

Technology and Policy



Karen Street
Berkeley MM



Photo of Geysers Geothermal Power Plant courtesy of Calpine



Reducing GHG Emissions from
Above

Berkeley Monthly Meeting

June 3, 2007

What do we want to accomplish?



Parents here and everywhere want a better world for their children, including material goods. For richer children, this includes travel, to live far from other relatives and still visit frequently.

What do we want to accomplish?

- Continued prosperity
- Better health (less pollution)
- Ecosystem protection
- Energy security -- protection against running out of energy, cartels, unanticipated problems.



Not all of us will get what we want.



Lear jets were used for the Hurley-Nayar wedding.

And by Al Gore as he travels to promote concern about climate change.



The current situation - a changed world

We are already seeing:

- heat waves, like the Eurasian 2003 event which killed tens of thousands
- increasing instability in permafrost areas, increasing avalanches
- earlier spring (leaves, migration, egg-laying)
- warmer water, affecting water quality
- changes in algal, plankton, and fish abundance, shifts in range
- shift in precipitation away from the equator to higher latitudes

The Future: Policy Assumptions

Population will continue to increase, per capita consumption will continue to increase, particularly in the third world. Voluntary behavior change will not be important to reducing GHG emissions.

Perhaps an **80%+** reduction in emissions will get to the level the Earth can absorb -- our share of the reduction should be greater, as Americans emit almost **5x** the world average.

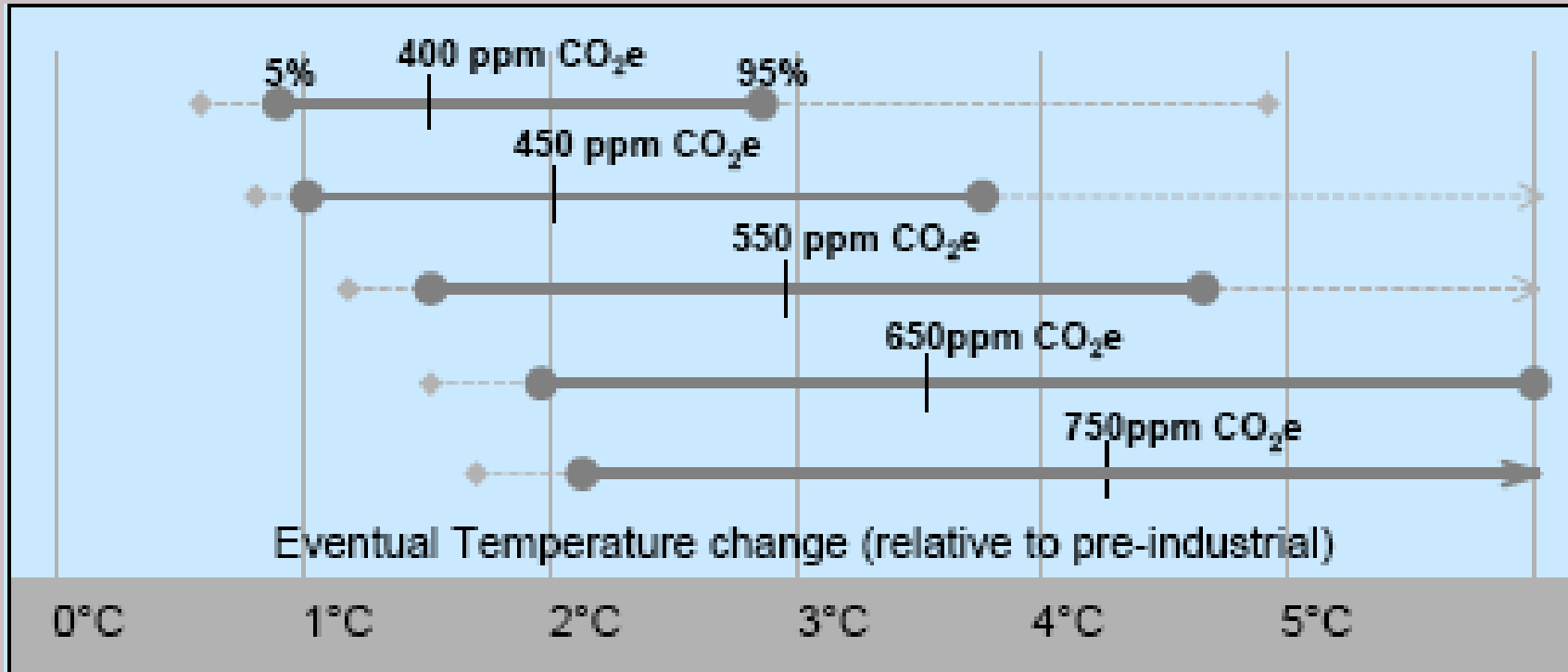
The CA plan: total emissions reduced to 80% below 1990 levels. Per capita reduction more than 90%.

Consider it insurance.

No one knows for sure:

- a given atmospheric GHG concentration --> what temperature increase?
- a given temperature increase --> what climate change?
- a given climate change --> ecosystem damage?
- a given ecosystem damage --> costs to humans and other species?

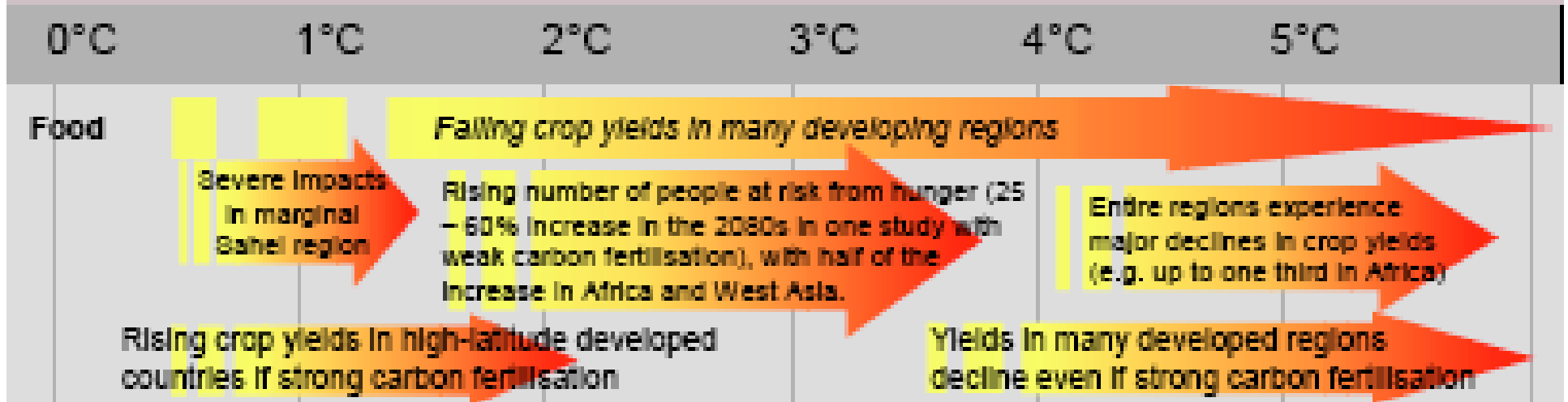
Consider it insurance.



550 ppm CO₂e is about 450 ppm CO₂ and 100 ppm other GHG.

Note: 450 ppm CO₂e has a 50% chance of $T > 2^\circ \text{C}$, and a 5% chance of $\Delta T > 5^\circ \text{C}$.

Burning Embers: Food



Burning Embers: Water

0°C

1°C

2°C

3°C

4°C

5°C

Water

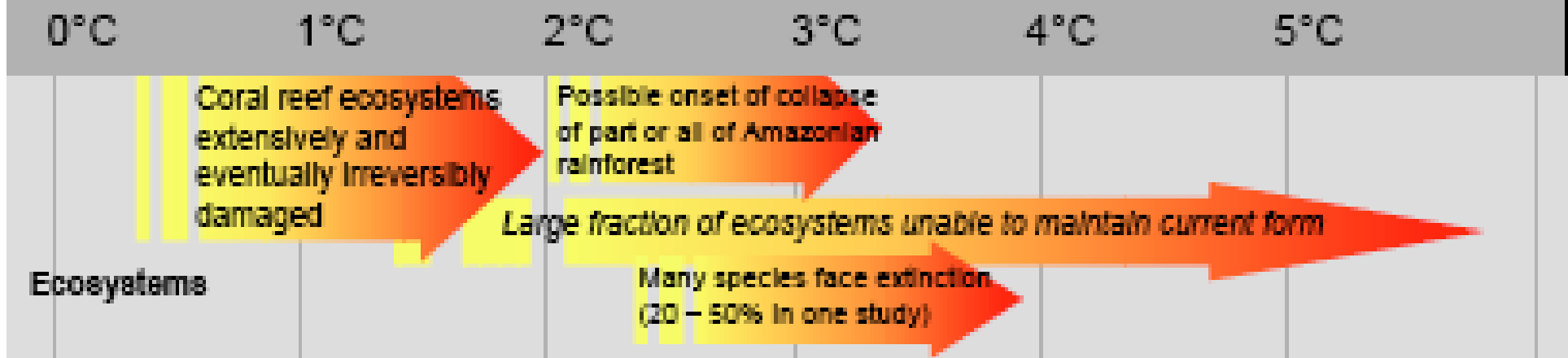
Small mountain glaciers disappear worldwide – potential threat to water supplies in several areas

