Policy and Technology for Living in a Greenhouse

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P8 Summit
of trustees of major pension funds

London, UK
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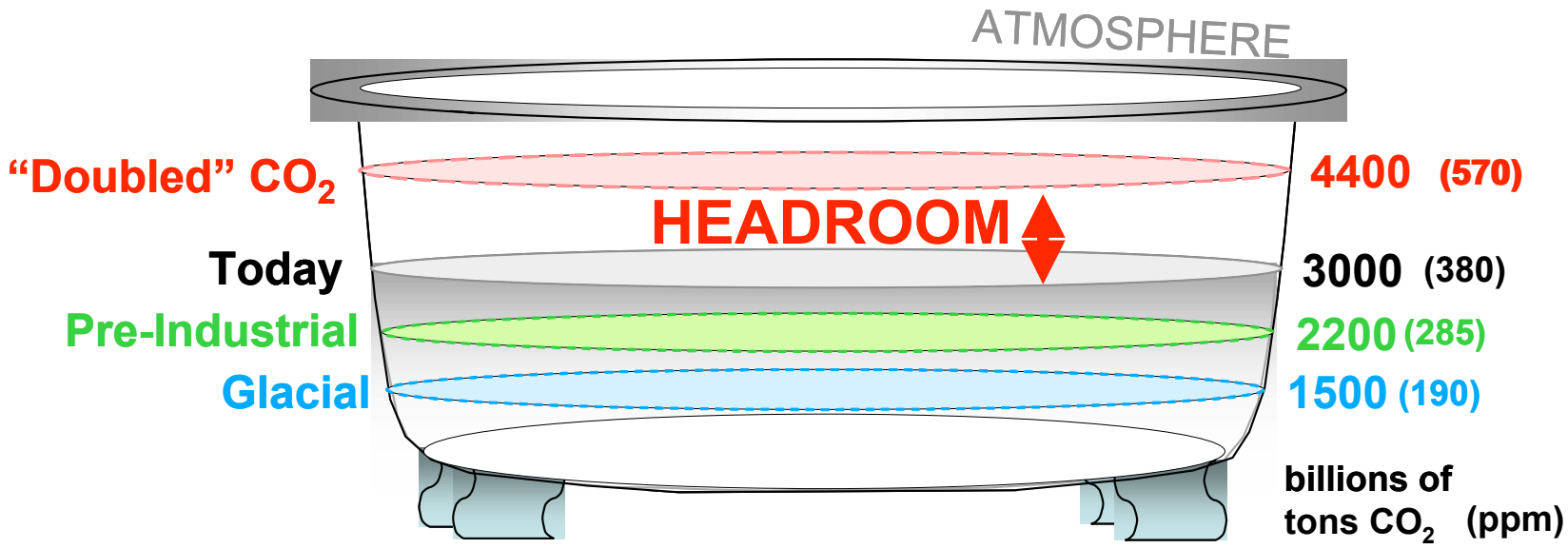
Three agents of change

- Public policy, changing the rules
- Consumers, changing preferences
- Owners, changing values

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

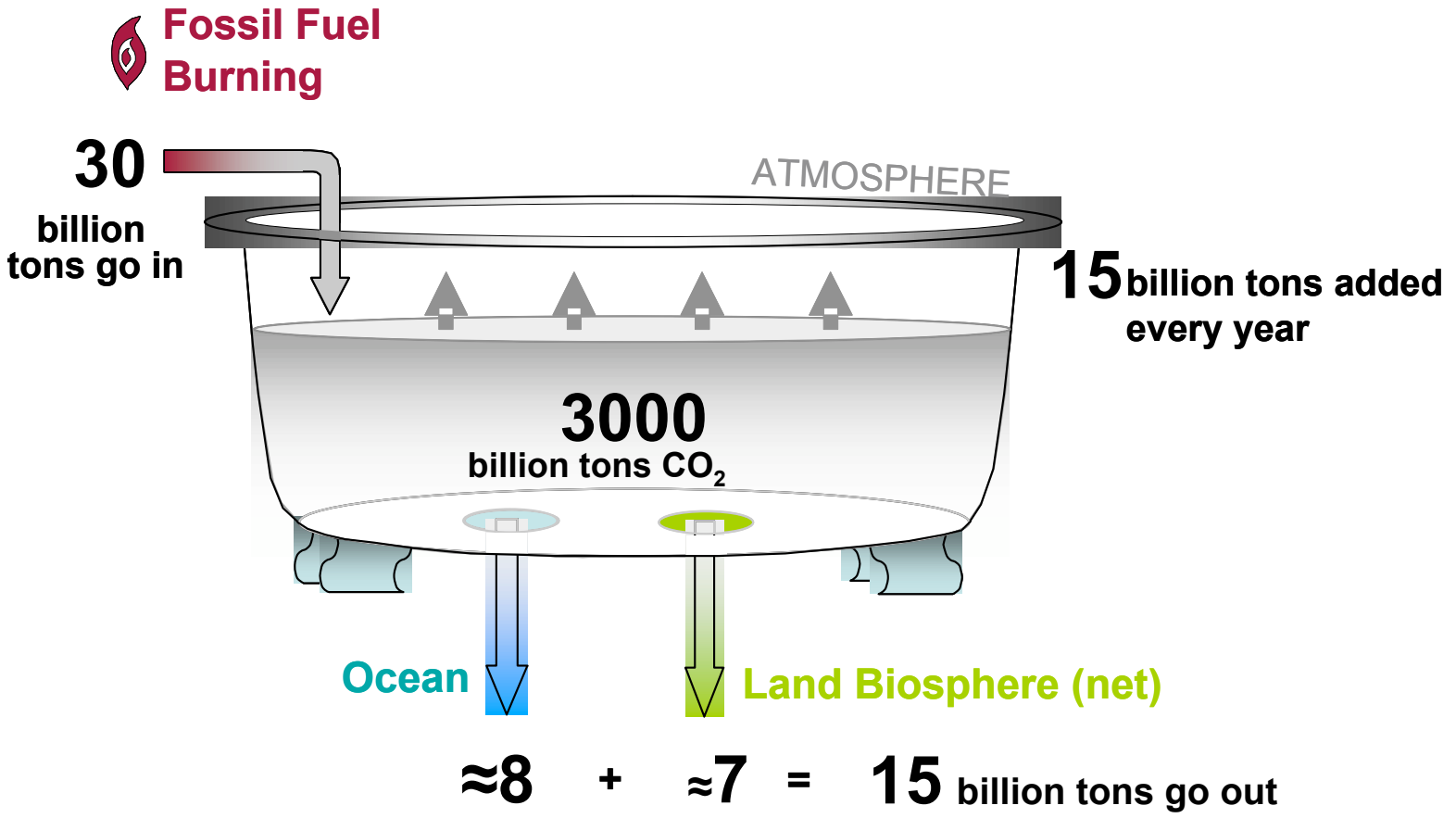


Rosetta Stone: To raise the concentration of CO_2 in the atmosphere by **one part per million:**

