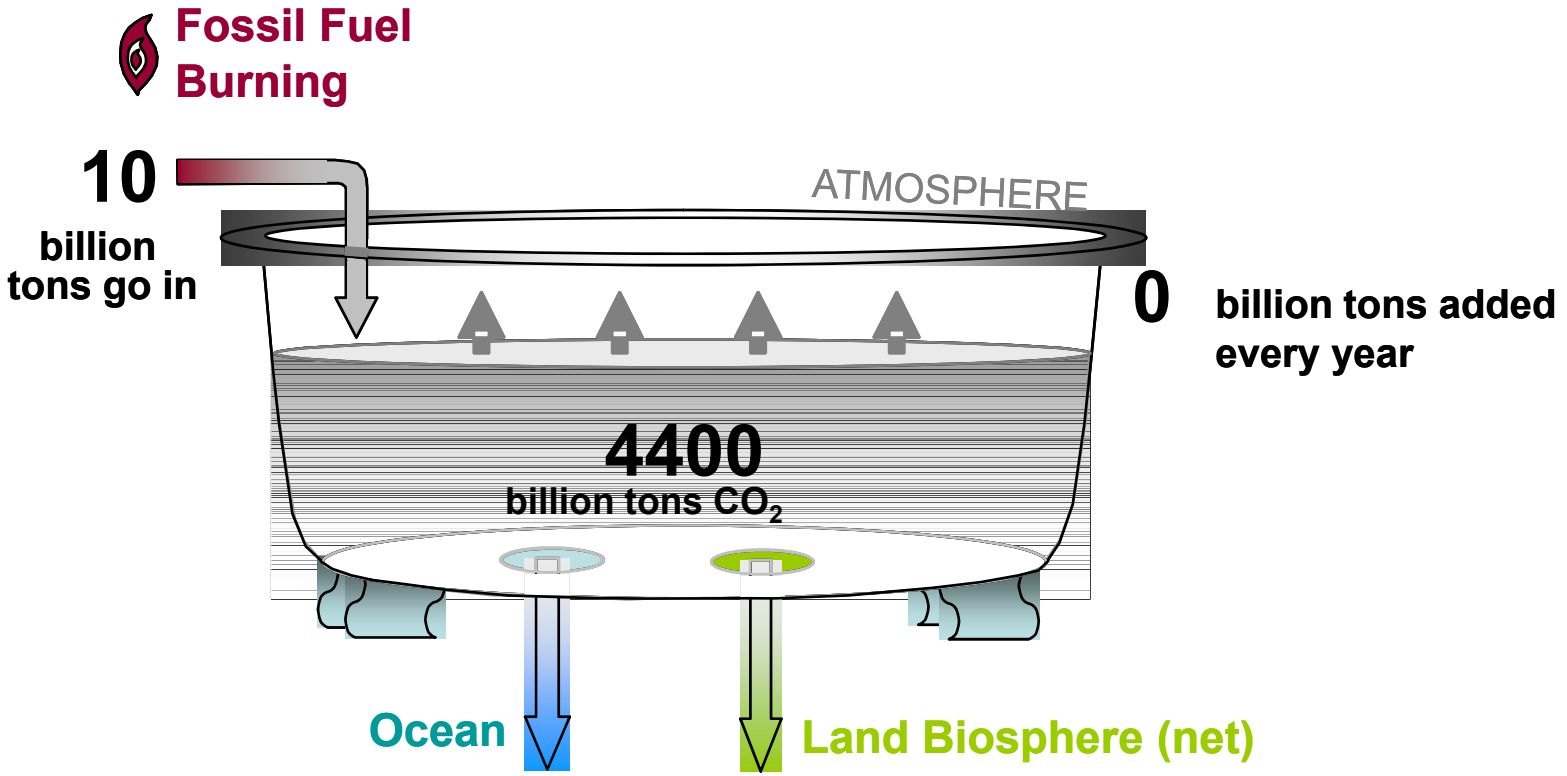
Source of data: Stern Review, 2006 citing Wigley et. al.; Murphy et. al.; Meinshausen. Based on a slide prepared by Hal Harvey.

About half of the carbon we burn stays in the atmosphere for centuries



Today, global per-capita emissions are ≈ 5 tCO_2/yr.

At “stabilization,” allowed emissions are about one-third of today’s.



Shown here: Stabilization at double the pre-industrial concentration.

“Stabilization”: 1 tCO_2/capita-yr

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 carbon emissions per capita in a climate-stabilized world are *not much more than 1 ton of CO_2 per year*, 20 times less than those of the average American today.