Significant changes in water availability (one study projects more than a billion people suffer water shortages in the 2080s, many in Africa, while a similar number gain water)

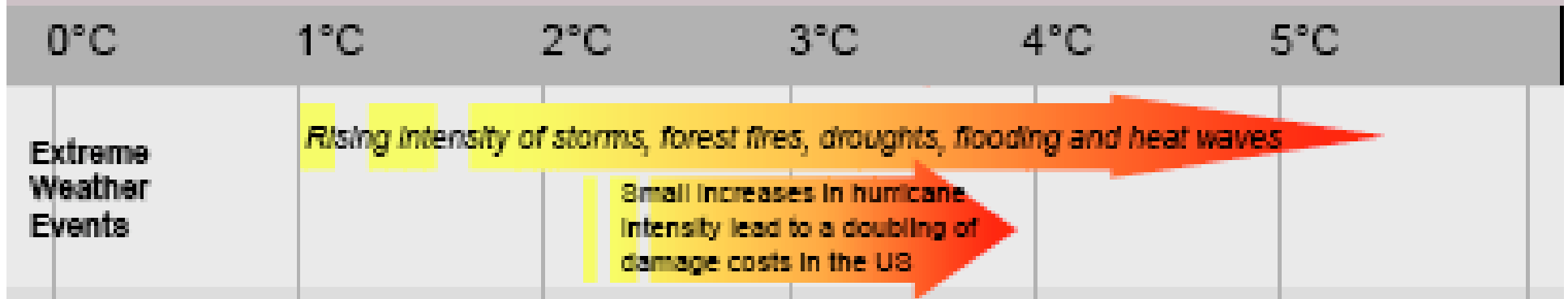
Greater than 30% decrease in runoff in Mediterranean and Southern Africa

Sea level rise threatens major world cities, including London, Shanghai, New York, Tokyo and Hong Kong

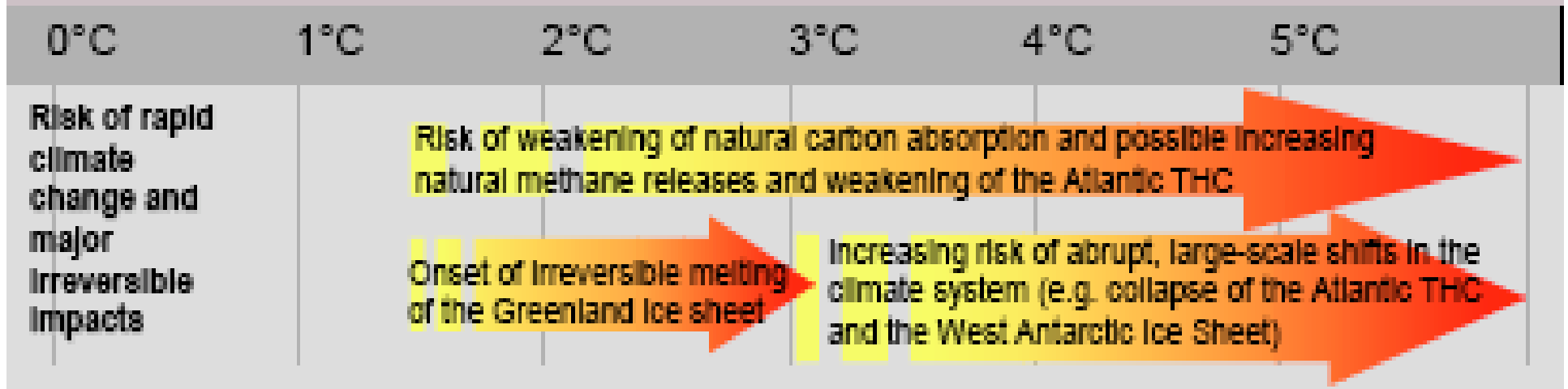
Burning Embers: Ecosystems



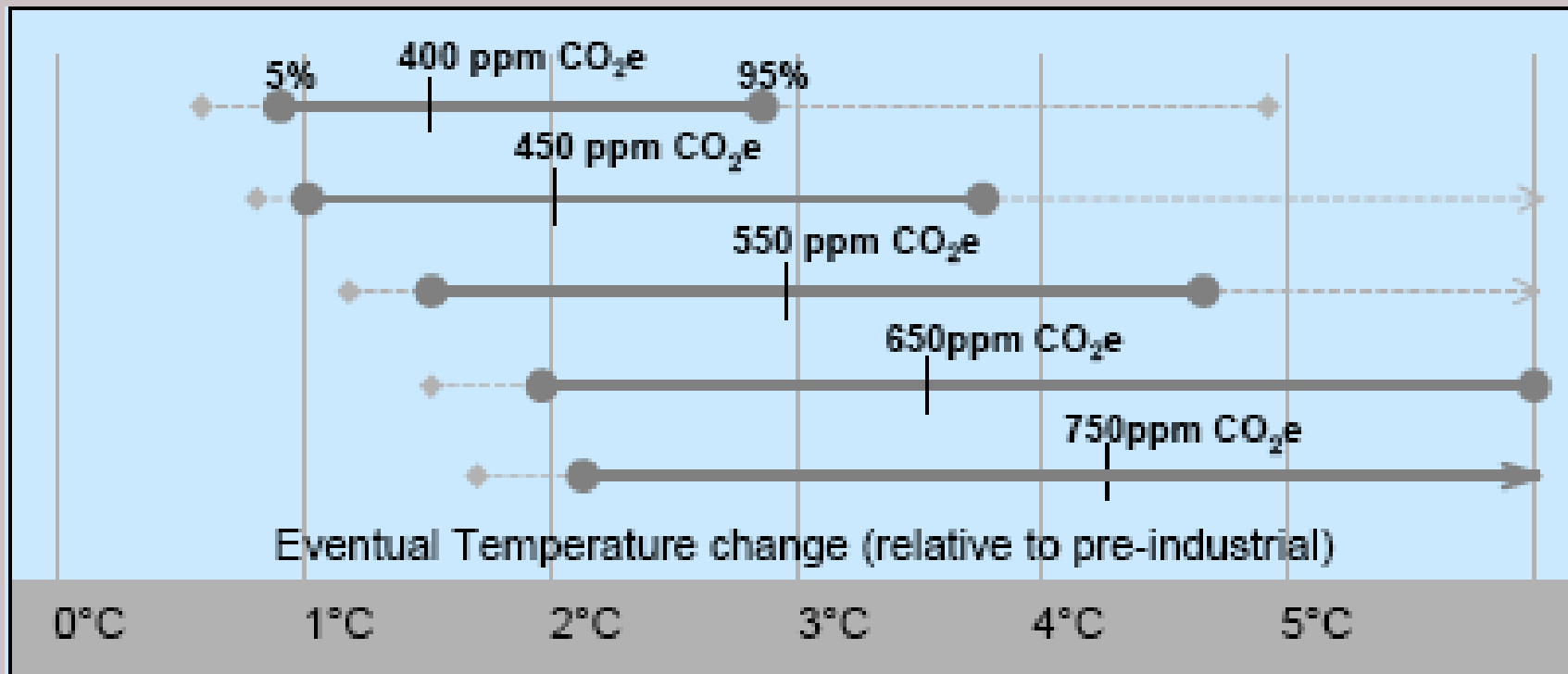
Burning Embers: Extreme Weather Events



Burning Embers: Greater Risks



Uncertainty about Temperature Increase



The Future

- Average temperature will continue to increase.
- Sea level will continue to rise.
- Precipitation will increase in some areas, decrease in others, and become more variable -- and fall more often in extreme events -- over much of the world.
- Farmers, and civil engineers, will not be able to predict the future as reliably.
- We are committed to temperature increases of 0.2 C/decade for the next two decades at least, and lower amounts in the future, if we add no more GHG to the atmosphere.

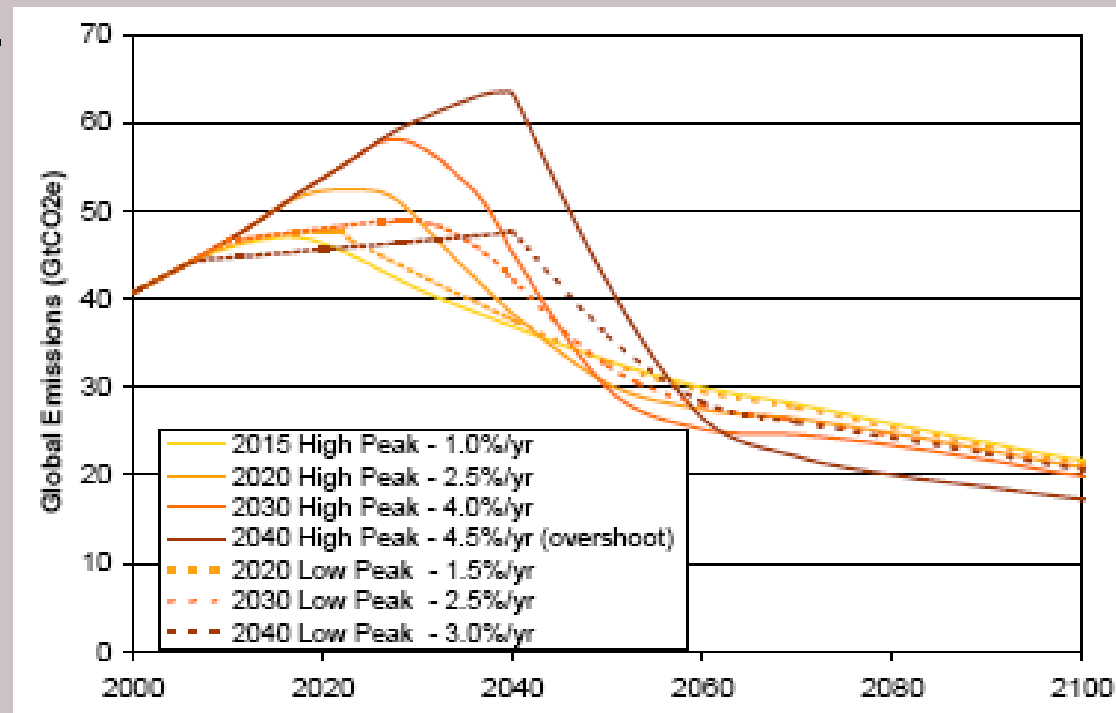
Goals

- To stabilize below 550 ppm CO₂e, GHG emissions must peak in the next 10 - 20 years, then fall by 1 - 3%/year to 25% below today's level by 2050. If Gross Domestic Product triples (or more), emissions/unit GDP will be cut by 3/4 (or more).
- To stabilize below 450 ppm CO₂e, GHG emissions must peak in the next 10 years, then fall by 5%/year. By 2050, emissions will need to be 70% below current levels.