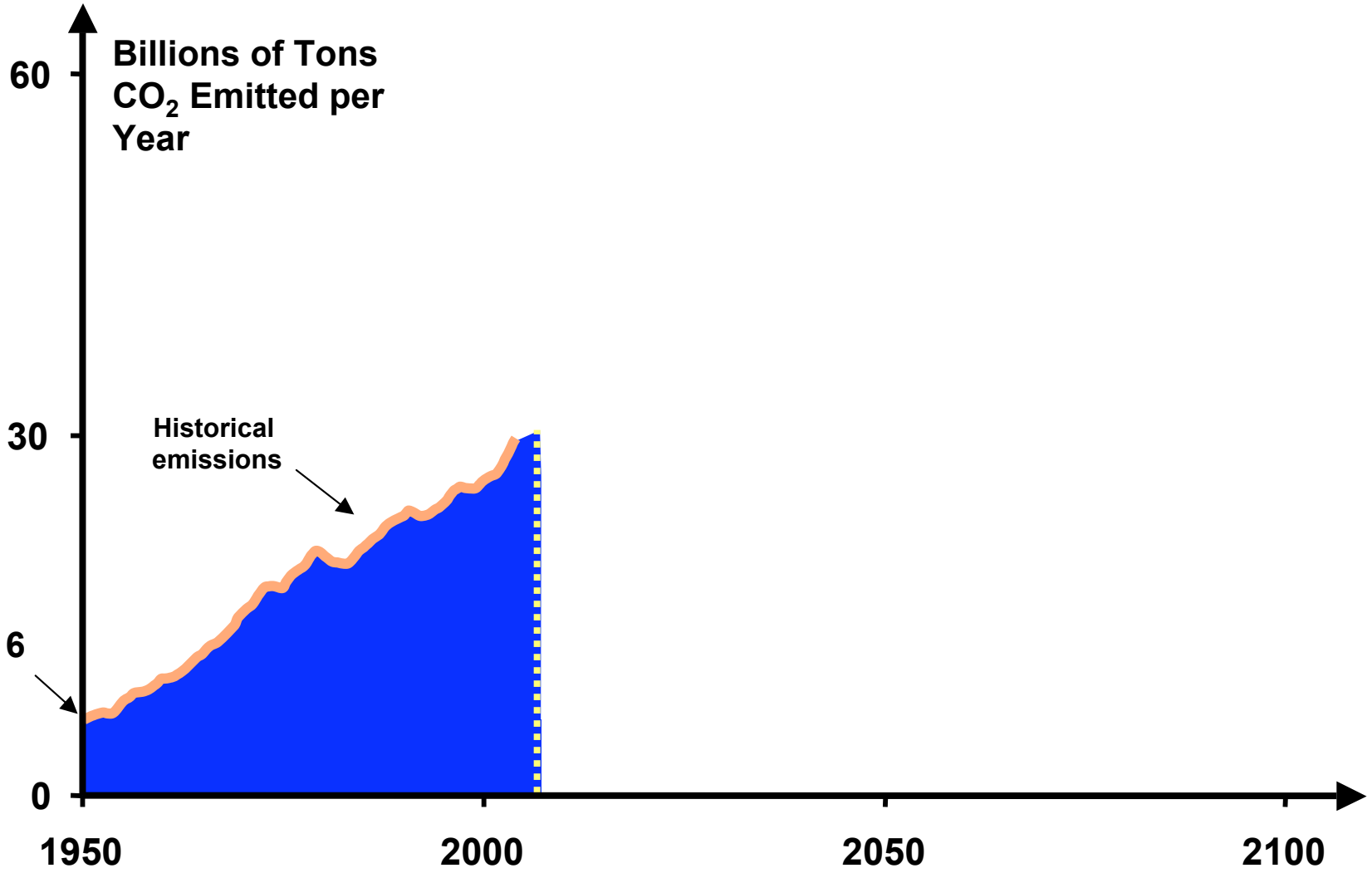
add **7.7 billion tons of CO_2,**

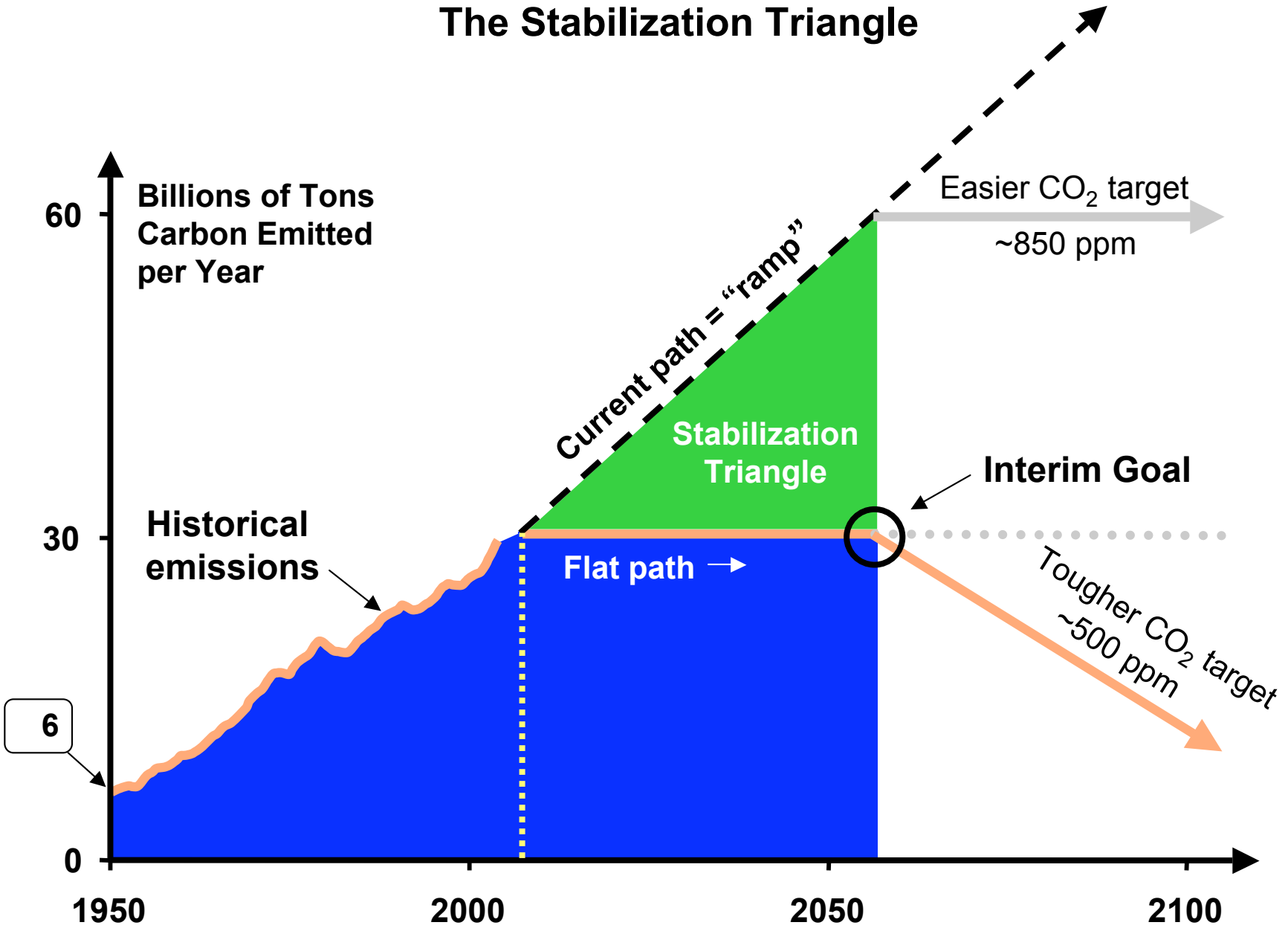
in which are **2.1 billon tons of carbon.**