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

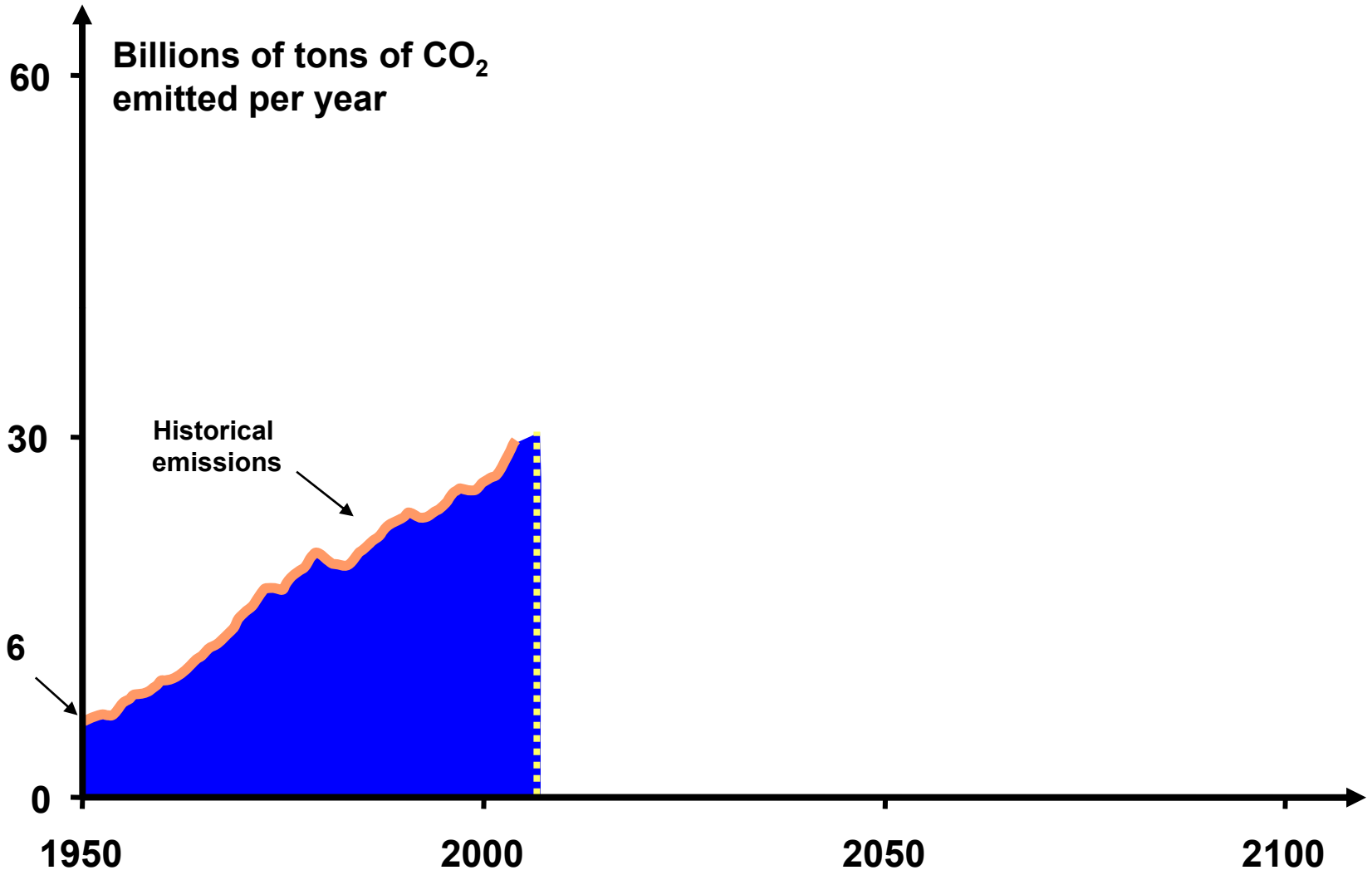
…not the other way around.

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

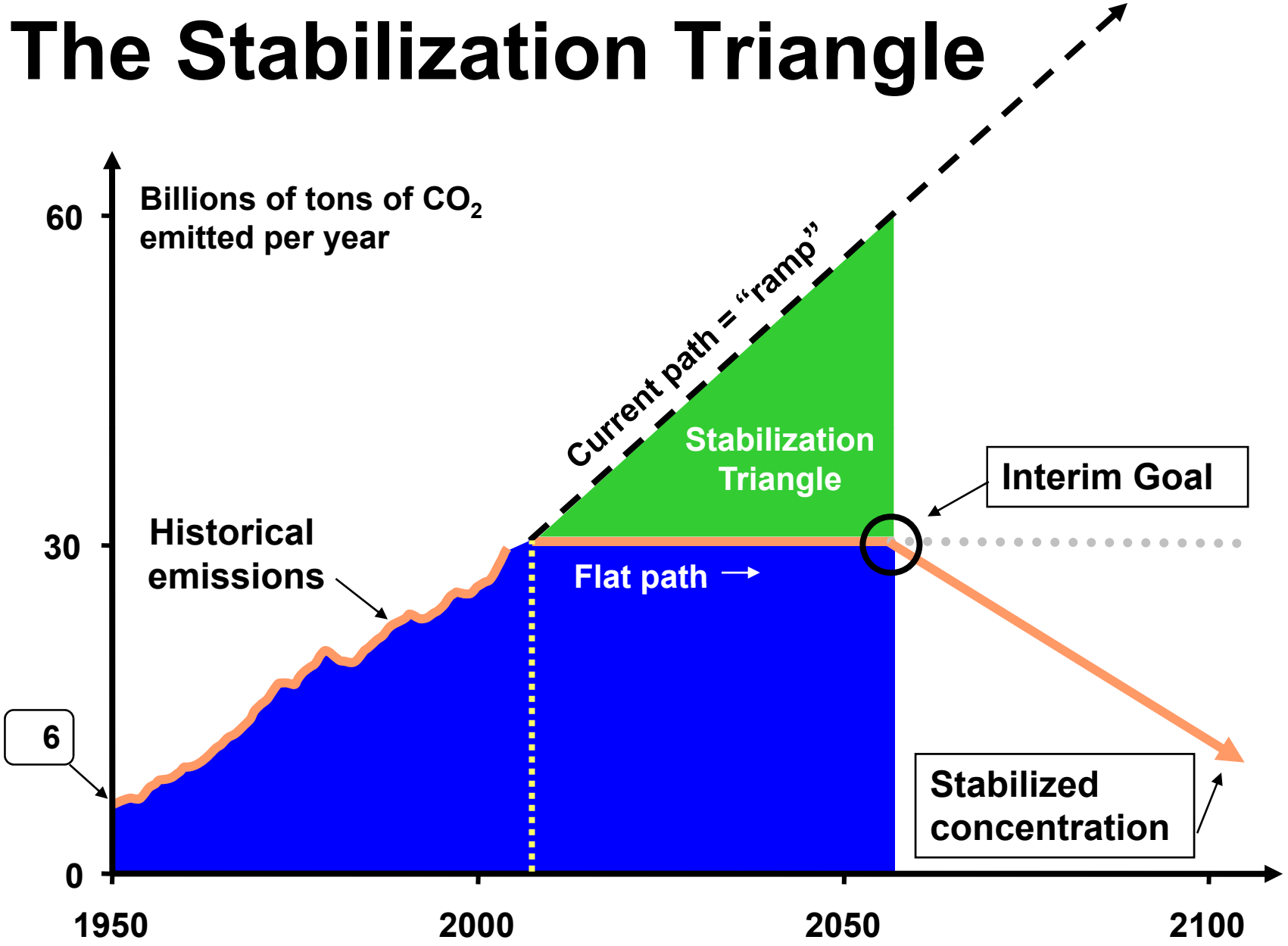
Nonetheless, grounds for optimism:

- 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.

Historical Emissions

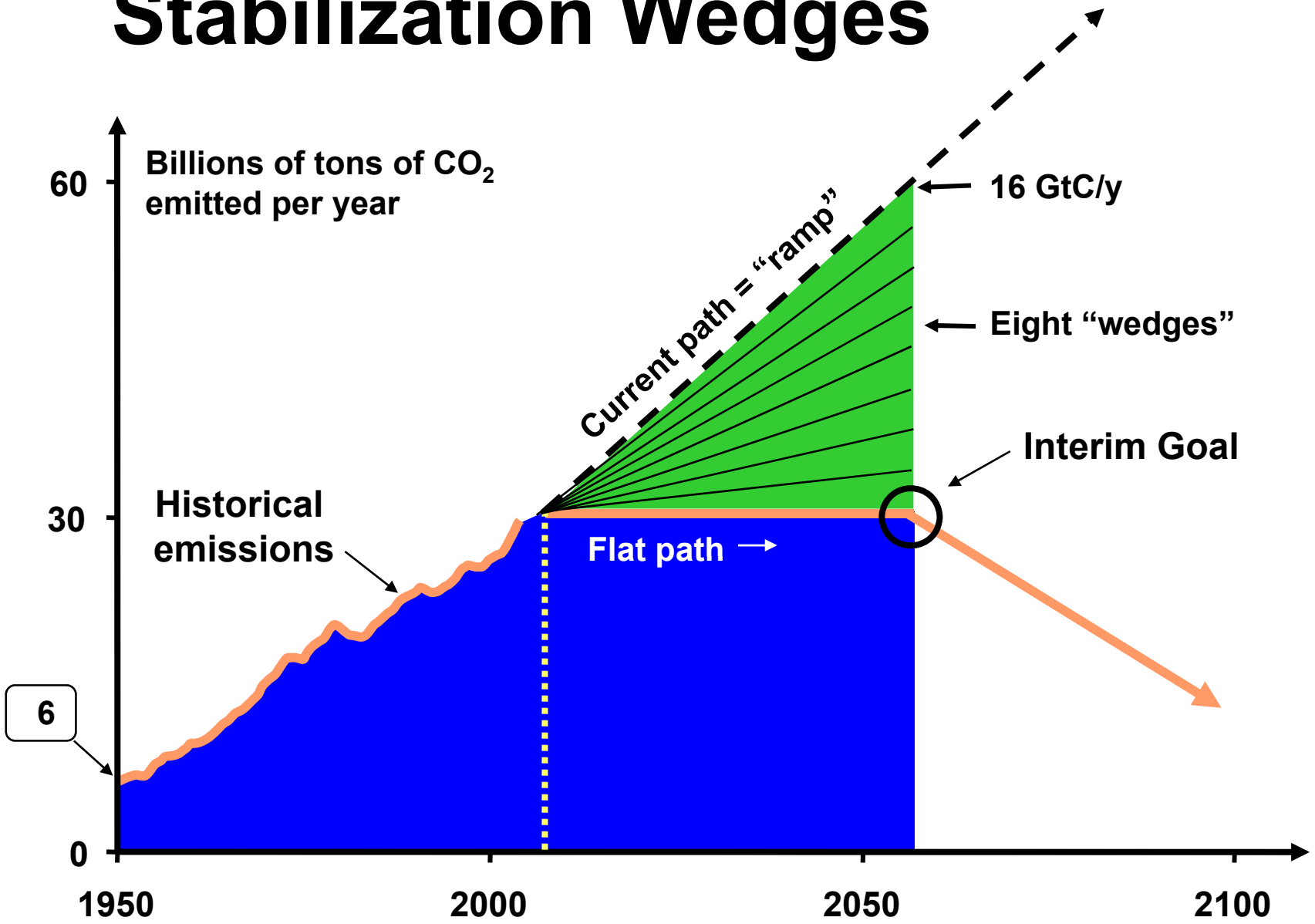


The Stabilization Triangle



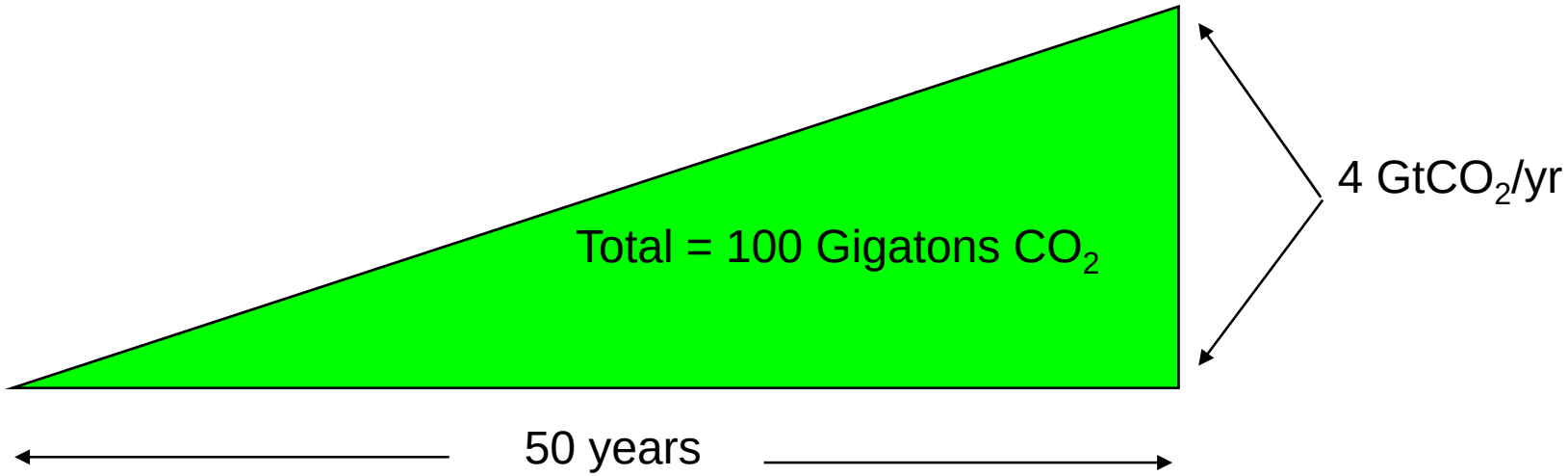
Today and for the interim goal, global per-capita emissions are ≈ 4 to 5 tCO_2/yr.