IPCC: goal -- 445 - 535 ppm CO₂e

Cost < 0.12% of world's GDP each year, plus the cost of adapting. This information is already out of date -- China built 100 GW in coal power in 2006.

Stern Review: Alternative cost is 5 - 20% (or more) of world's GDP, forever.



450 - 550 ppm CO₂e

Stern Review: continued gains in wealth possible if we spend on mitigation. If we spend too little today, we are likely to spend much more soon.

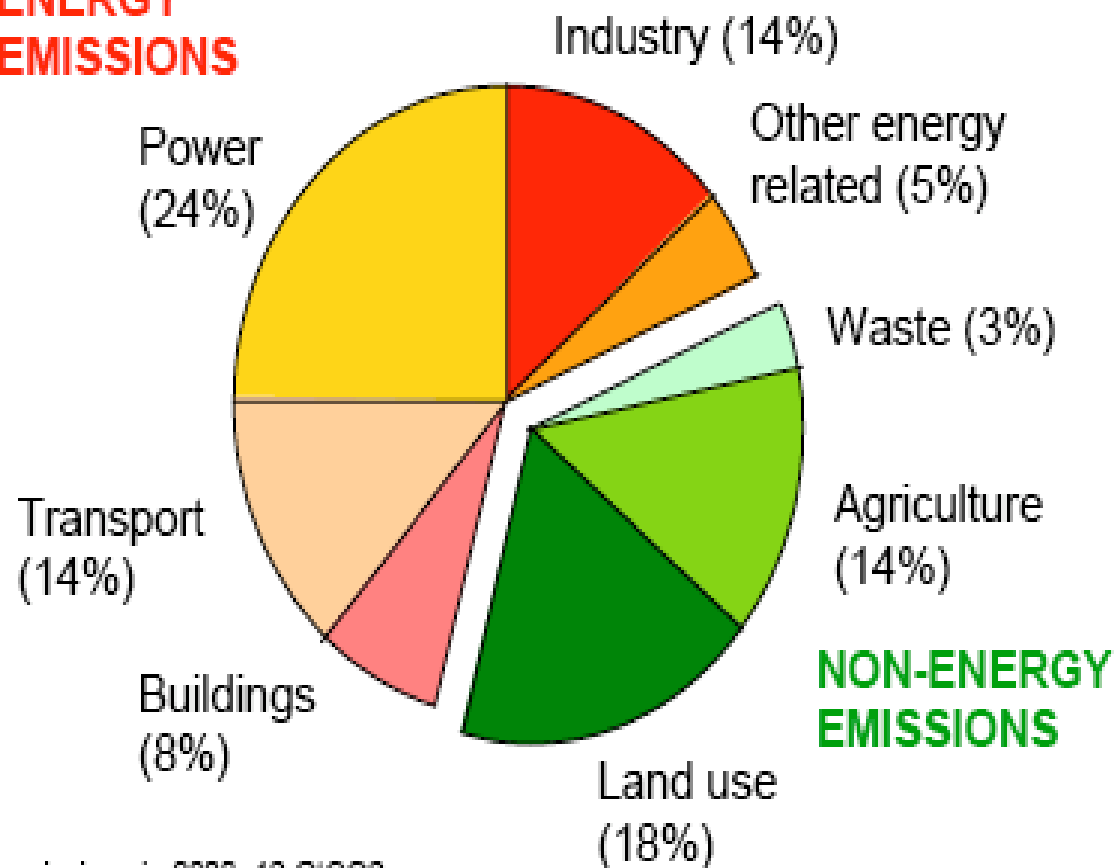
Costs of mitigation and failing to reduce GHG sufficiently are uncertain, and uncertainty increases with time. Costs rise significantly with delay.

Stabilizing at 450 ppm CO₂e almost out of reach.

Climatologists mostly uncomfortable with all or part of this range.

The current situation - GHG Emissions

ENERGY EMISSIONS



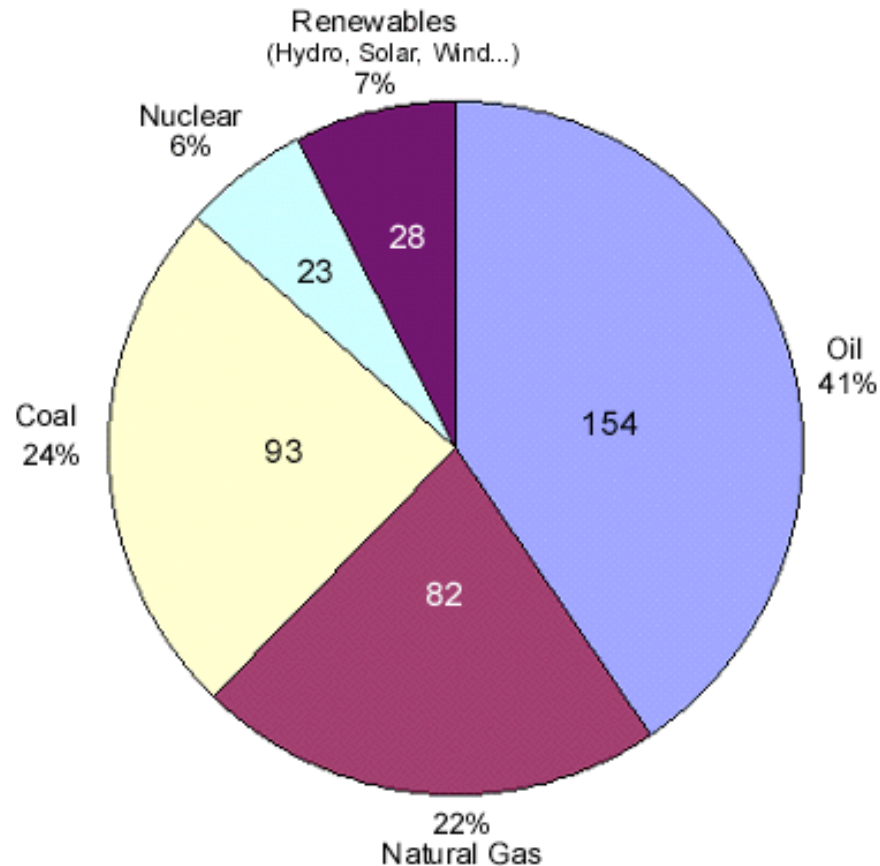
Policy experts must address greenhouse gas emissions from both energy and non-energy sources.

Total emissions in 2000: 42 GtCO₂e.

Energy emissions are mostly CO₂ (some non-CO₂ in industry and other energy related).
Non-energy emissions are CO₂ (land use) and non-CO₂ (agriculture and waste).

The current situation -- Energy Use

1997 Global Energy Consumption by Type
(Quadrillion BTUs)



Total Consumption - 380 Quad BTUs

Source: U.S. Dept. of Energy

- Fuels for transportation
- Power (electricity)
- Heating and cooking (fuel oil, natural gas, propane)

More than 40% of CO₂ emissions come from coal.

Technology change is part of the solution.

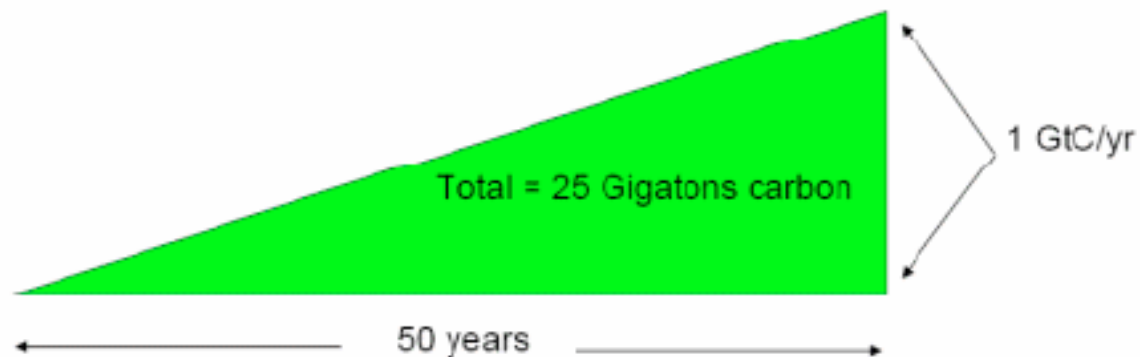
We need to understand some terms:

- GW (gigawatt) is a measure of how much electricity a power plant can produce at maximum rate
- Wedge

Socolow Wedges

What is a “Wedge”?