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



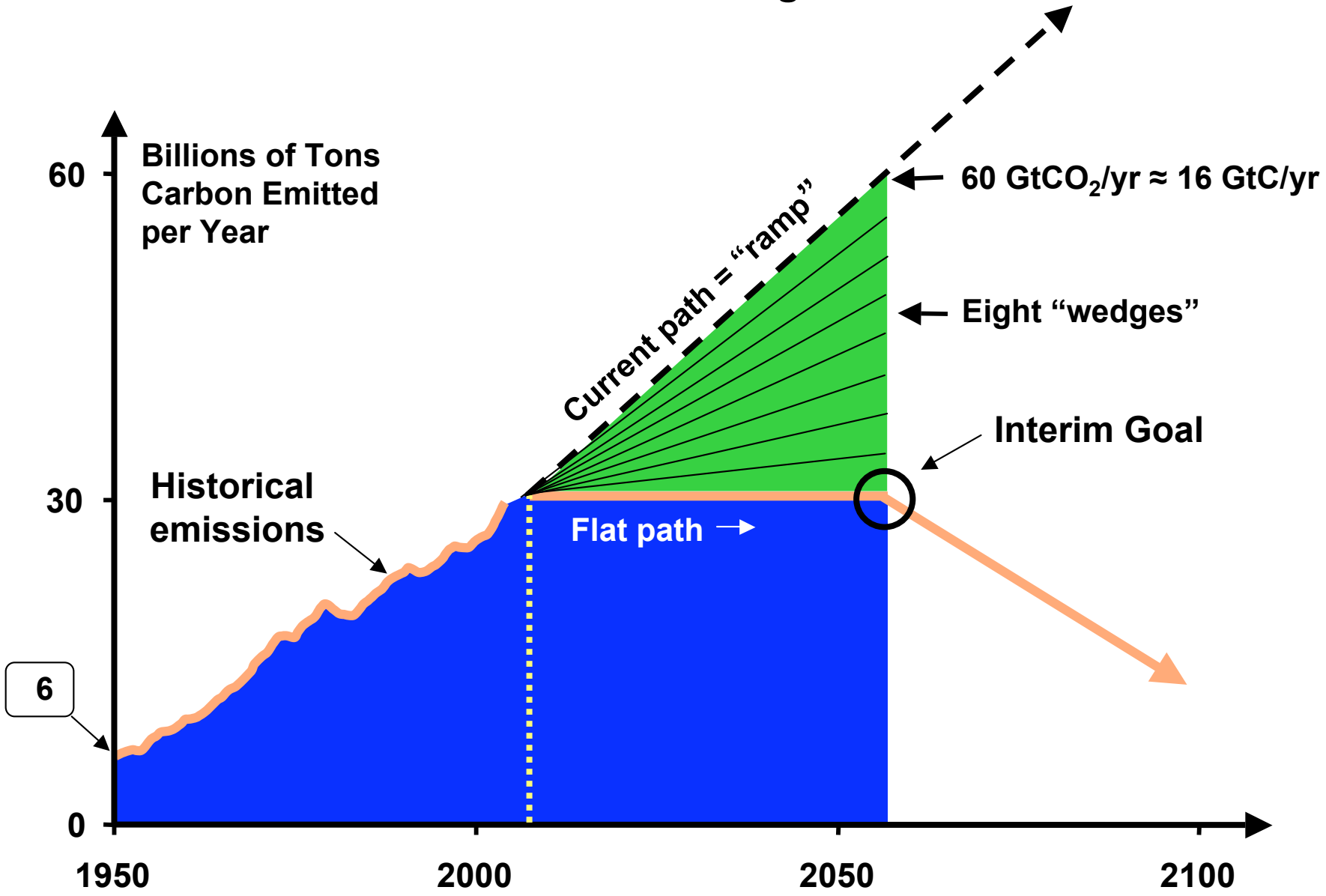
Historical Emissions





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

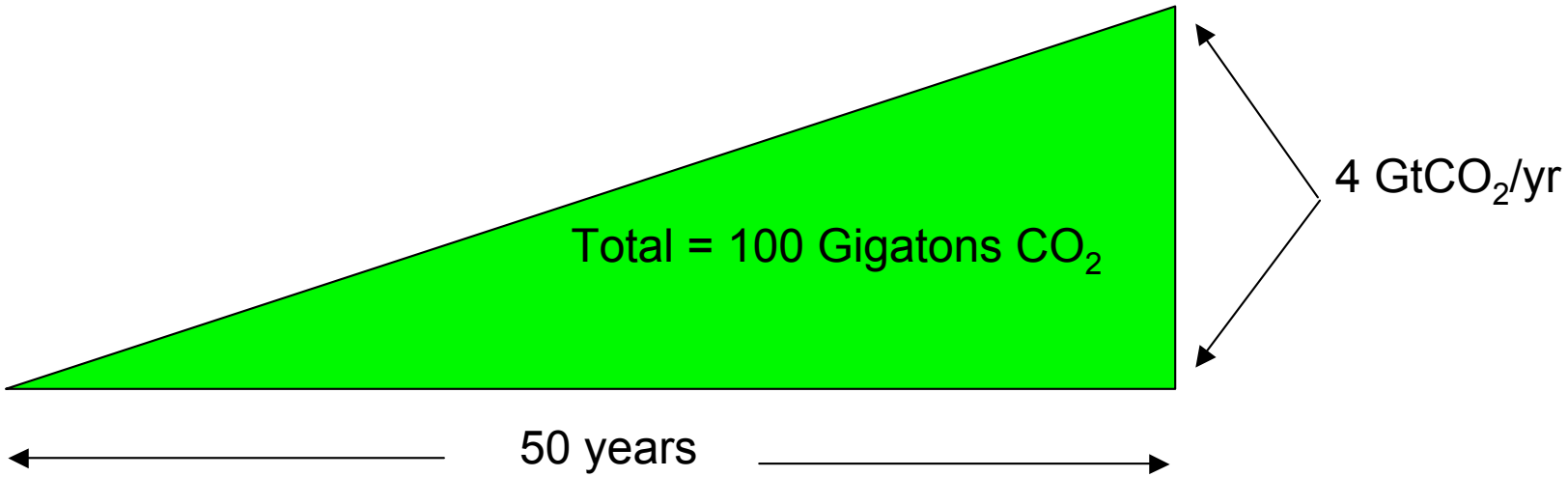
Stabilization Wedges



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

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.

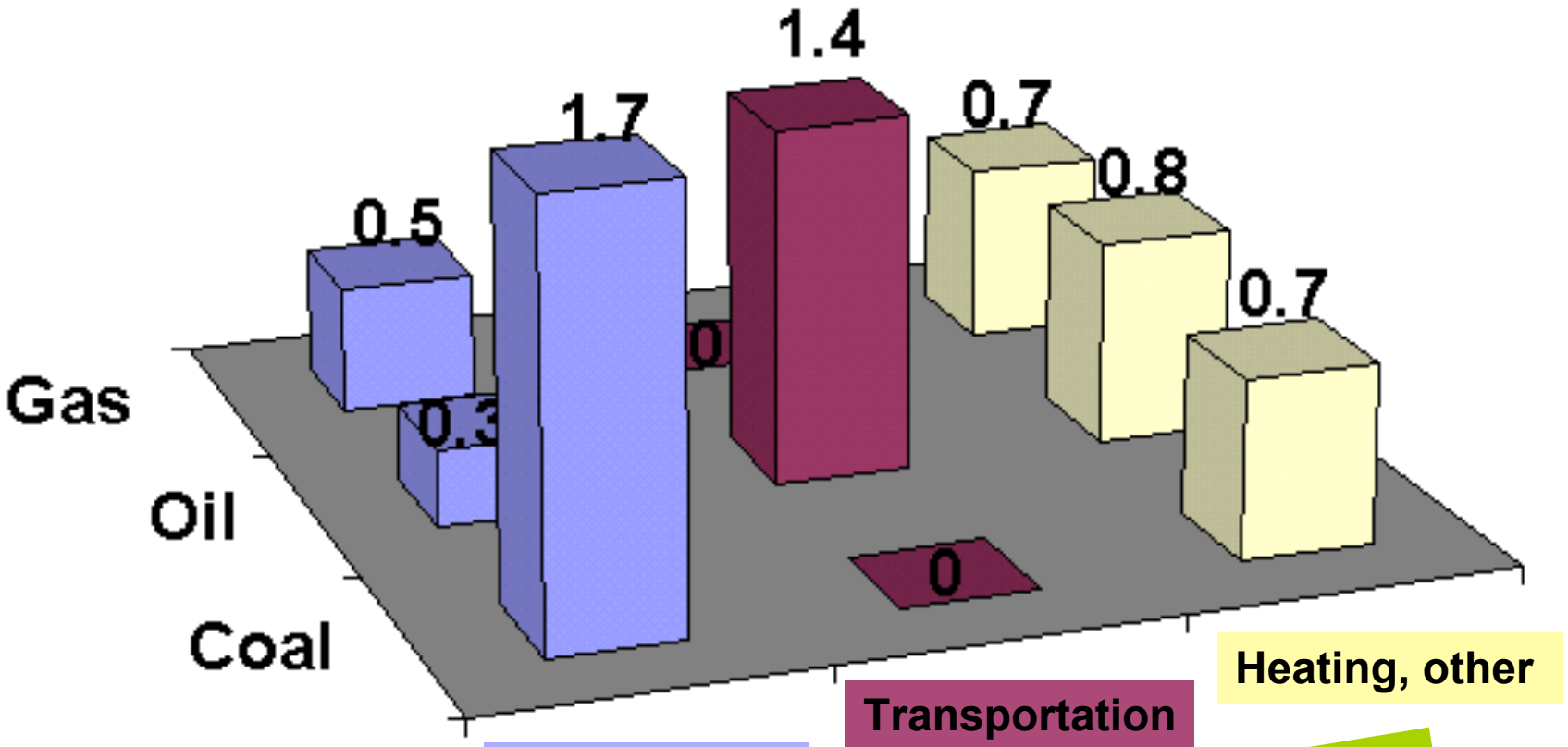


Cumulatively, a wedge redirects the flow of 100 $GtCO_2$ in its first 50 years. **This is three trillion dollars at $30/tCO$_2$.**

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

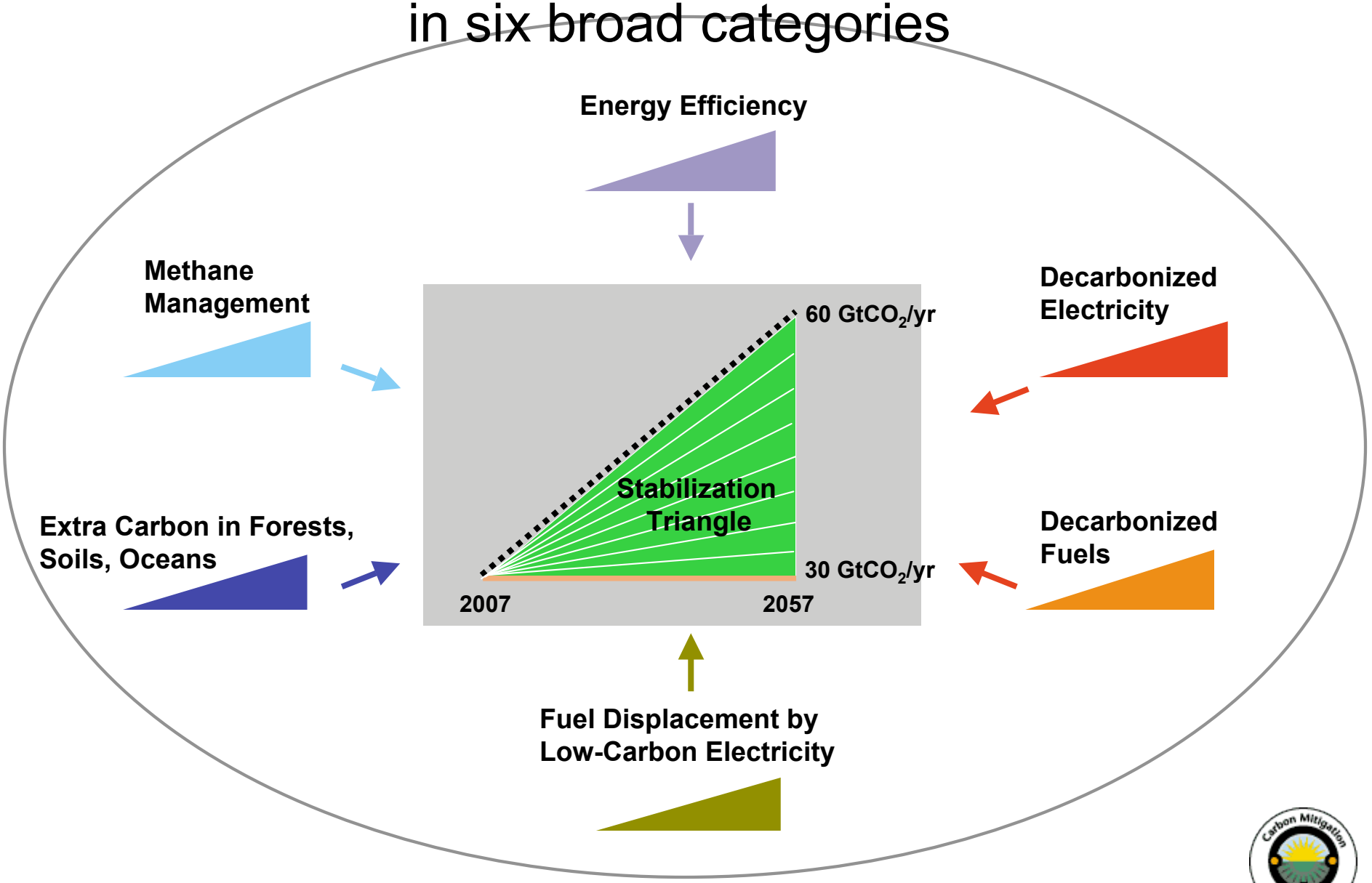
Global CO_2 Emissions by Sector and Fuel