Stabilization Wedges



What is a “Wedge”?

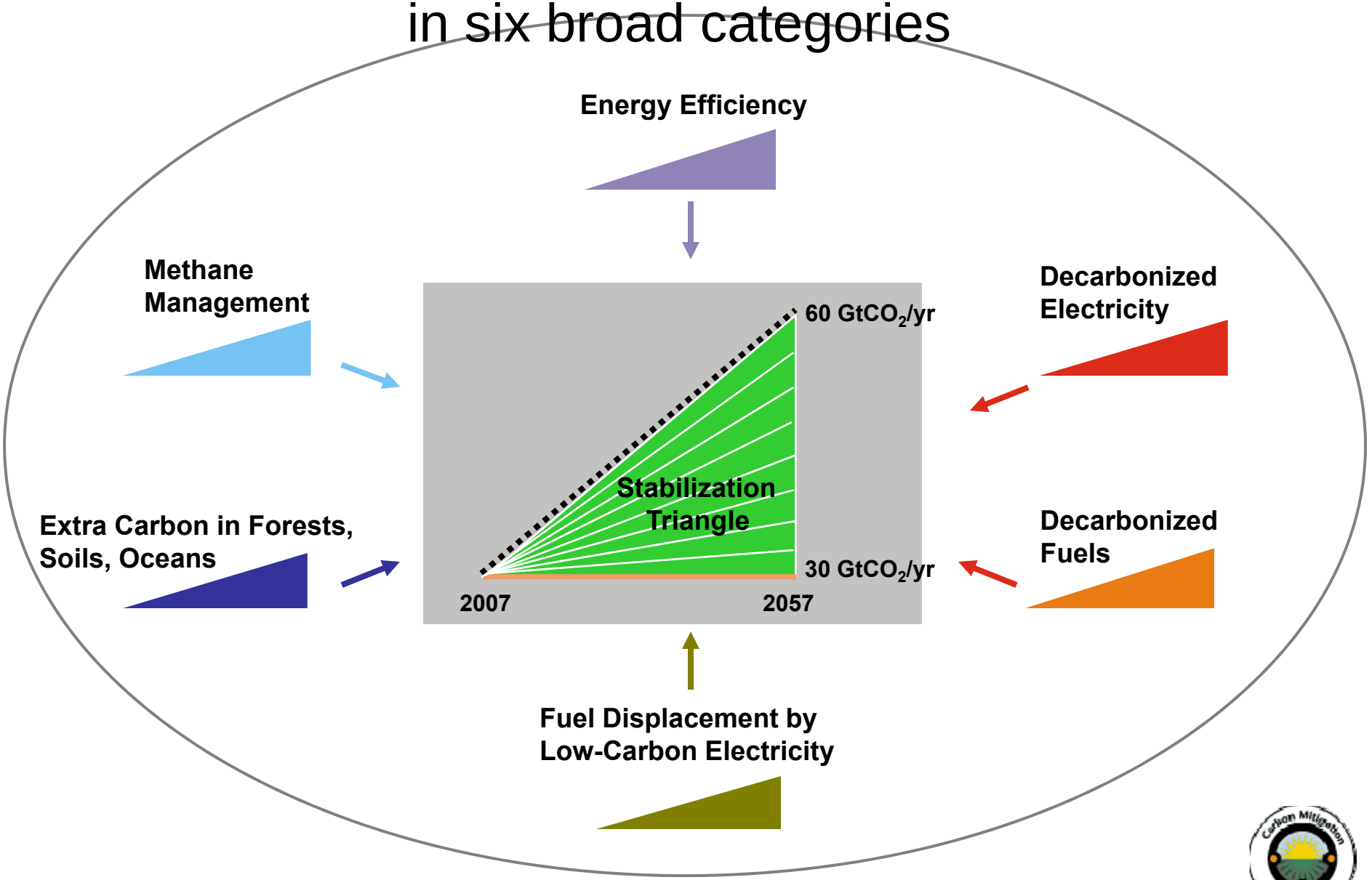
A “wedge” is a strategy to reduce carbon emissions that grows in 50 years from zero to 4 $GtCO_2$/yr. The strategy has already been commercialized at scale somewhere.