A “wedge” is a strategy to reduce carbon emissions that grows in 50 years from zero to 1.0 GtC/yr. The strategy has already been commercialized at scale somewhere.

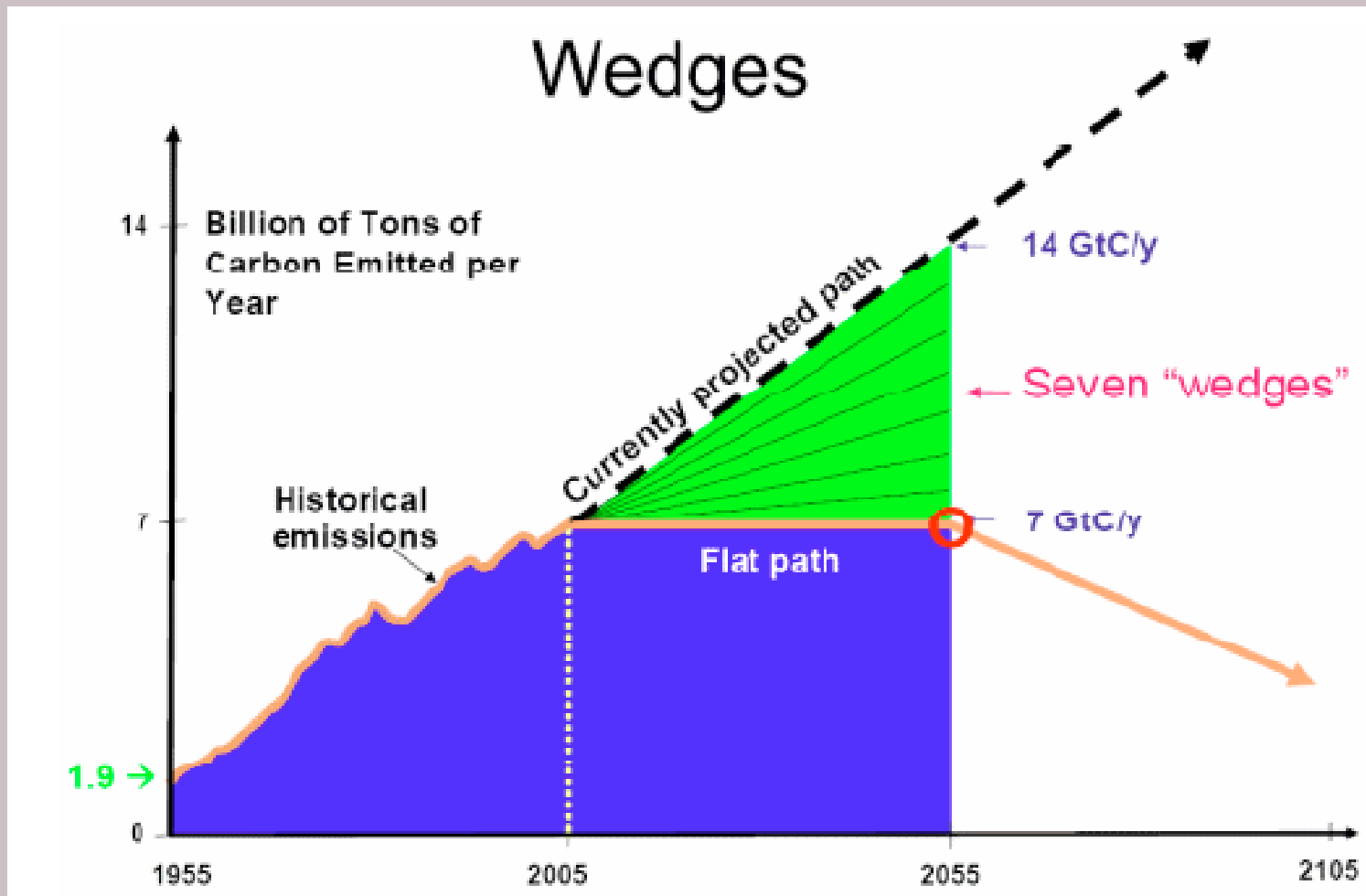


Cumulatively, a wedge redirects the flow of 25 GtC in its first 50 years. This is 2.5 trillion dollars at \$100/tC.

A “solution” to the CO₂ problem should provide at least one wedge.

1 metric tonne C = 4 tons CO₂, \$100/tC = \$25/ton CO₂

Socolow Wedges



How much do we need to reduce GHG emissions?

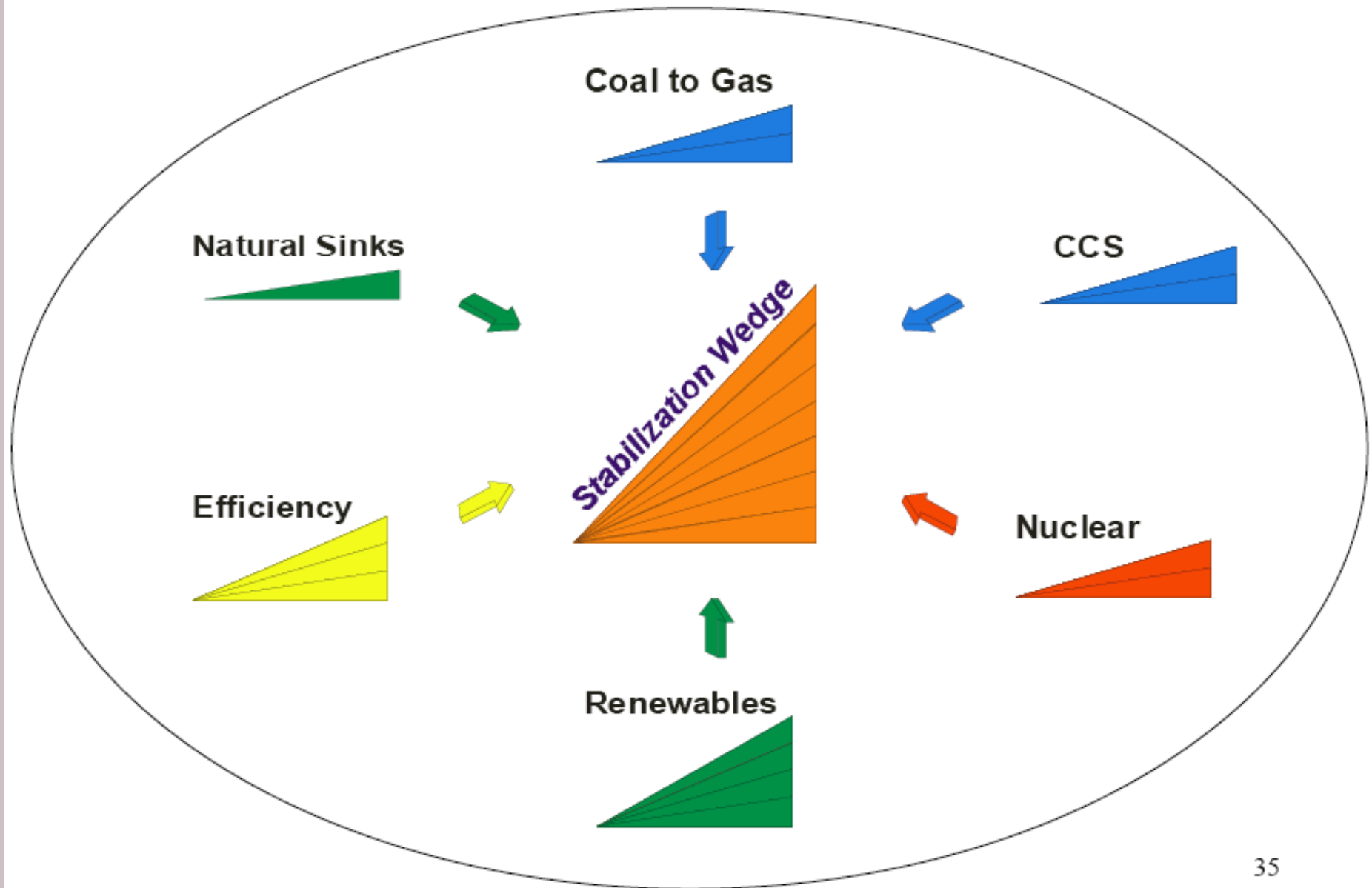
Socolow estimates 7 wedges will stabilize greenhouse gas emissions by 2057.

But the goal is to reduce emissions by 2050. In this time frame, positive feedbacks, such as warming soil releasing carbon dioxide and methane, is likely to be important, requiring even more wedges to counteract. So 10 wedges? 12? more?

California policy analysts recommend an 80% reduction in GHG emissions in the developed world, even as population and per capita consumption increase. The British goal of 60% is seen as dangerously low.

Cost: 0.12% (or more) of GDP to stabilize at 445 - 535 ppm.

There may be many possible wedges



Socolow wedge: trees and other plants

- biological sequestration: 1 wedge from zeroing out deforestation plus significant afforestation -- this wedge is iffy.