Allocation of 6.2 GtC/yr (22.7 $GtCO_2$/yr) emitted in 2000



Electricity: 40%; fuels used directly: 60%.

Fill the Stabilization Triangle with Eight Wedges in six broad categories

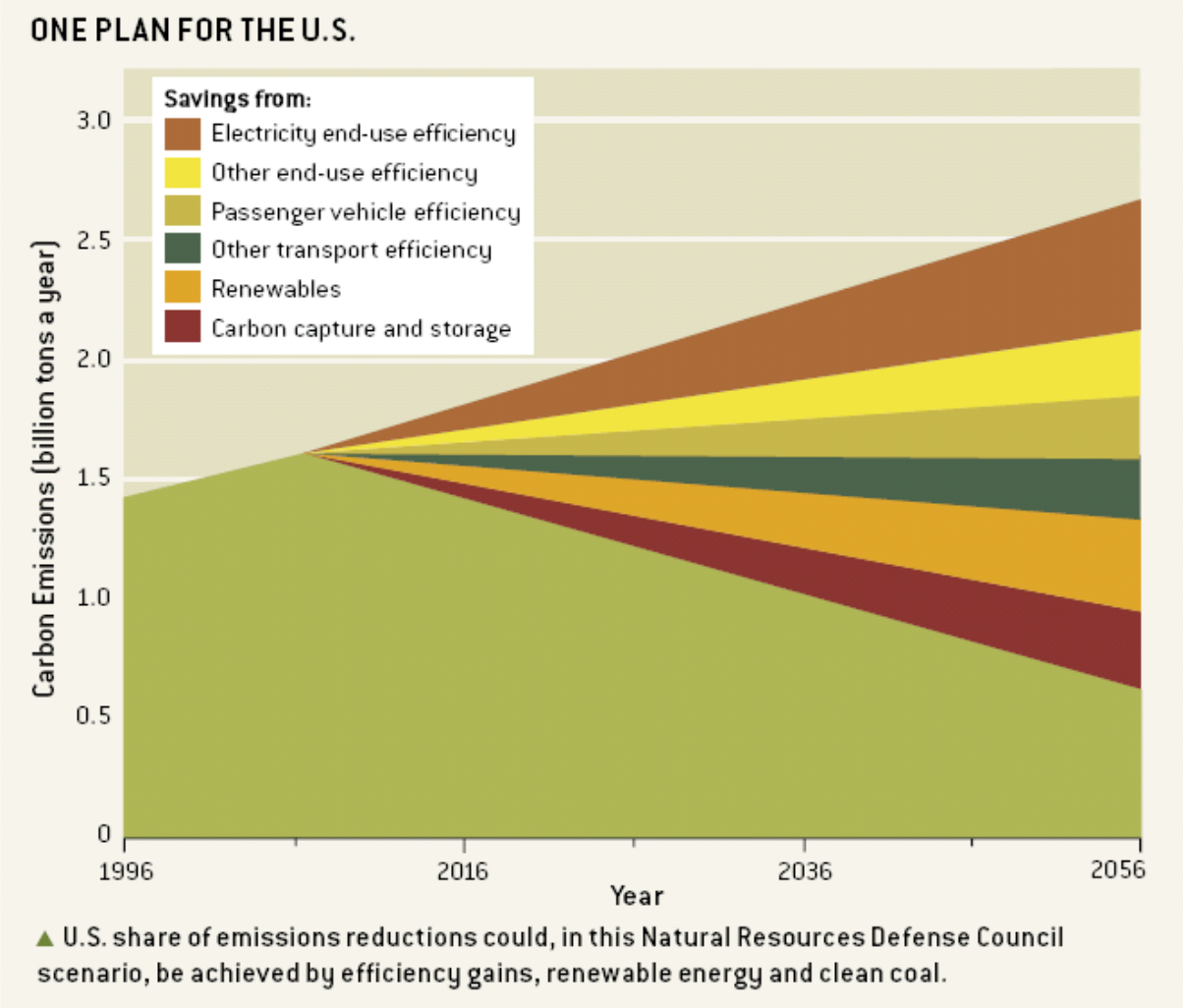


“The Wedge Model is the IPOD of climate change: You fill it with your favorite things.”

David Hawkins, NRDC, 2007.

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

U.S. Wedges



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

Now we go on a hunt for wedges

Today:

- **Efficiency wedges**
- **Wedges displacing conventional coal power**

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

Efficient Use of Electricity

motors

lighting

cogeneration

Effort needed by 2055 for 1 wedge:

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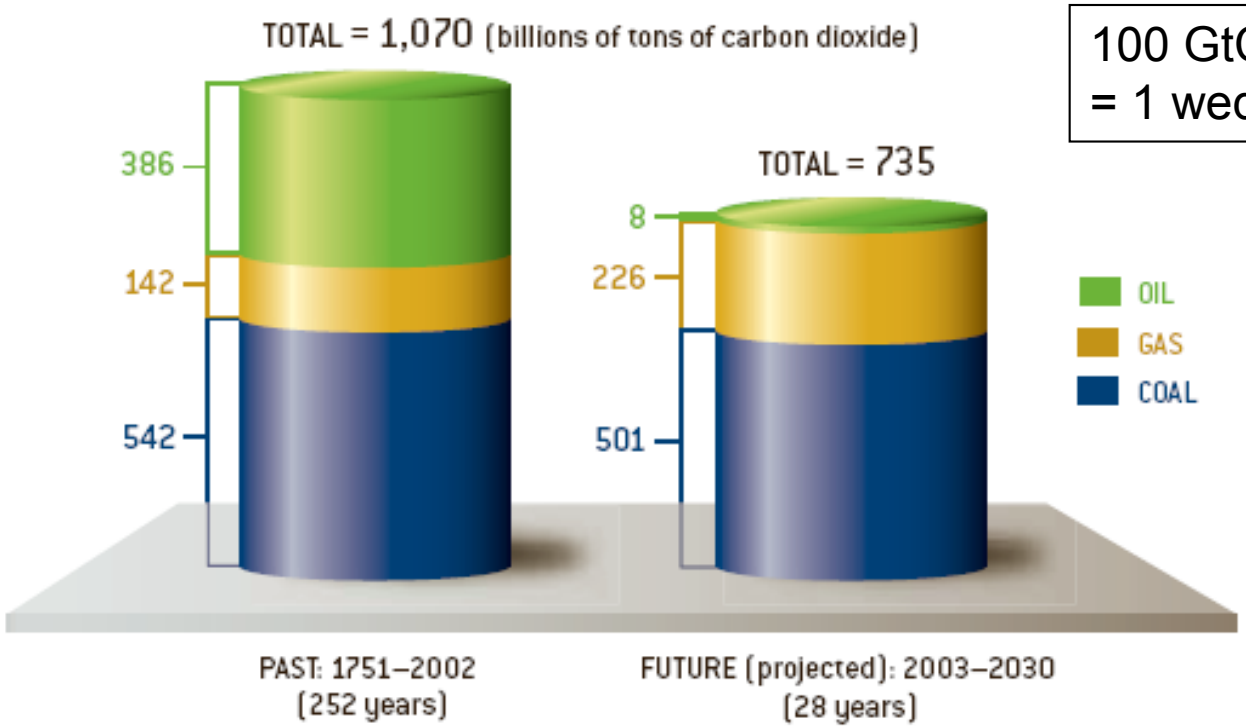
25% reduction in expected 2055 electricity use in commercial and residential buildings

Target: Commercial and multifamily buildings.