Cumulatively, a wedge redirects the flow of 100 $GtCO_2$ in its first 50 years. This is **three trillion dollars** at \$30/tCO_2.

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

Fill the Stabilization Triangle with Eight Wedges in six broad categories



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

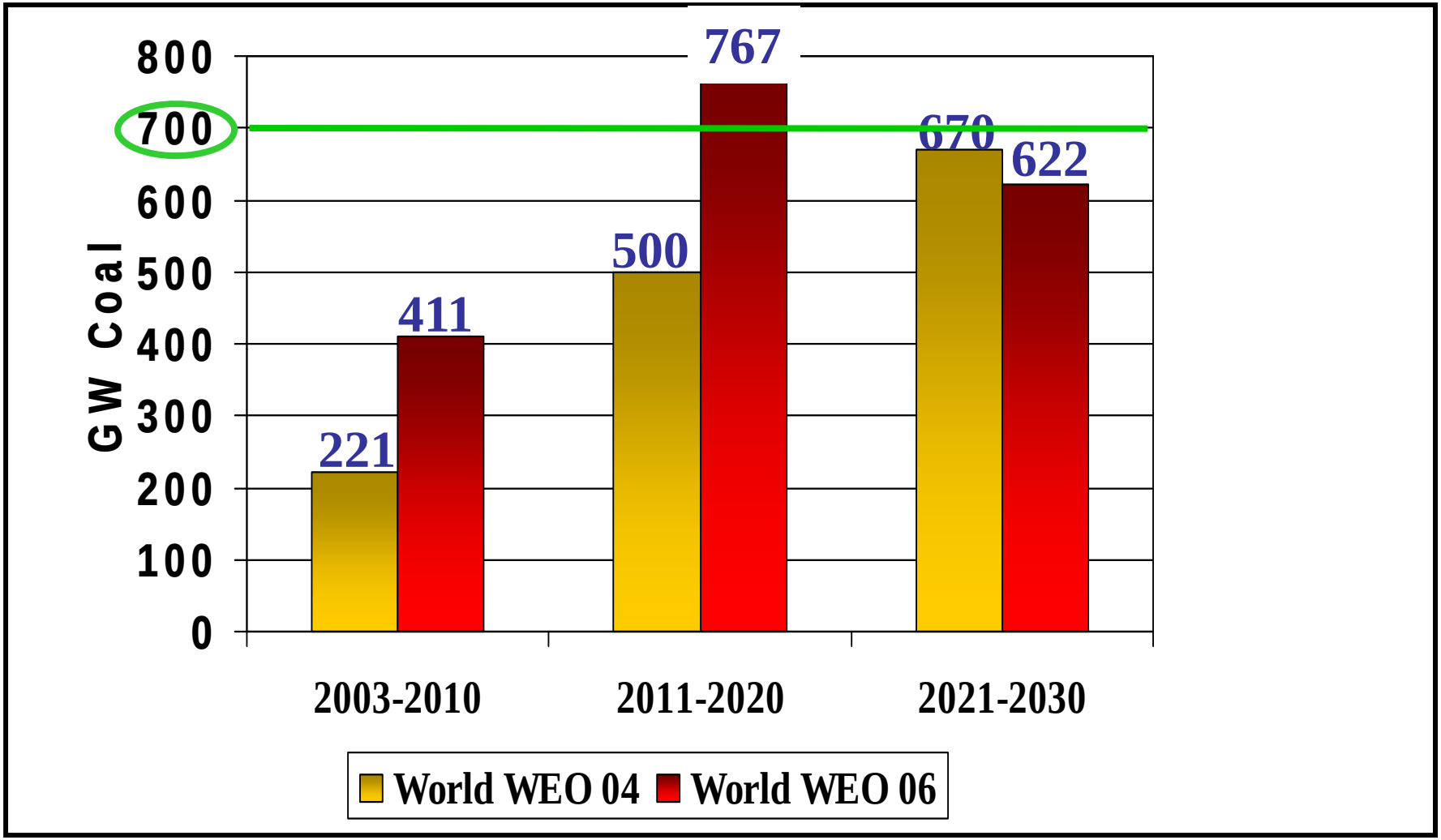
David Hawkins, NRDC, 2007.

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

Wedges that avoid construction of conventional coal plants

700 GW of baseload coal plants, with CO_2 vented, emit 4 billion tons of CO_2 each year. So, one wedge results from not building these plants.

