The Energy Exchange Series

Fossil fuels and climate change – lessening the damage from the collision

Professor Robert H Socolow

Princeton University

Customs House, Brisbane

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Four world views

		Are fossil fuels hard to displace?	
		NO	YES
Is climate change an urgent matter?	NO		
	YES		

Four world views

		Are fossil fuels hard to displace?	
		NO	YES
Is climate change an urgent matter?	NO	A nuclear or renewables world unmotivated by climate.	Most people in the fuel industries and most of the public are here. **5°C.**
	YES	Environmentalists, nuclear advocates are often here. **2°C.**	WHY WE'RE IN THE ROOM **3°C?**

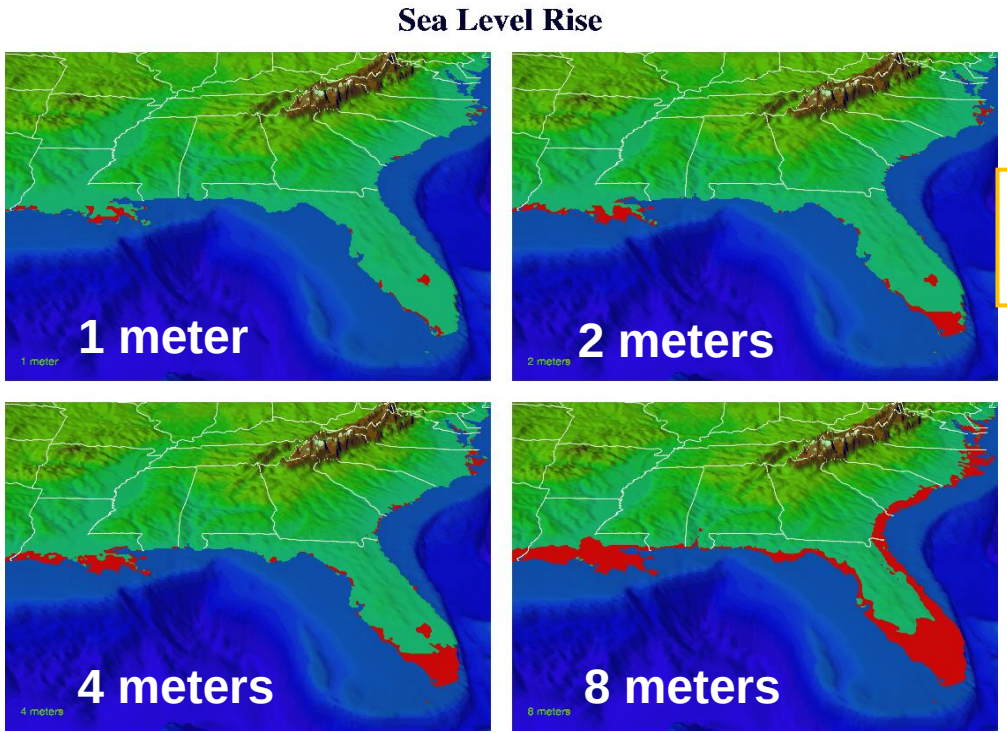
What happens when an irresistible force meets an immovable object?

The irresistible force: Fossil fuels, as vital as ever.

The immovable object: Climate change, which looms ominously.

Confronting the paradox is our job.

Uncertain timing of climate change



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

Cumulative emissions (net) and temperature

1°C will result from anthropogenic CO_2 emissions to date.

2°C results from future emissions equaling historical emissions.

3°C will result from roughly tripling the historical total.

The probability is about 1/6 for both:

getting ≥3°C while aiming for 2°C (being unlucky)
getting ≤2°C while aiming for 3°C (being lucky).

“Carbon budgets”: drivers of climate policies

Tough choices:

- When?
- Whose?
- Used where?
- For what purpose?
- Which fossil fuels ($CH_{0.8}$ *vs.* CH_4)?

Which fossil fuels will we judge to be “unburnable” and leave in the ground? Who decides?