Four ways to emit 4 tonCO_2/yr

Activity	**Amount producing 4tCO_2/yr (1tC/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) Use lights and appliances	300 kWh/month when all coal-power (600 kWh/month, natural-gas-power)

Efficiency investments can displace investments in coal power



100 $GtCO_2$ not emitted = 1 wedge

Historic emissions, all uses

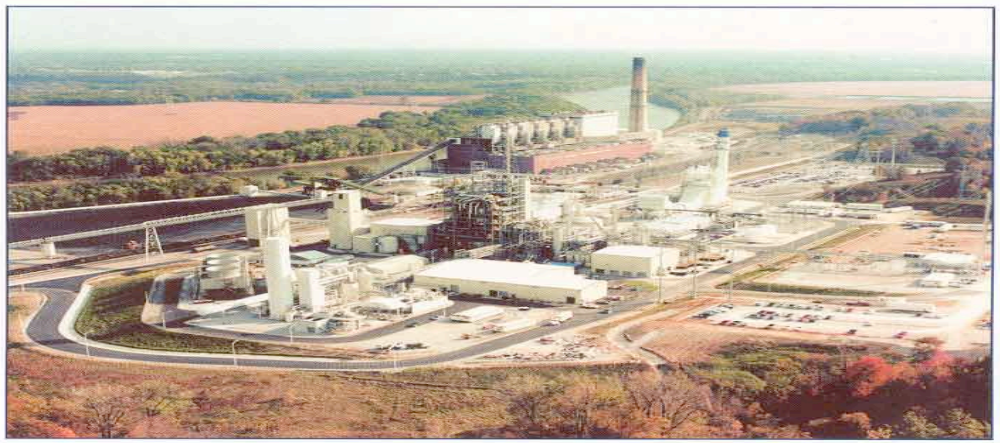
2003-2030 power-plant lifetime CO_2 commitments
WEO-2004 Reference Scenario.
Lifetime in years: coal 60, gas 40, oil 20.

Policy priority: Deter investments in new long-lived high-carbon stock: not only carbon-dumb power plants, but also carbon-dumb buildings.

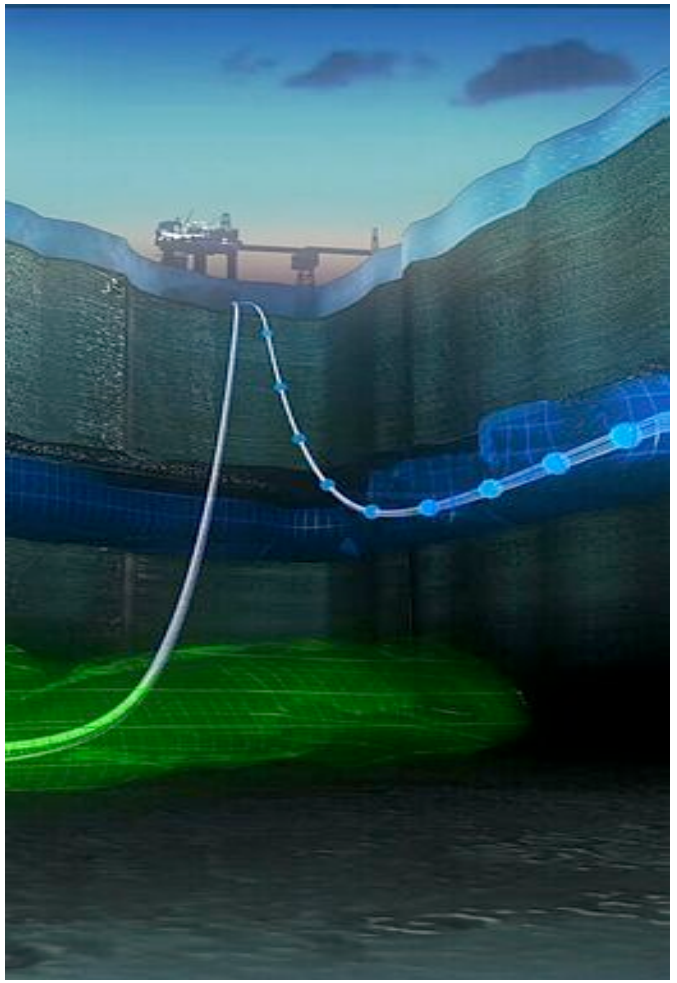
***Needed*: "Commitment accounting."**

Credit for comparison: David Hawkins, NRDC

Coal with Carbon Capture and Storage



Graphics courtesy of DOE Office of Fossil Energy



Graphic courtesy of Statoil ASA

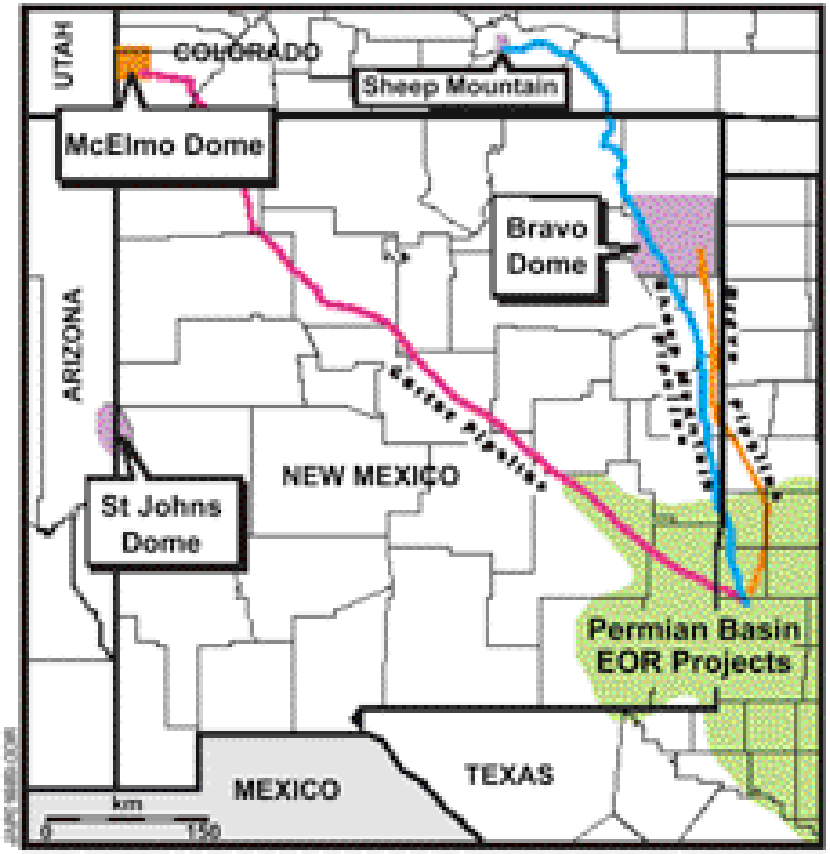
Effort needed by 2055 for 1 wedge:

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

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

Natural CO_2 fields in southwest U.S.

- McElmo Dome, Colorado: 1500 $MtCO_2$ in place
- 800 km pipeline from McElmo Dome to Permian Basin, west Texas, built in the 1980s for enhanced oil recovery



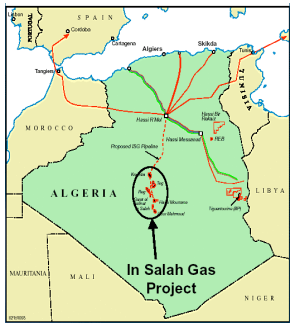
Two conclusions:

1. CO_2 in the right place is valuable.

2. CO_2 from McElmo was a better bet than CO_2 from any nearby site of fossil fuel burning.

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

Wind Electricity

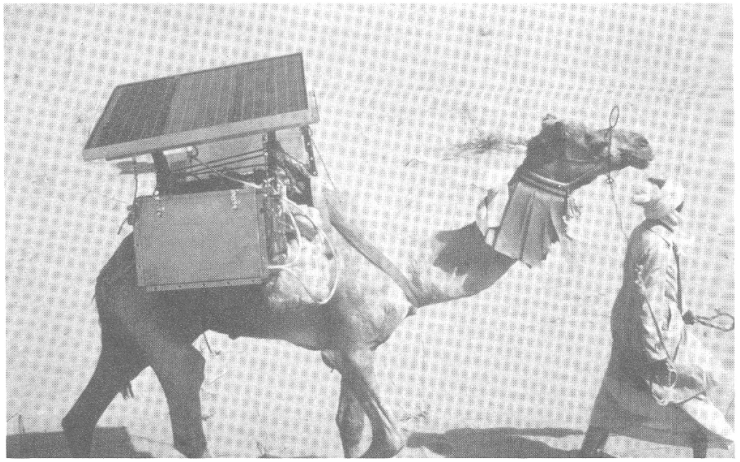
Effort needed by 2055 for 1 wedge:

One million 2-MW windmills displacing coal power.