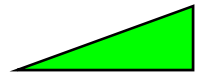
The Rush to Coal



Incremental new coal capacity by decade

***Source*:** IEA, WEO 2004, 2006 (preliminary data, reference case), via NRDC.

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, not for forever.

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

Wind Electricity

Effort needed by 2055 for 1 wedge:

One million 2-MW windmills displacing coal power.

2008: 100,000 MW (5%)

Wind turbines invisible from the shore.

Source: Hal Harvey, TPG talk, Aspen, CO, July 2007

Photovoltaic Power

#1: Distributed, connected to smart grid

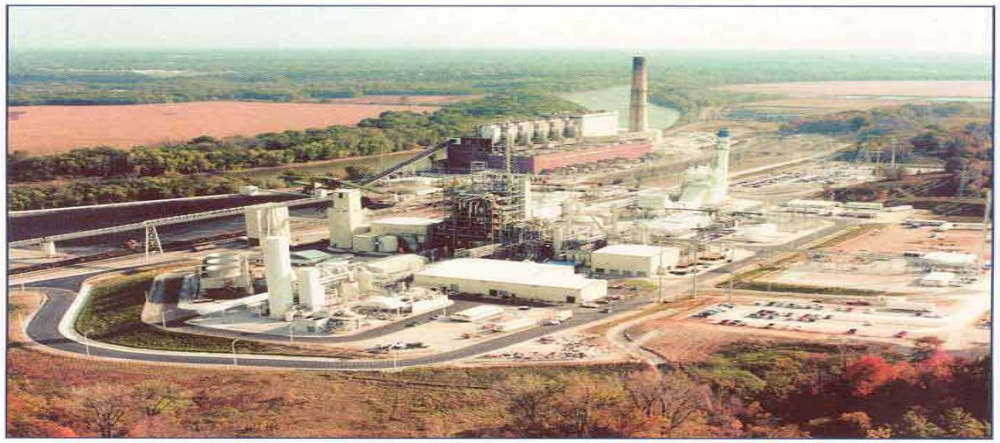
Effort needed by 2055 for one wedge:

2000 GW_{peak} (250 x capacity in 2007)

200 million 100-m^2 rooftop units
(80 x 100 miles of desert collectors)

Graphics courtesy of DOE Photovoltaics Program

Coal with Carbon Capture and Storage



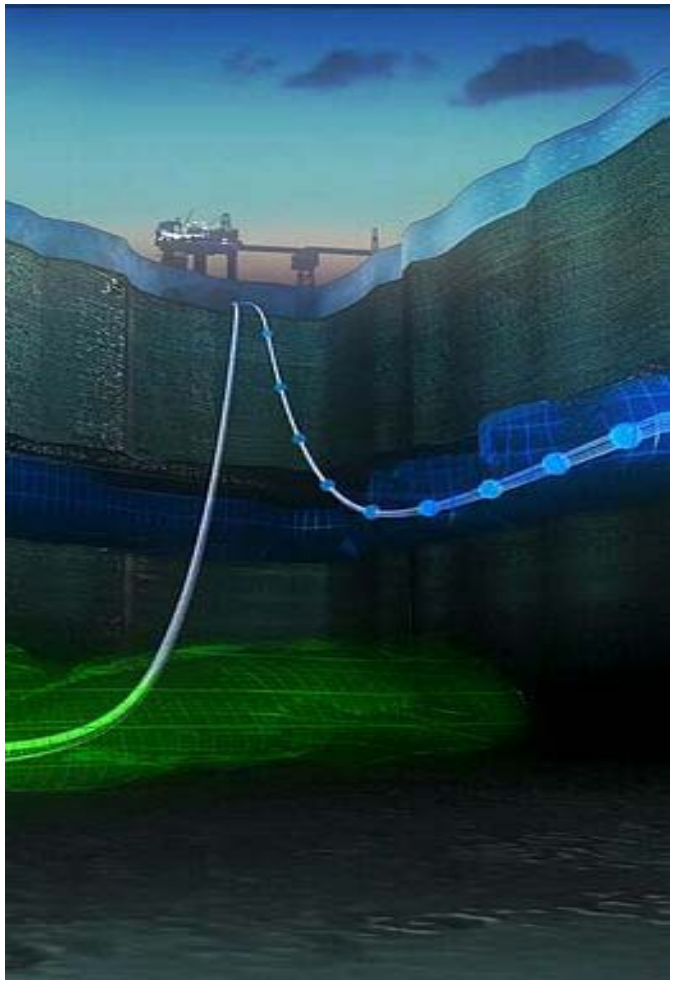
The Wabash River
Coal Gasification Repowering Project

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*

Efficient Use of Electricity

motors

lighting

cogeneration

Effort needed by 2055 for 1 wedge:

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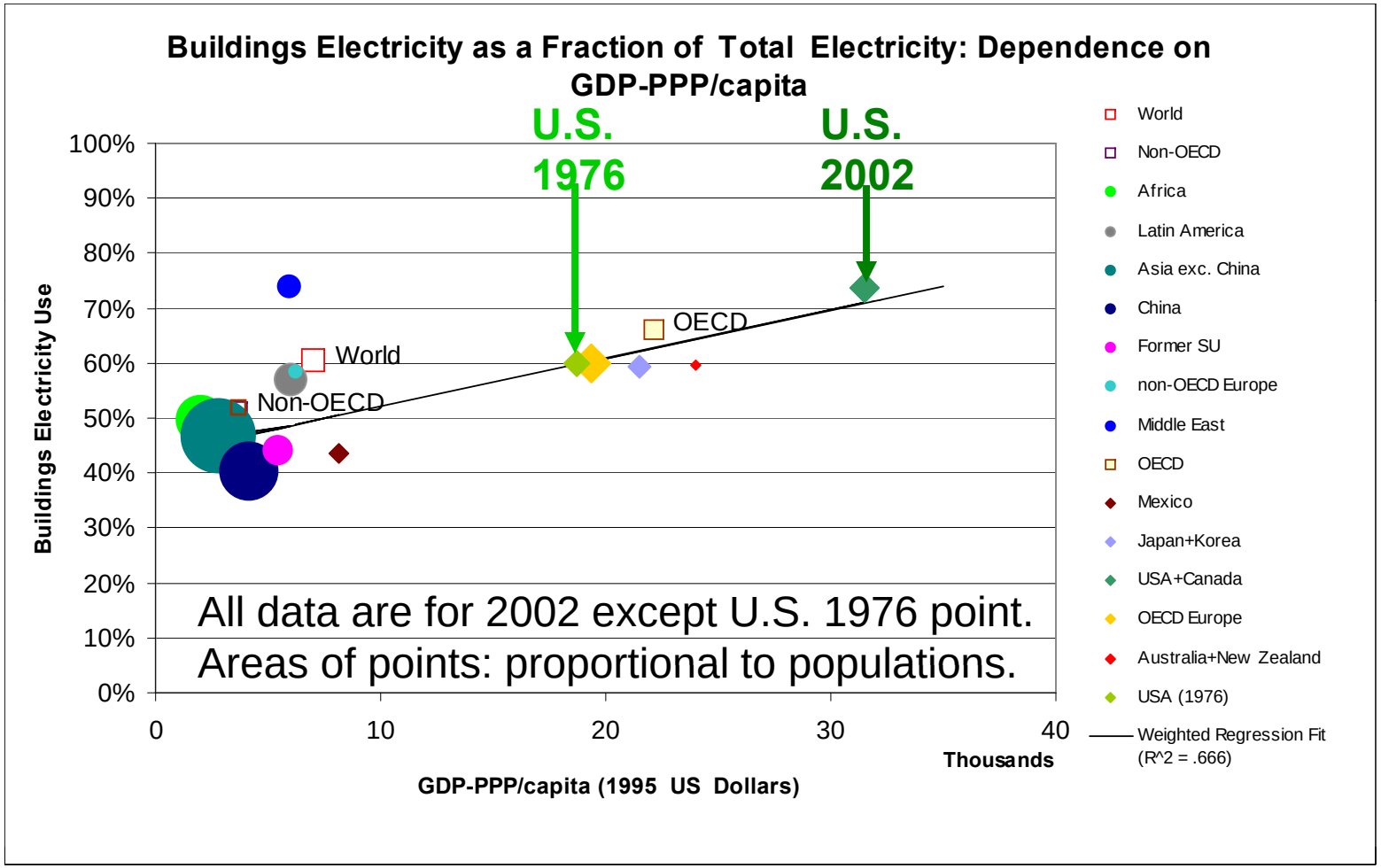
25% reduction in expected 2055 electricity use in commercial and residential buildings

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

A larger fraction of electricity goes to buildings in rich countries



"Buildings Electricity" = 100% Commercial and Residential + 15% Industrial + 10% Agricultural.

Data provided by Paul Waide, graphics by Shoibal Chakravarty

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

The Promise of Nuclear Power

Small flows. To produce the thermal energy required to produce 1000 megawatts of power for a year:

Fission one ton of uranium

Burn 3,000,000 tons of coal.

Abundant resources: uranium and thorium, relative to coal.

Minimal increments on background radiation (if it works properly)

Minimal CO_2 emissions.

A route to fuels as well as power.