“Unburnable” fossil fuels

1000 billion tons of CO_2 (1000 $GtCO_2$):

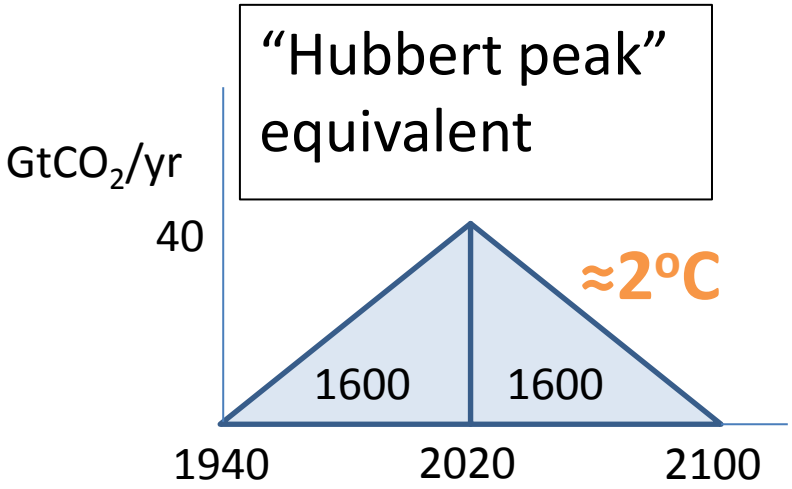
2 trillion barrels of oil
20,000 trillion cubic feet of gas
300 billion tons of coal

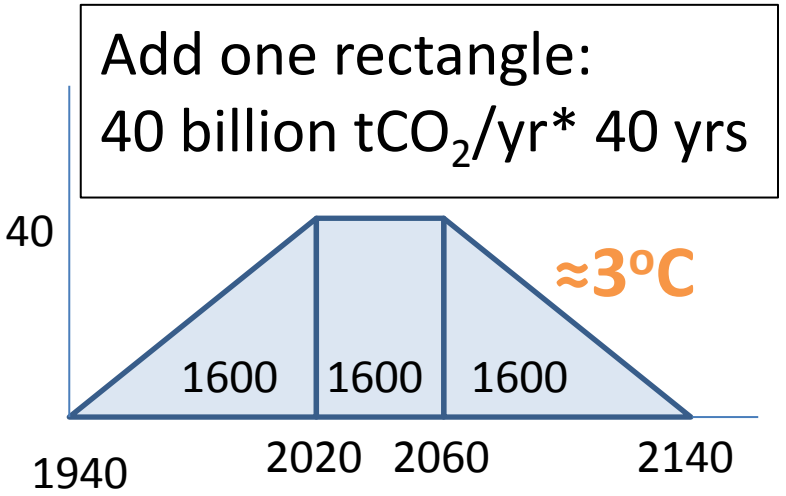
Resources in the ground ($GtCO_2$):

Oil	8,000
Gas excluding clathrates	3,000
Clathrates	40,000
Coal	20,000
Total	**70,000**

Source: Rogner, H-H, 1997. “An assessment of world hydrocarbon resources,” *Ann. Rev. Energy and Env*. *22*, pp. 217-262. The table reworked here is on p. 249. Estimates include “additional” resources.

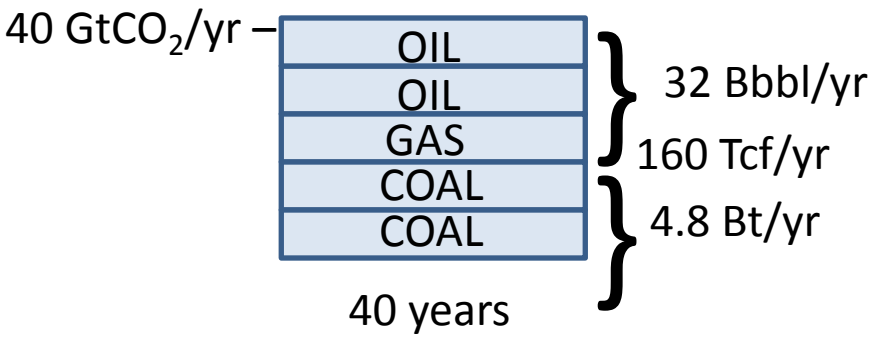
Carbon emission trajectories for 2°C and 3°C