2006: 75,000 MW (4%)

Prototype of 80 m tall Nordex 2,5 MW wind turbine located in Grevenbroich, Germany (Danish Wind Industry Association)

Photovoltaic Power



Effort Needed by 2055 for one wedge:

2000 GW_{peak} (400 x current capacity)

2 million hectares (80 x 100 miles)

Graphics courtesy of DOE Photovoltaics Program

Concentrating Solar Power (CSP)

Effort Needed by 2055 for one wedge:

2000 GW_{peak}

2 million hectares*
(80 x 100 miles)

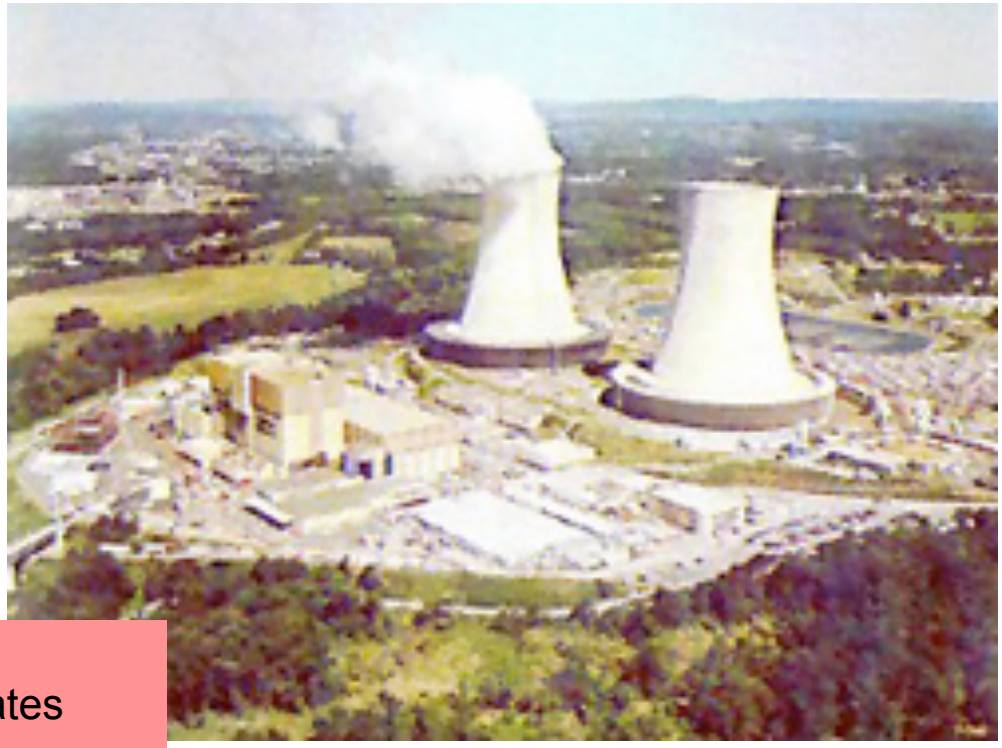
*assumes same 10% site-conversion efficiency as PV

Source: Noah Kaye, SEIA, April 2007

Nuclear Electricity

Effort needed by 2055 for 1 wedge:

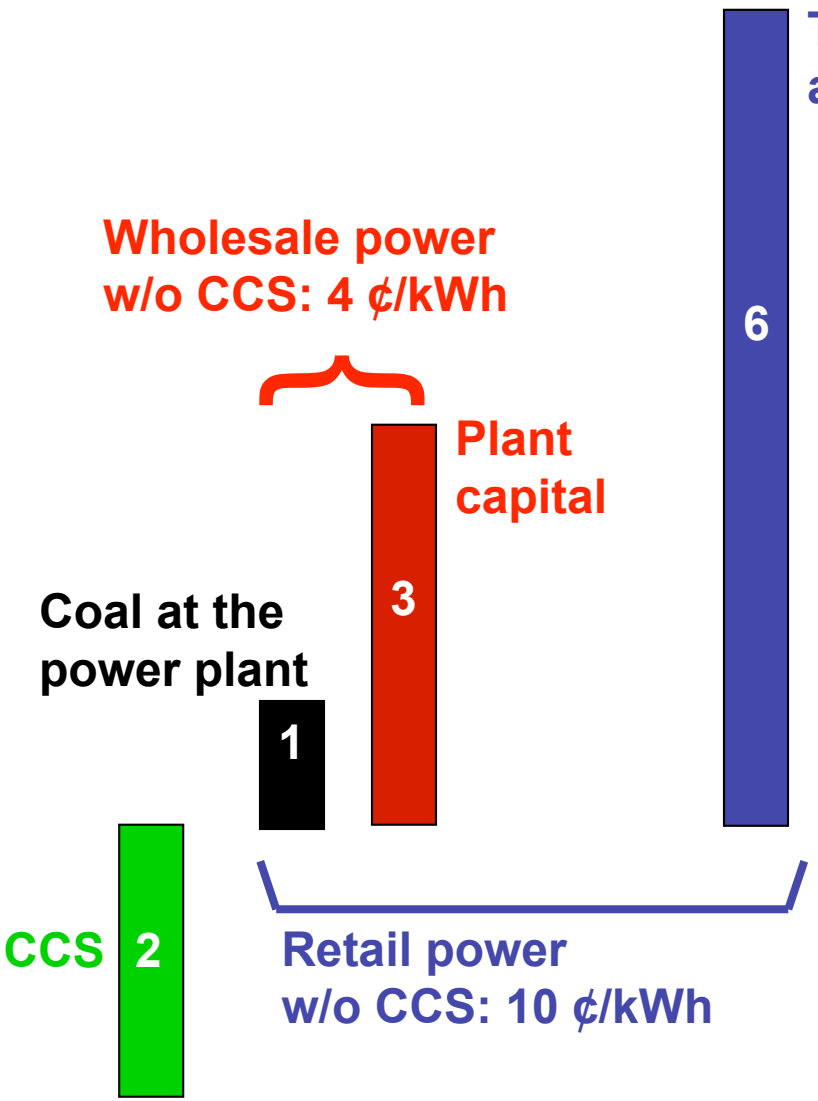
700 GW (twice current capacity) displacing coal power.



Graphic courtesy of NRC

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

$30/tCO$_2$ ≈ 2¢/kWh induces CCS. Three views.



A coal-gasification power plant can capture CO_2 for an added 2¢/kWh ($30/tCO$_2$). This:

- **triples the price of delivered coal;**
- **adds 50% to the busbar price of electricity from coal;**
- **adds 20% to the household price of electricity from coal.**

Benchmark: $30/tCO$_2$

Carbon emission charges in the neighborhood of $30/tCO$_2$ can enable scale-up of most of the wedges, if supplemented with sectoral policy to facilitate transition.

Form of Energy	**Equivalent to $30/tCO$_2$ (≈ $100/tC)**
Natural gas	**$1.60/1000 scf**
Crude oil	**$13/barrel**
Coal	**$70/U.S. ton**
Gasoline	25¢/gallon (ethanol subsidy: 50¢/gallon)
Electricity from coal	2.4¢/kWh (wind and nuclear subsidies: 1.8 ¢/kWh)
Electricity from natural gas	1.1¢/kWh

$30/tCO$_2$ is the current European Trading System price for 2008 emissions.
At this price, current global emissions (30 GtCO$_2$/yr) cost $900 billion/yr, 2% of GWP.

Every wedge strategy can be implemented well or poorly

Every wedge has a dark side, generating opposition that thwarts implementation.

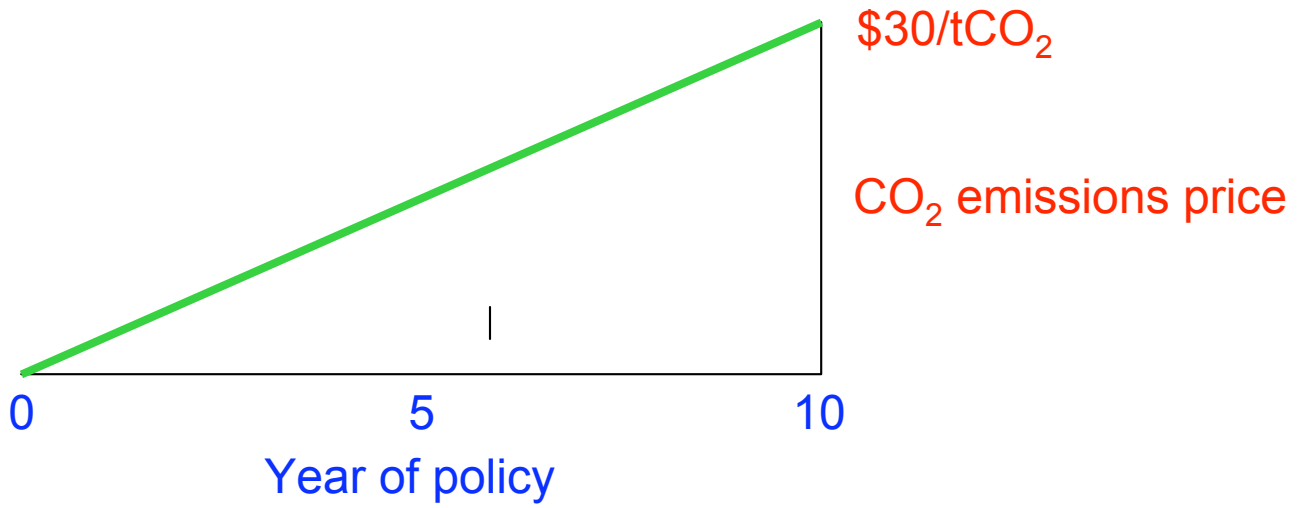
Conservation	Regimentation
Renewables	Competing uses of land
Nuclear power	Nuclear war
“Clean coal”	Mining: worker and land impacts

“Solution science” is emerging: the study of the environmental and social costs and benefits of stabilization strategies.