Nuclear power has not grown as its advocates predicted

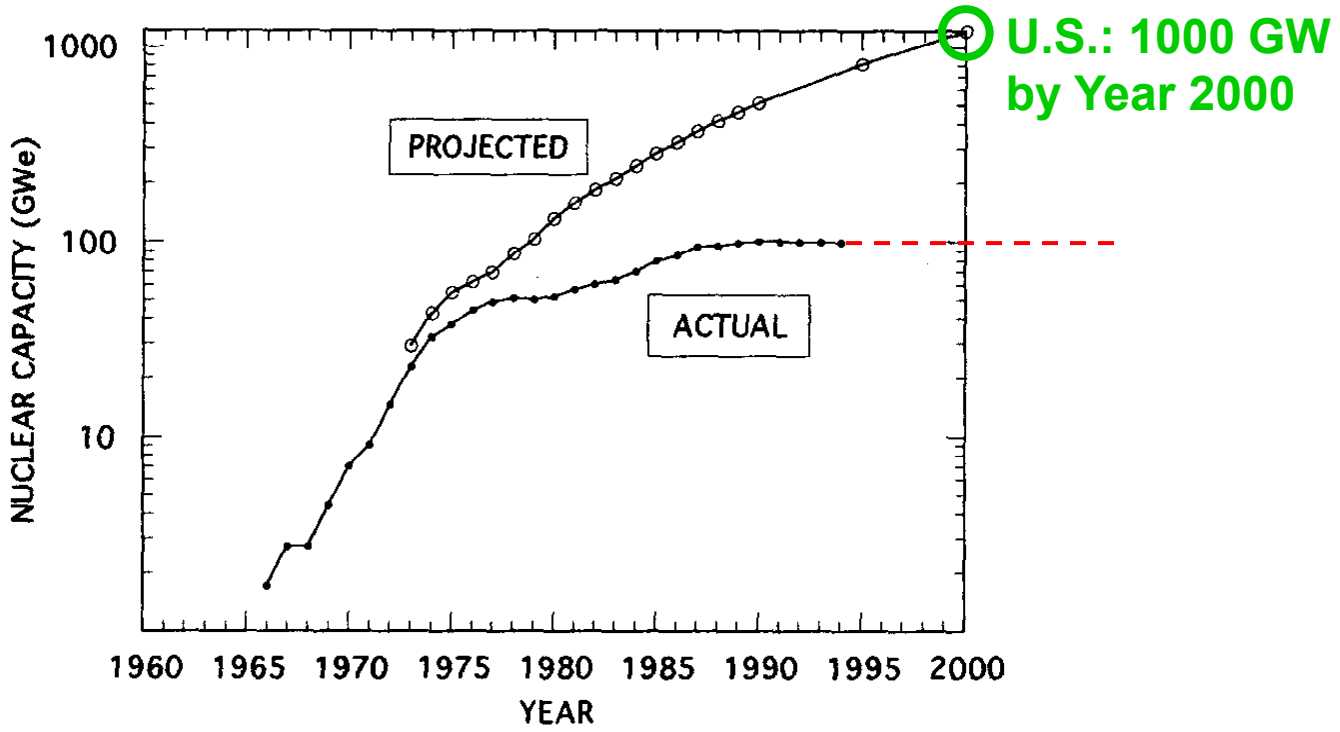


Figure 1.4. Comparison of U.S. nuclear capacity, projected in 1972 and actual.

What we should acknowledge

Nuclear power expansion could increase the risk of nuclear war.

A nuclear power plant could be attacked in a war.

Duplicity is rampant today as many countries make the case for their first nuclear power plant.

Bottlenecks will limit the rate of expansion: mining, enrichment, production of pressure vessels, trained people, legal frameworks.

There is little tolerance for error in managing the 350 GW of current reactors and their fuels, if nuclear power is to revive.

The nuclear industry is a poor advocate for itself and doesn’t know why.

Accidents

The dread-to-risk ratio

Dread is deeply felt and deserves respect.

"Explaining" that the problem is minimal (K-40 internal dose, cosmic rays, radon) doesn't work.

The relicensing conundrum

The nuclear industry is doubtful about the wisdom of 80-year permits. Doesn't that mean that the public should be doubtful about the wisdom of 60-year permits?

The mutual hostage

Will an accident at one plant shut them all down?

The military target

There is no taboo against attacking a nuclear power plant.

Waste Disposal and Retrievability

Isn’t it time to ask the world to settle for retrievable storage?

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

A leading alternative, *transmutation*, is peculiar: The goal is to turn isotopes with half-lives of thousands of years into short-lived isotopes.

Would you rather have a 3000-year half-life isotope or a 30-year one?

Re: identifying a wholesome
“regulatory and licensing environment”
that is the task of this meeting:

Isn’t a world that has
delegitimized nuclear weapons
a more wholesome environment
for the prospering of nuclear power?

Proliferation and the Futility of a Two-tier Supplier-User World

A Story:

In May 2006, in Delhi, I asked several leaders of the Indian nuclear enterprise to comment on the merits of a supplier-user arrangement of the world. They refused to do so until they knew in which category India would be.

If the U.S. informed them that they were users, would they go underground?

Revival proposals

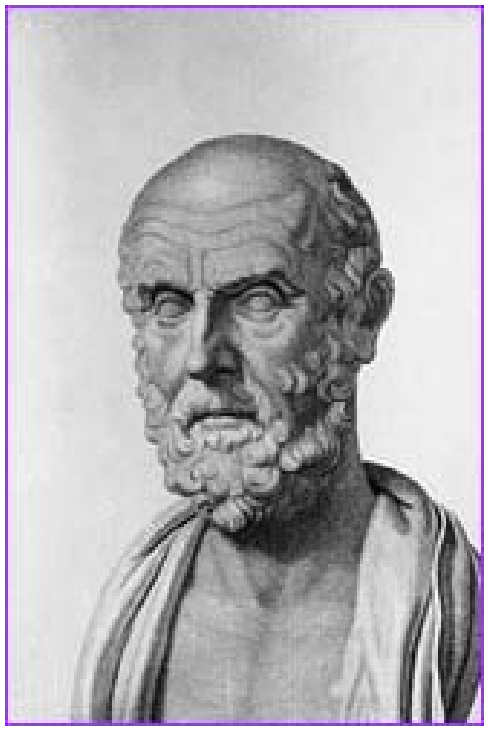
- Safety: Create counter-incentives to plant relicensing, so that aging plants are retired.
- Storage: Revise the contract with society in favor of retrievable storage. Deploy dry-cask storage.
- Proliferation, plutonium: Deploy only once-through cycles (indefinitely postpone reprocessing).
- Proliferation, uranium: *Establish a one-tier world.* Immediately place all enrichment facilities, *including ours*, under international governance. (Is there an attractive natural-uranium power plant?)
- Delegitimize nuclear weapons

Do we come out ahead?

To present nuclear power as a response to climate change is to raise in many people's minds the question: "When is the cure worse than the disease?"

"I will prescribe regimens for the good of my patients according to my ability and my judgment and never do harm to anyone."

http://en.wikipedia.org/wiki/Hippocratic_Oath



Hippocrates