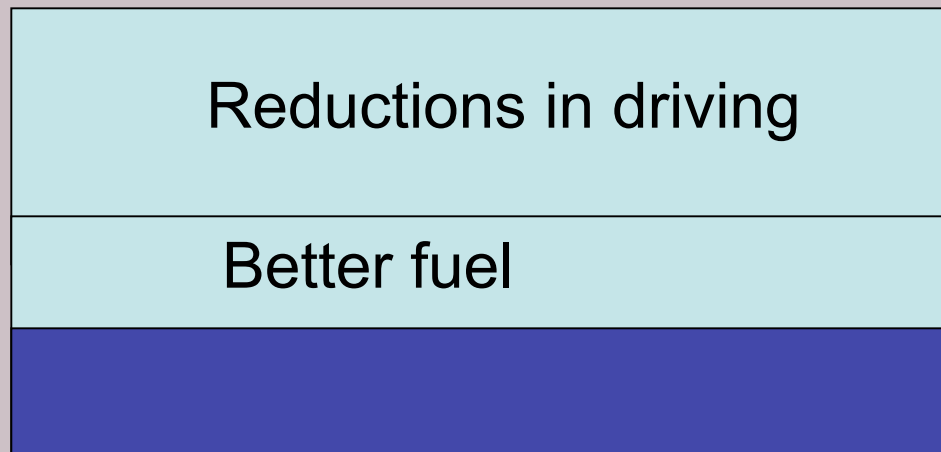
Afforestation in China



Wedges don't add up

Doubling fuel economy from 30 to 60 mpg will save one wedge.

Reducing driving by half will save one wedge.



Doing both is
1.5 wedges.

Socolow wedge: efficiency

- double fuel economy to 60 mpg in 50 years (while number of cars quadruples): 1 wedge
- improve buildings, lighting, appliances: 2+ wedges

Efficiency may be the single largest contribution.

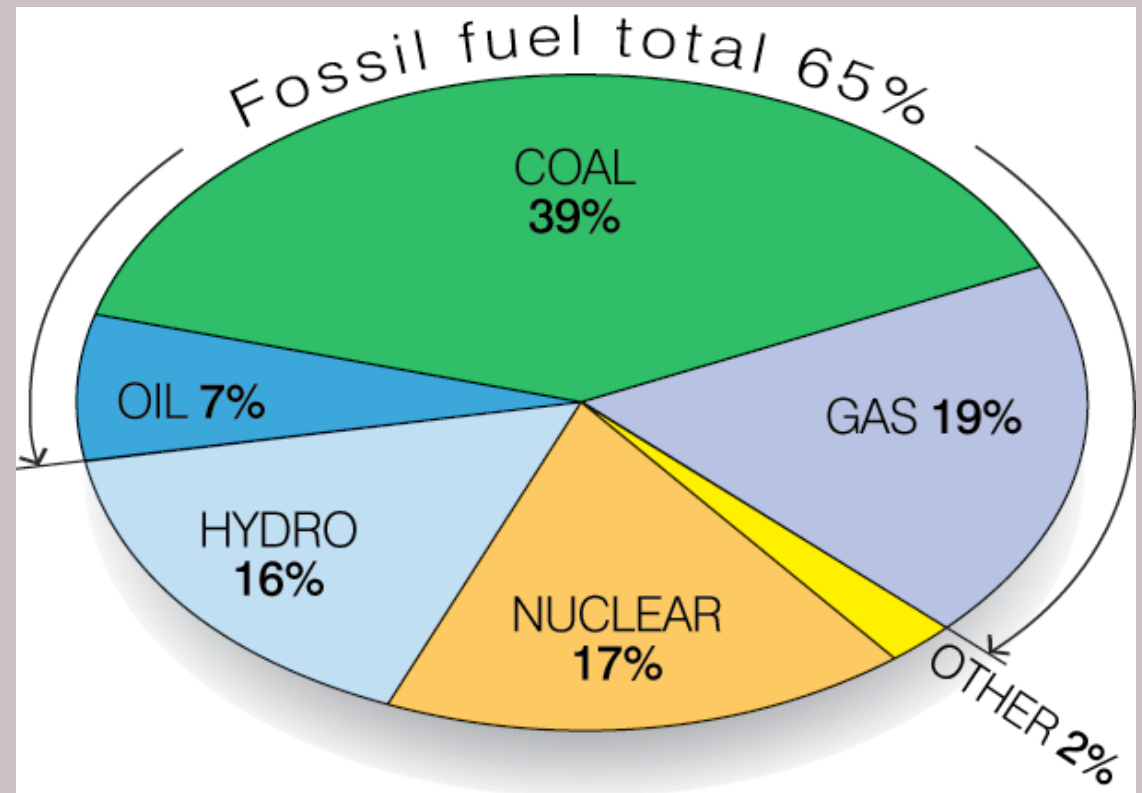
Possible policy choices:

- ban most incandescent bulbs
- improve miles/gallon in cars -- \$spent improving efficiency = \$saved on fuels.

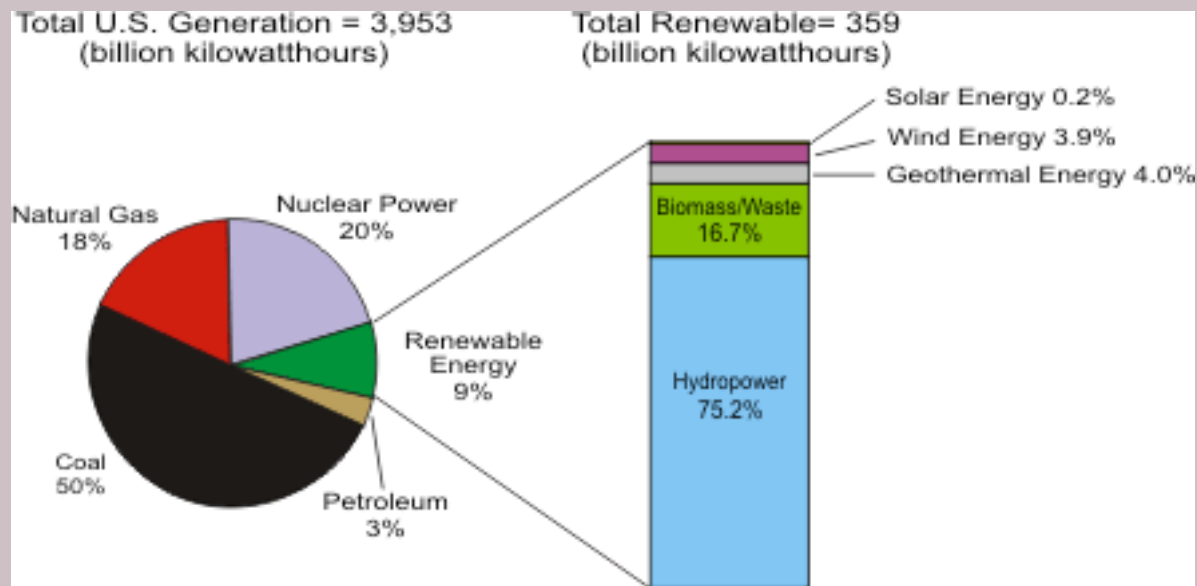
Decarbonizing Power (Electricity)

To stabilize at 550 ppm CO₂e, 60 - 75% of power must be decarbonized, even as power production grows rapidly.

Electricity is easier to decarbonize than fuel (and reducing driving + flying), but both decarbonizing and reducing transportation will be necessary.



Decarbonizing Power



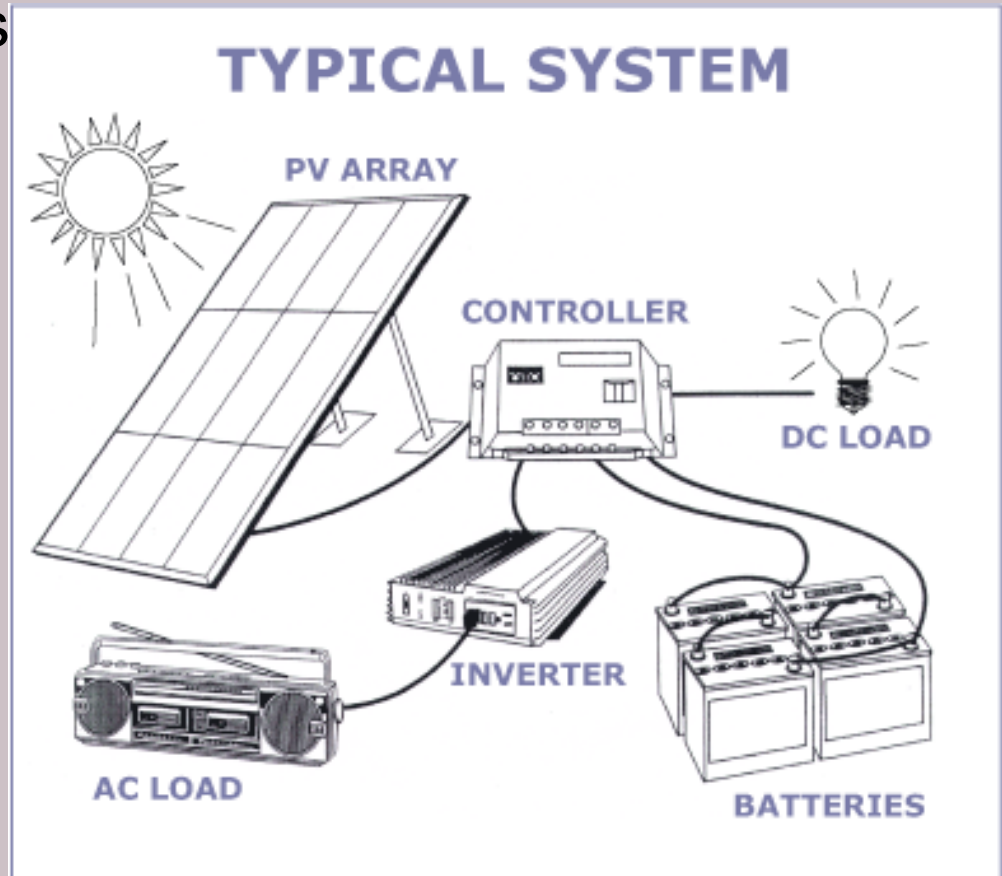
The US power has lots of room to decarbonize power. Currently, >150 new coal plants have been proposed. Not the right direction!