Avoid Mitigation Lite

Mitigation Lite: The right words but the wrong numbers. Companies' investments are unchanged: the emissions price is a cost of business. Individuals change few practices.

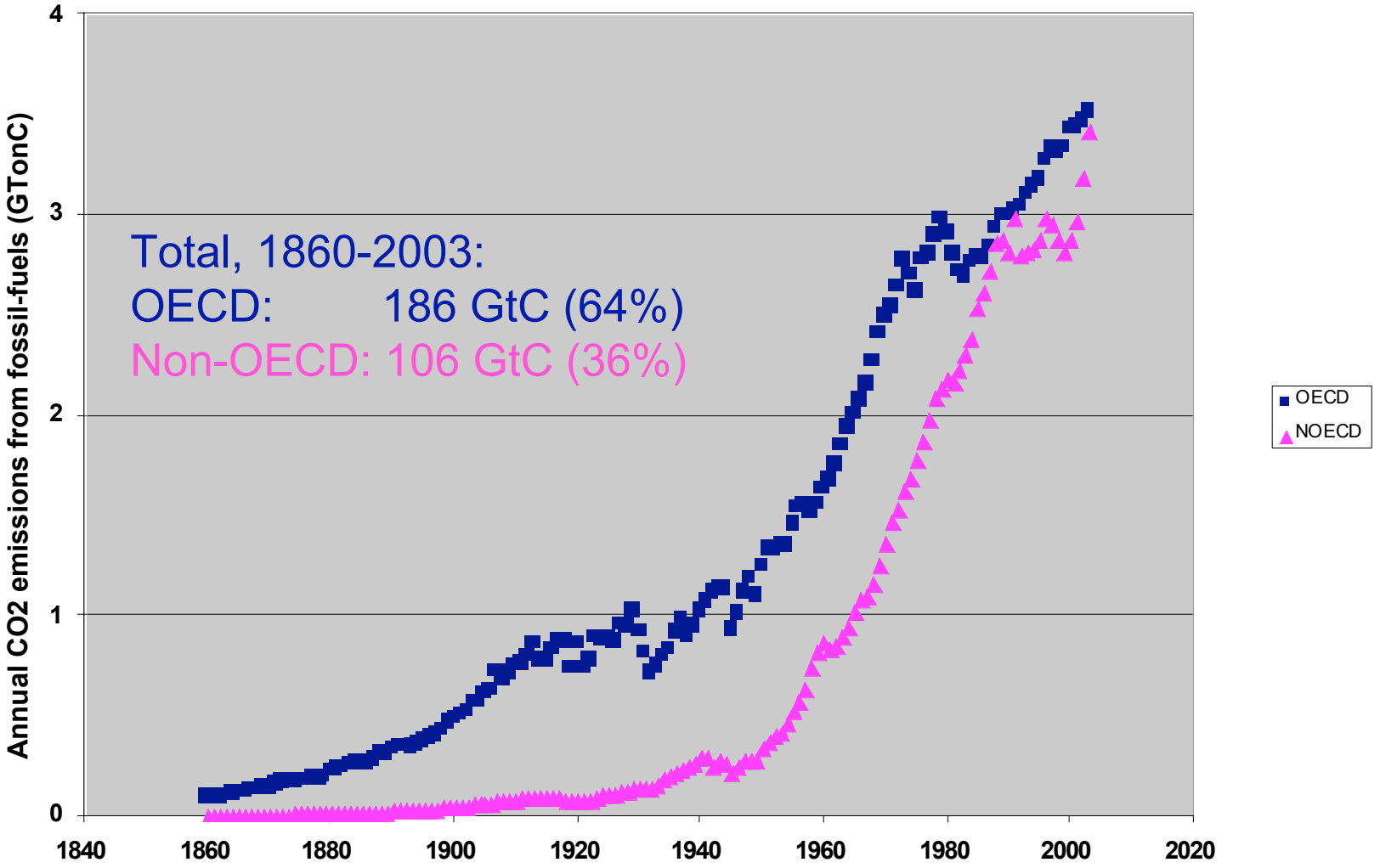
For specificity, consider a price ramp that is *not* "lite," one rising from zero to \$30/tCO_2 over 10 years.



Some carbon policy principles

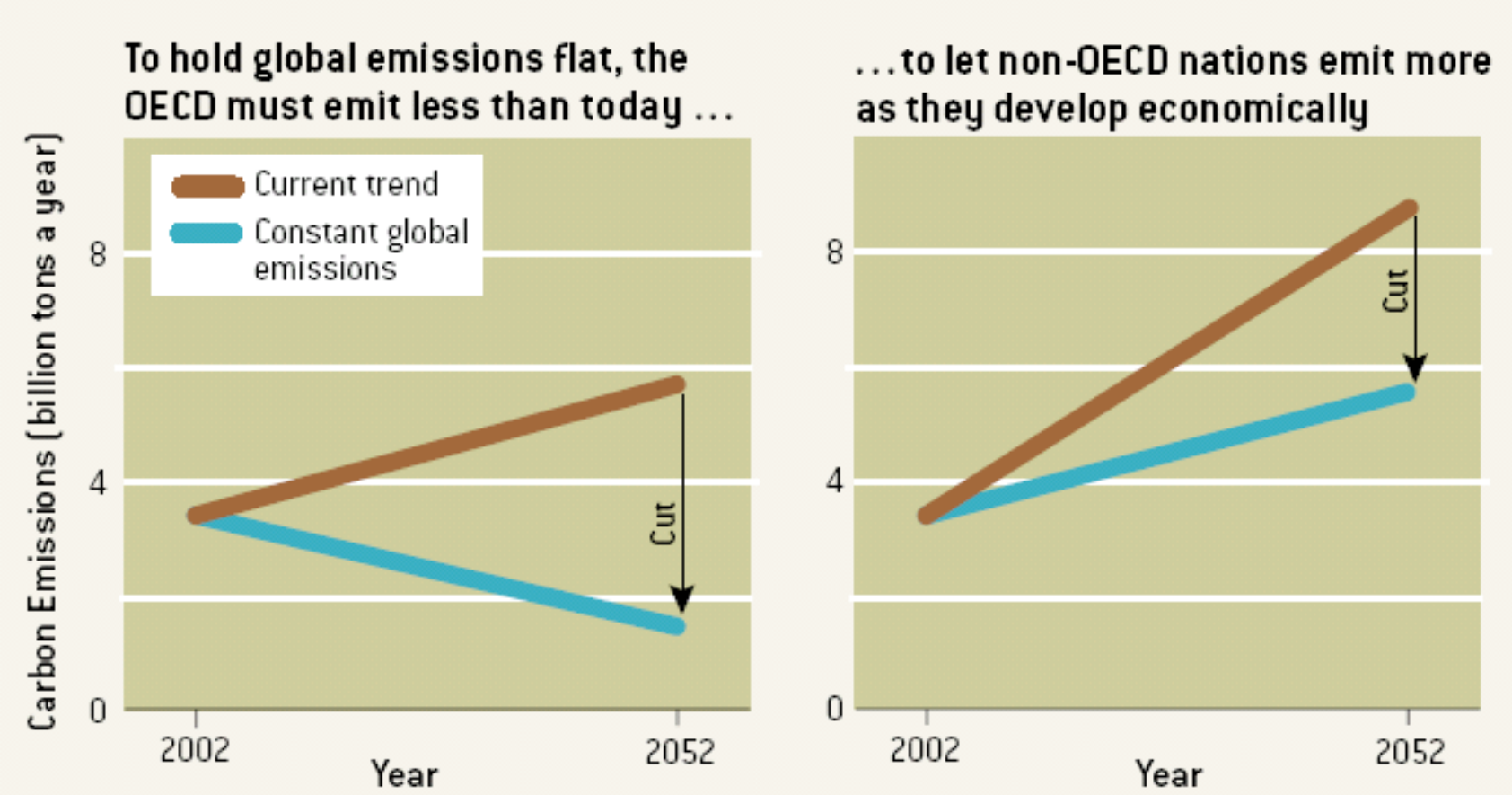
- Establish a CO_2 price schedule forceful enough to drive investment decisions.
- Make the price salient as far upstream as possible (best, when C comes out of the ground or across a border).
- Supplement the price with sectoral policies (RPS, CCS, CAFE, appliance mandates).
- Stimulate international coordination.
- Allow a teething period.