Socolow wedge: solar

1 wedge = increase by 1,000 - 1,500 x

CA Million Solar Roofs Initiative: hopefully 3 GW by 2017 -- this will produce as much electricity as a 0.6 GW nuclear power plant.

Photovoltaic panels last 25 - 30 years.



Capacity Limits

If the sun were always shining at the right angle, then 1 GW (gigawatt, or billion watts) of solar panels will always produce 1 GW power. US solar averages 19% -- and European values are lower.

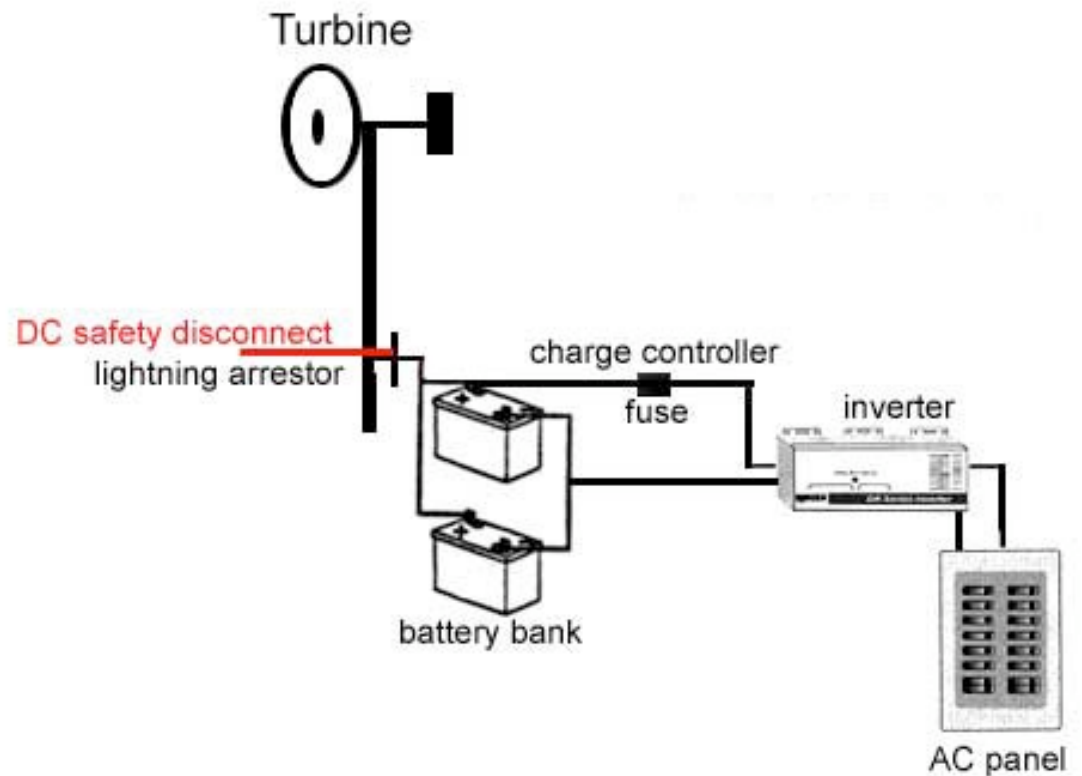
Political Map of the World, April 2000



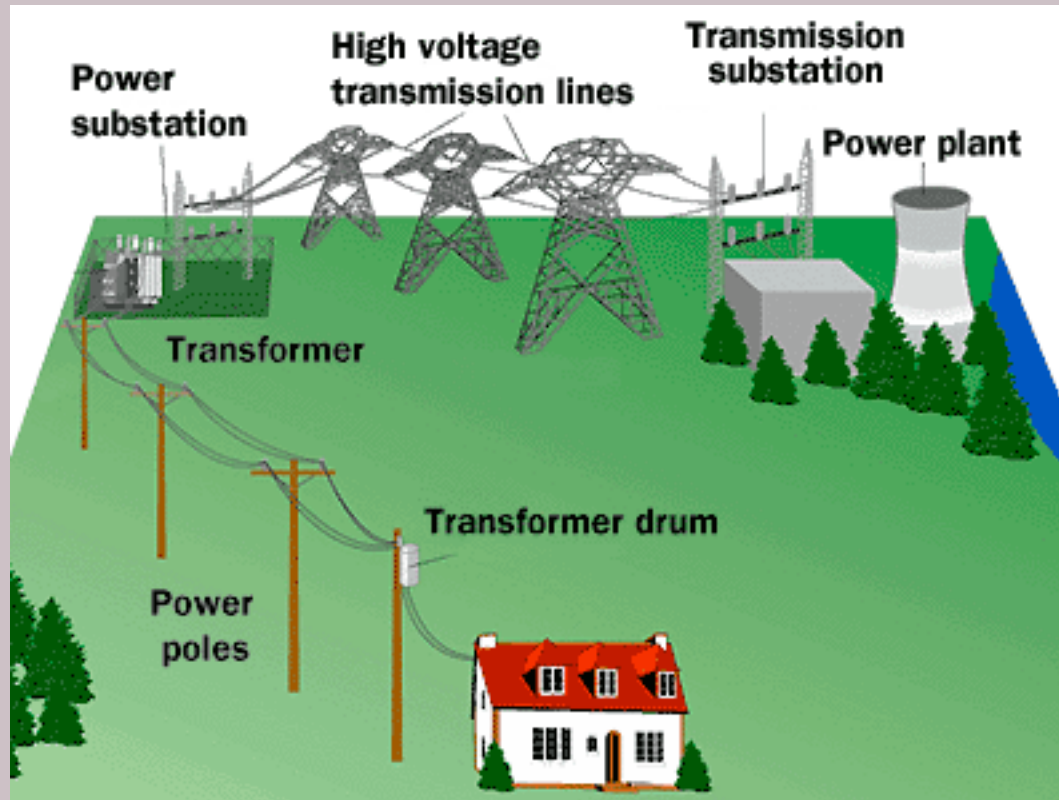
Socolow wedge: wind

1 wedge = 33 x current amount of wind, assumes windmills placed where wind blows more, and more consistently.

Windmills last 20 - 30 years. They operate much less when it's very hot or cold. Backup with hydro or inefficient natural gas.



Solar and wind require upgrading grid.



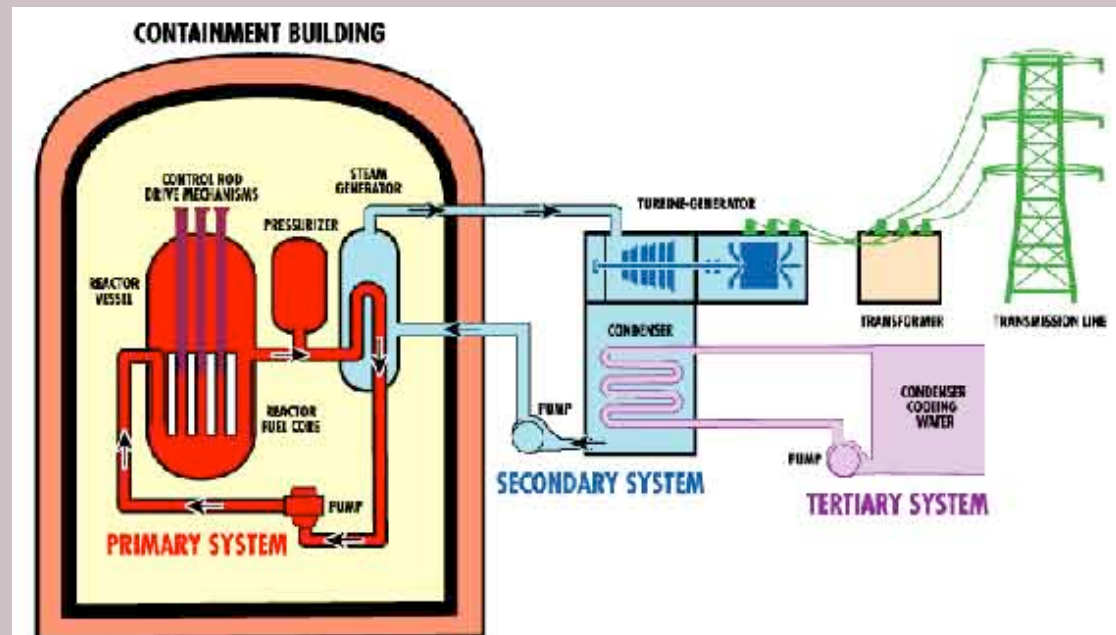
Complexity increases dramatically as number of nodes increases

Socolow wedge: nuclear

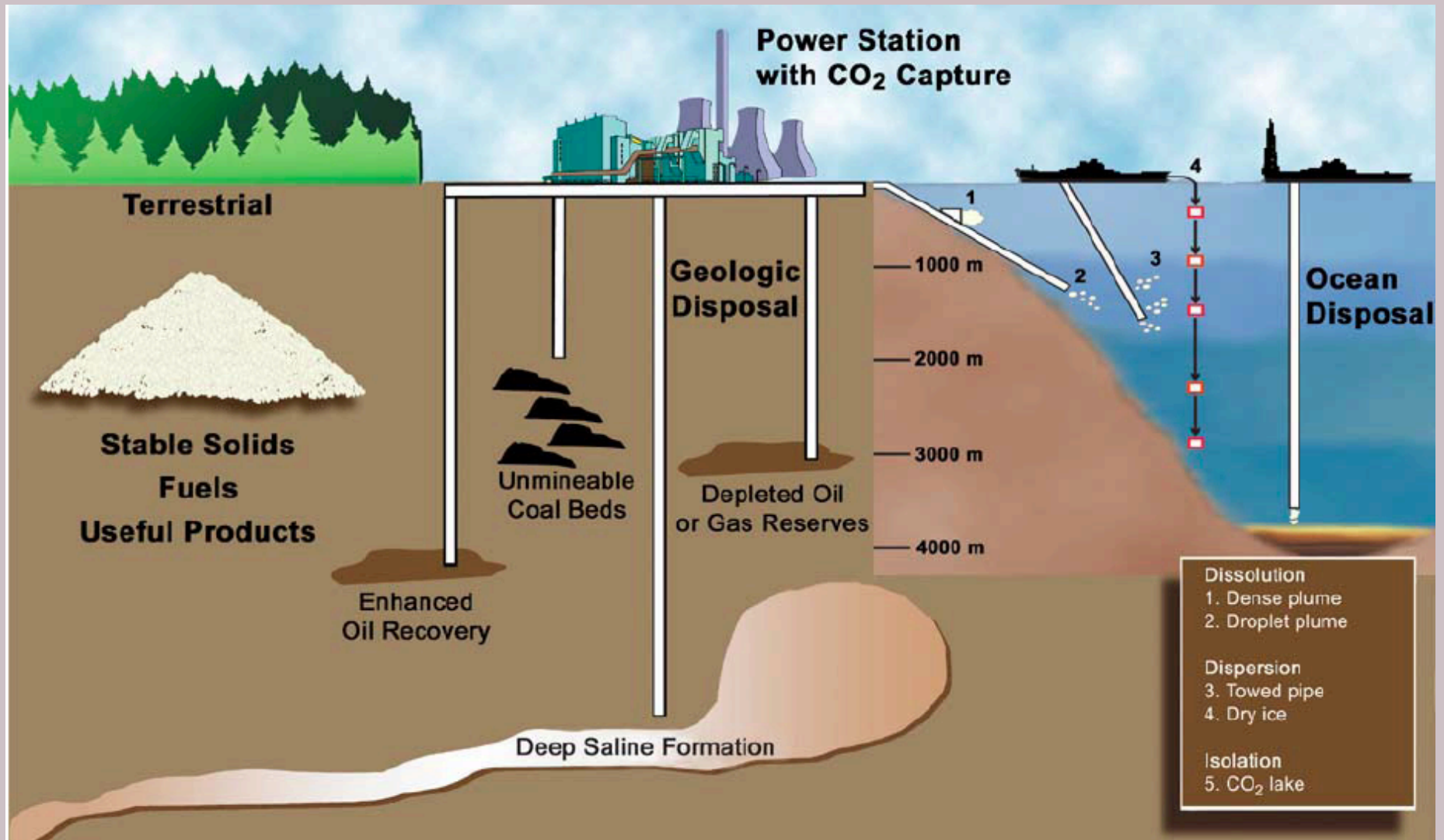
1 wedge = 2 x current installed capacity, about 500 reactors.

Nuclear power plants last 60 years+.

Pressurized water reactor



Socolow wedge: carbon capture and storage (CCS)



Source: CO2CRC

Carbon Storage Options

Socolow wedge: carbon capture and storage for coal

Geological sequestration -- 80 - 90% of GHG from coal can be stored in the ground. Changing plant design later is too expensive; initial design must include sequestration plans. Demonstration projects, more research needed. Partially tested technology, large potential, reduces GHG emissions by 80 - 90%, at a cost of money and energy. Ramp up could be rapid.

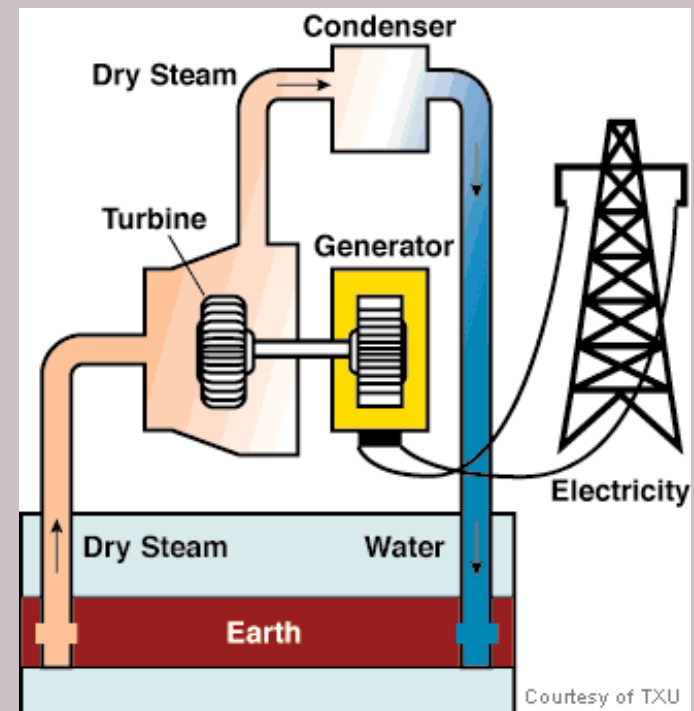
1 wedge: about 800 GW coal power.

Other: China added 100 GW coal power without CCS in 2006. A cost of \$25-30/tonne CO₂ makes CCS economic.

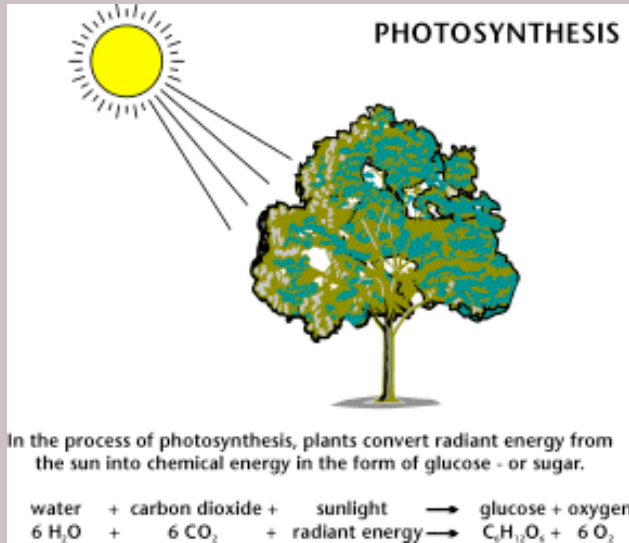
Mini-wedge: geothermal

1 wedge = 70 x current world capacity, assumes operating 22 hours/day, rather than 18.

MIT study: 1/7 this amount could be in US by 2050.



Socolow wedge: cellulosic biofuels



No plans exist for replacing jet fuel with biofuels.

Plants are made of CO₂ and H₂O.

Possibilities: trees (eg, poplar), construction site and municipal residue, corn stover, cereal straws, and grasses.

One wedge = 34 million barrels/day in 50 years, >500 billion gallons/year, <50 times today's production, assuming no GHG emitted in process.

Current biofuels



BORNEAN ORANGUTAN *Pongo pygmaeus pygmaeus*
© 2006 Dr. Ellen K. Rudolph

The Guardian:

“About 80% of orang-utan habitat in south-east Asia has been destroyed in the past 20 years because of soaring demand for land to produce palm oil for western markets...”

UN-Energy: “Recent oil price increases have had devastating effects on many of the world’s poor countries...[For many countries] the arguments for supply diversification are strong. [But...]

“Bioenergy is being used all over the world. In some instances, it is truly sustainable, and in others it is highly destructive.”

Europe’s 10% biofuels by 2020 mandate depends heavily on imported ethanol.

Electricity displacing fuels

Much of the electricity produced at night (nuclear, coal, wind) is wasted. Additionally, utility managers would like to see more balanced day and night use because peak power tends to be expensive (and inefficient).

Plug-in hybrids will get 100? miles to the gallon, with a charging cost of \$1?/gallon. Cars use only electricity for short trips (< 25 miles/day?), charge up at night. Not useful for long-distance trucking.

Other: batteries are expensive and polluting.

Policy change is part of the
solution.

Smart growth

Or finding ways to encourage us to change our behavior.

Current laws can require much of the city be devoted to the car.



Smart growth

Governor Schwarzenegger proposes cutting subsidies to buses.



NA Transit - (www.natransit.com)

Stephen Lam, 2002-06

Policies to get us there

Stern Review:

- carbon pricing
- technology policy
- removing barriers to change

Carbon Pricing

Cap and trade -- emissions known, cost uncertain.