CO_2 emissions, OECD and non-OECD, 1860-2003



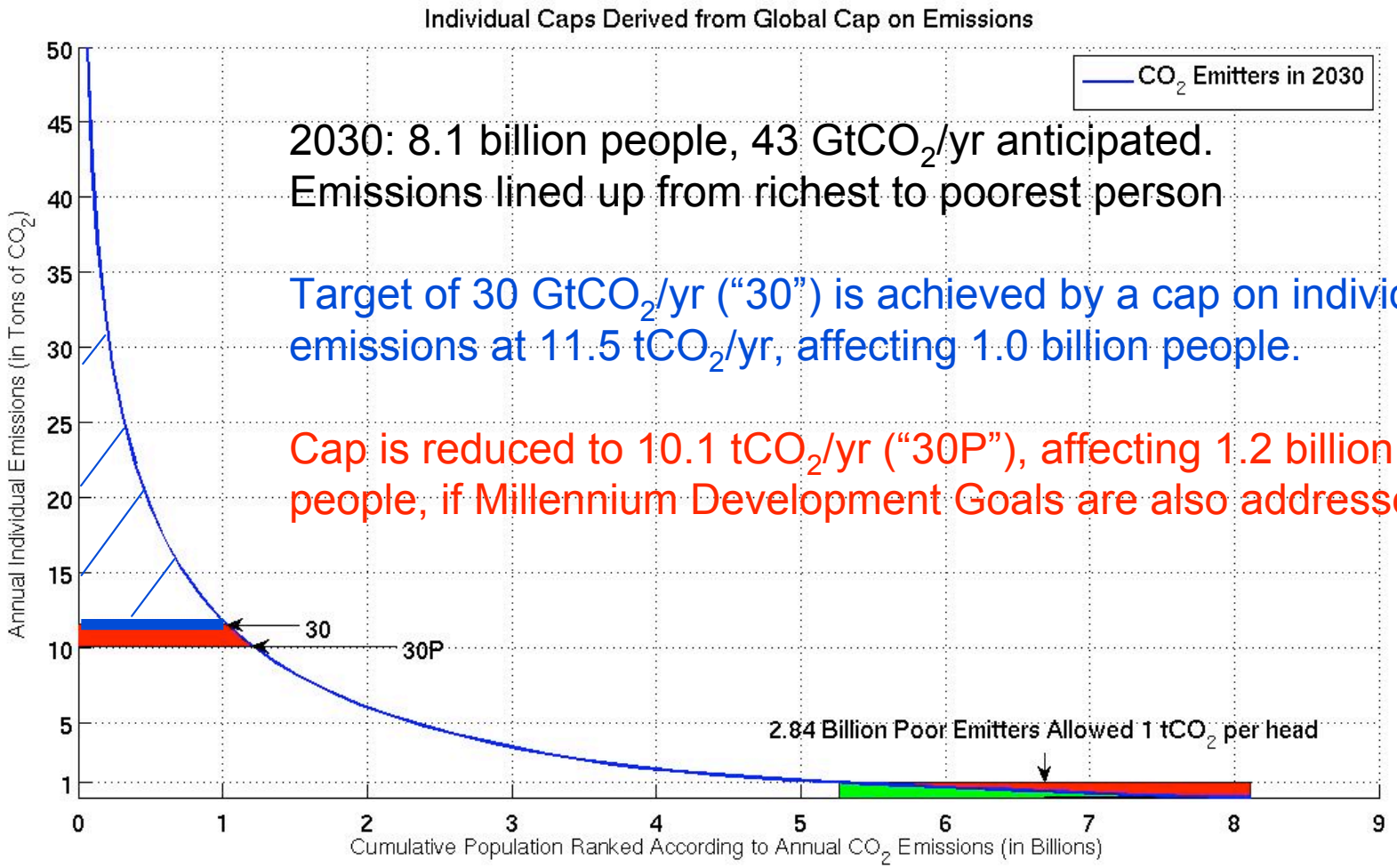
Source: Adrian Ross

OECD and non-OECD shares



*Source*l Socolow and Pacala, *Scientific American*, September 2006, p.56

CO_2 emissions in 2030 by the world's individuals

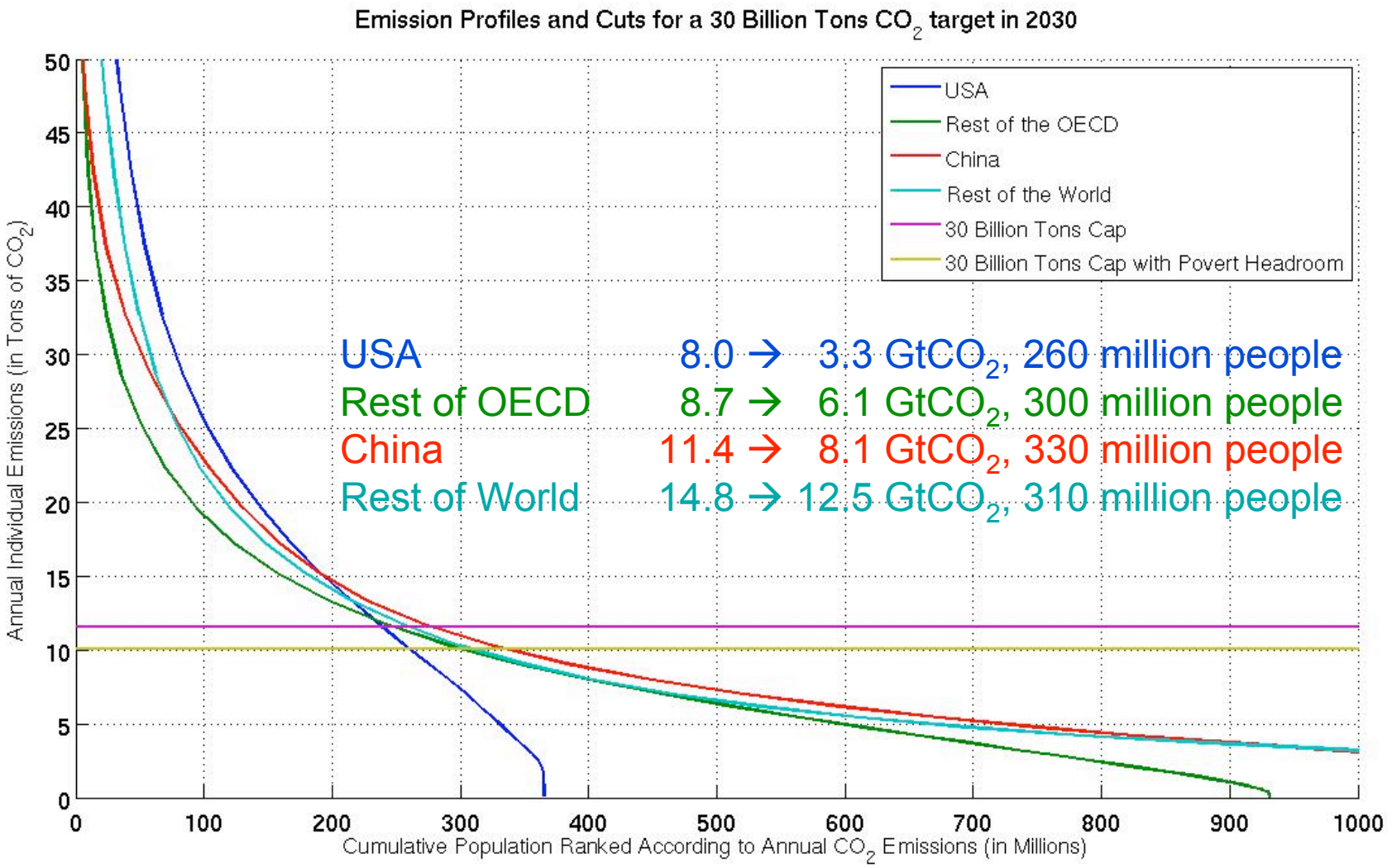


2030: 8.1 billion people, 43 $GtCO_2$/yr anticipated.
Emissions lined up from richest to poorest person

Target of 30 $GtCO_2$/yr ("30") is achieved by a cap on individual emissions at 11.5 tCO_2/yr, affecting 1.0 billion people.

Cap is reduced to 10.1 tCO_2/yr ("30P"), affecting 1.2 billion people, if Millennium Development Goals are also addressed.

Four comparable assignments



An equity-based CO_2 strategy

1. ***Meet Basic Human Needs without considering carbon.***

   Don't discourage diesel engines for village-scale power or LPG for cooking.

   Expect a poor family to respond to a better insulated home by raising the indoor temperature ("takeback").

2. ***Attain all savings from the largest emitters***

3. ***Mitigate uniformly for the same income level across all countries.***

   Coordinated development and deployment of efficient appliances, urban mass transit, videoconferencing, CO_2 capture and storage, renewables, and nuclear power.

A world transformed by deliberate attention to carbon

A world with the same total CO_2 emissions in 2057 as in 2007 will also have:

1. Institutions for carbon management that reliably communicate the price of carbon.
2. If wedges of *nuclear power* are achieved, strong international enforcement mechanisms to control nuclear proliferation.
3. If wedges of *CO_2 capture and storage* are achieved, widespread permitting of geological storage.
4. If wedges of *renewable energy* and *enhanced storage in forests and soils* are achieved, extensive land reclamation and rural development.
5. **A planetary consciousness**.

Not an unhappy prospect!