Tax -- cost known, emissions uncertain.

GHG cap and trade -- center of European Union policy.

Some countries, some sectors, GHG taxes make more sense.

Avoid locking into C-intensive decisions today (any new coal plant). There will have to be a transition, first for industrialized countries to get emissions trading scheme going well, and then to bring in developing world.

Policies to make GHG reduction urgent.

- R&D, demonstration, early deployment -- double R&D to \$20 billion/year (world)
- Deployment incentives should rise by 2 - 5 times (now \$34 billion)

Removing barriers to behavior change

Provide

- reliable information -- labeling, sharing information, and the Cambridge plan
- financing
- regulation when pricing signal is too muted



Adaptation

Needed no matter how rapid the mitigation.



Maple industry is moving north, other crops shifting as well. Should CA grapes be planted in CA or WA?

Adaptation



Irrigation will increase even in many places where precipitation increases.

In some places, electricity is used, others, manual labor.

Adaptation

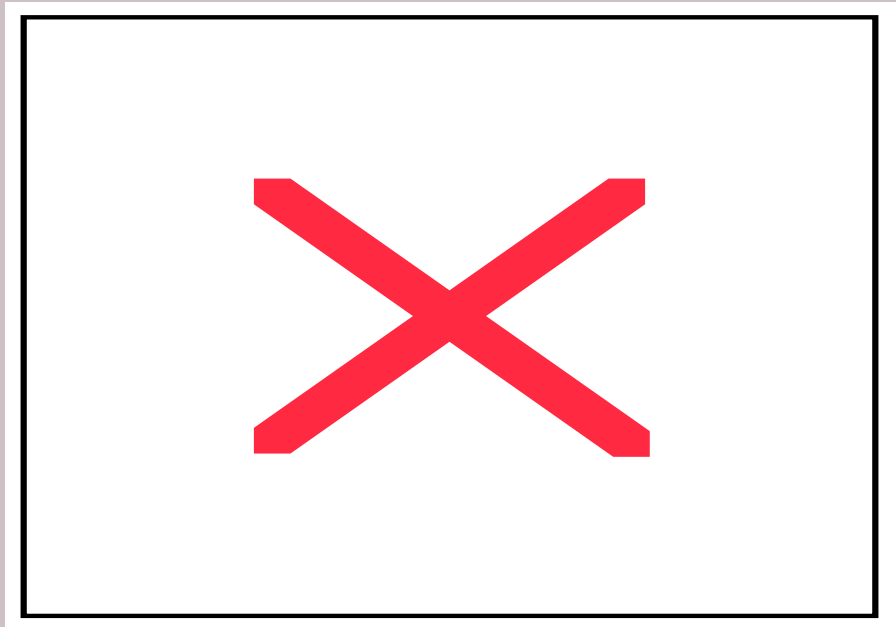


Floating houses are becoming more common in the Netherlands in areas prone to sea level incursion.

Adaptation

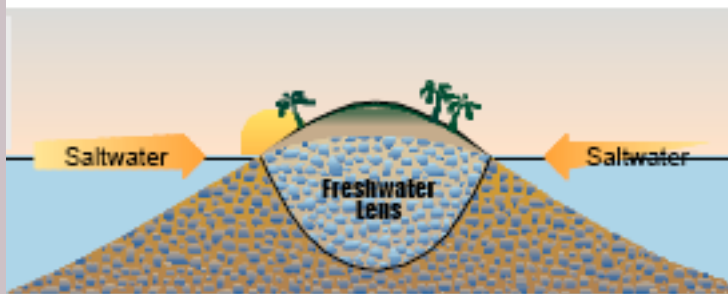


Summer 2004, hundreds dead, millions flee, 38% of country under water.



Bangladeshis move because of storms, but also from salt water incursion into ground water. Elsewhere, a combination of sea level rise and overconsumption is affecting availability of fresh water.

Freshwater Lens Effect in Island Hydrology



Other Issues

Cost

- Solar
- Coal, carbon capture and storage
- Wind, etc
- R&D today will bring price down tomorrow

Coal: about 5¢/kWh for new coal (more in Germany, where coal is heavily subsidized).

Wind: almost as cheap as nuclear in US, but in Europe, wind operators are paid 12¢/kWh; a Danish utility puts cost to build new offshore windmills at 18¢/kWh.

Solar: CA will add \$2.9 billion in subsidies to federal subsidies and purchase price. Goal: by 2017, 3 GW solar. \$2.9 billion would buy >1.5 GW nuclear, which would produce 2x the electricity/year, and last 2x as long. Construction time: 4 years with standard design.

Other Issues

- NIMBY
 - grid upgrade
 - LNG
 - wind

- Coal to liquids?



- Energy security

- the face of geopolitics: location of oil and natural gas vs. coal and uranium



Other Issues

- Health and environmental considerations

Includes damage to human health, ecosystems, crops, and dangers from accidents.



Remains of
reactor 4

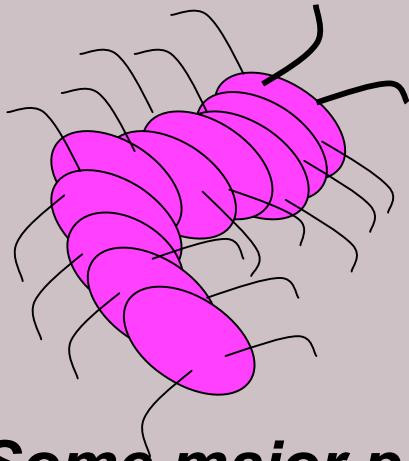


Ukraine coal
mine blast kills
80, March 2000

Coal Accidents in 2007*

- May 24 Siberia 35 die in mine gas blast
- Mar. 20 Siberia Search for miners after 100 killed
- Mar. 19 Siberia Mine explosion kills more than 100 88 miners had been rescued after the blast at the Ulyanovskaya mine ... At least 43 are missing after a methane gas explosion....
- Mar. 11 Northern China 22 die in 'danger' mine flood
- Feb. 3 Colombia Gas blast traps miners.. trapping 31 miners and killing at least 3...
- Jan. 3, 2006 USA Only one miner reported alive

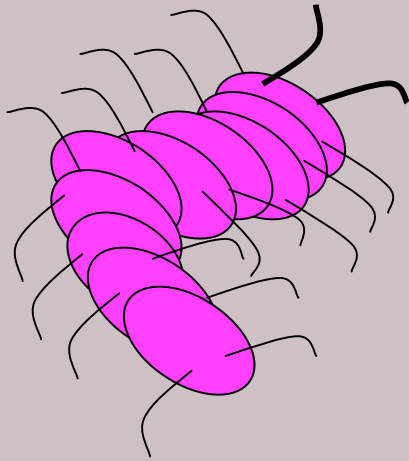
***World Mine Accident Timeline**



Meetings and Climate Change

Some major public discussions in the US and elsewhere (early resolution would benefit policy makers):

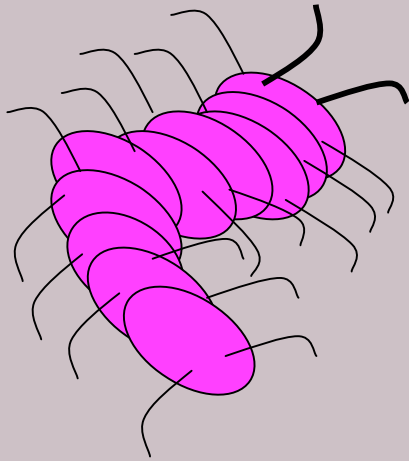
- Can I, will I change my consumption patterns to reduce GHG emissions? Should we stop subsidizing air flights -- and price tickets high enough to discourage flying (for all but the rich)?
- Should we allow/encourage governments to pass strong laws affecting public behavior: mandating high efficiency bulbs, cars, and appliances, or mandating lighting or temperature limits in public buildings?



Meetings and Climate Change

Some major public discussions in the US and elsewhere (early resolution would benefit policy makers) cont.:

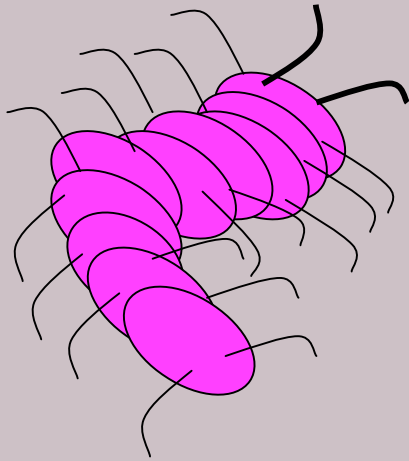
- Should people in the industrialized world, particularly the US, pay 0.1% or more of our Gross Domestic Product for reducing GHG emissions and funding research?
- Should we pay the same amount again for third world, particularly for economic competitors such as China?



Meetings and Climate Change

Some major public discussions in the US and elsewhere
(early resolution would benefit policy makers) cont.:

- Should we reconsider nuclear power?



Meetings and Climate Change

Major public discussions in the US and elsewhere (early resolution would benefit policy makers) cont.:

How can we facilitate public discussions of the knotty issues?

Blog and Web Sites

A Musing Environment

<http://pathsoflight.us/musing>

Friends Energy Project

<http://www.quaker.org/fep/>

Talks at Cal

<http://cbc.berkeley.edu/thisweek.html>