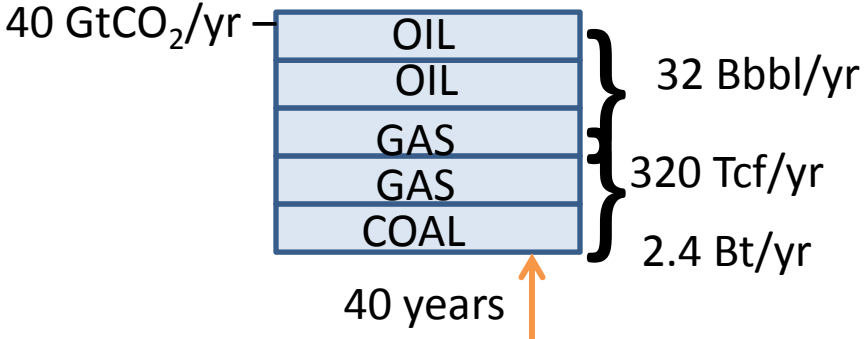




Fossil fuels are so abundant that, for even a weak climate target, *attractive* fossil fuel will be left in the ground.

Gas v. coal: two 1600 $GtCO_2$ rectangles





$G = B = 10^9$, $T = 10^{12}$

Additional primary energy: ≈3000 EJ

Future coal plant, CO_2 captured and stored

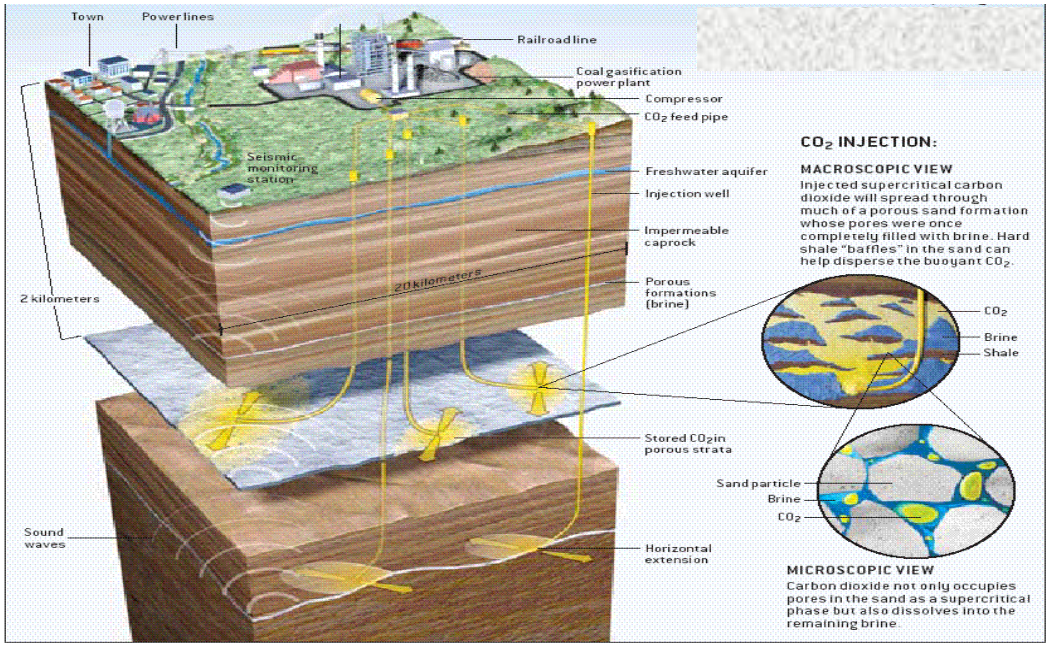


ILLUSTRATION BY DAVID FIERSTEIN, CONCEPT BY JULIO FRIEDMANN Lawrence Livermore National Laboratories

Assume:

1000 MW coal plant

10 years of operation

60 m usable, vertically

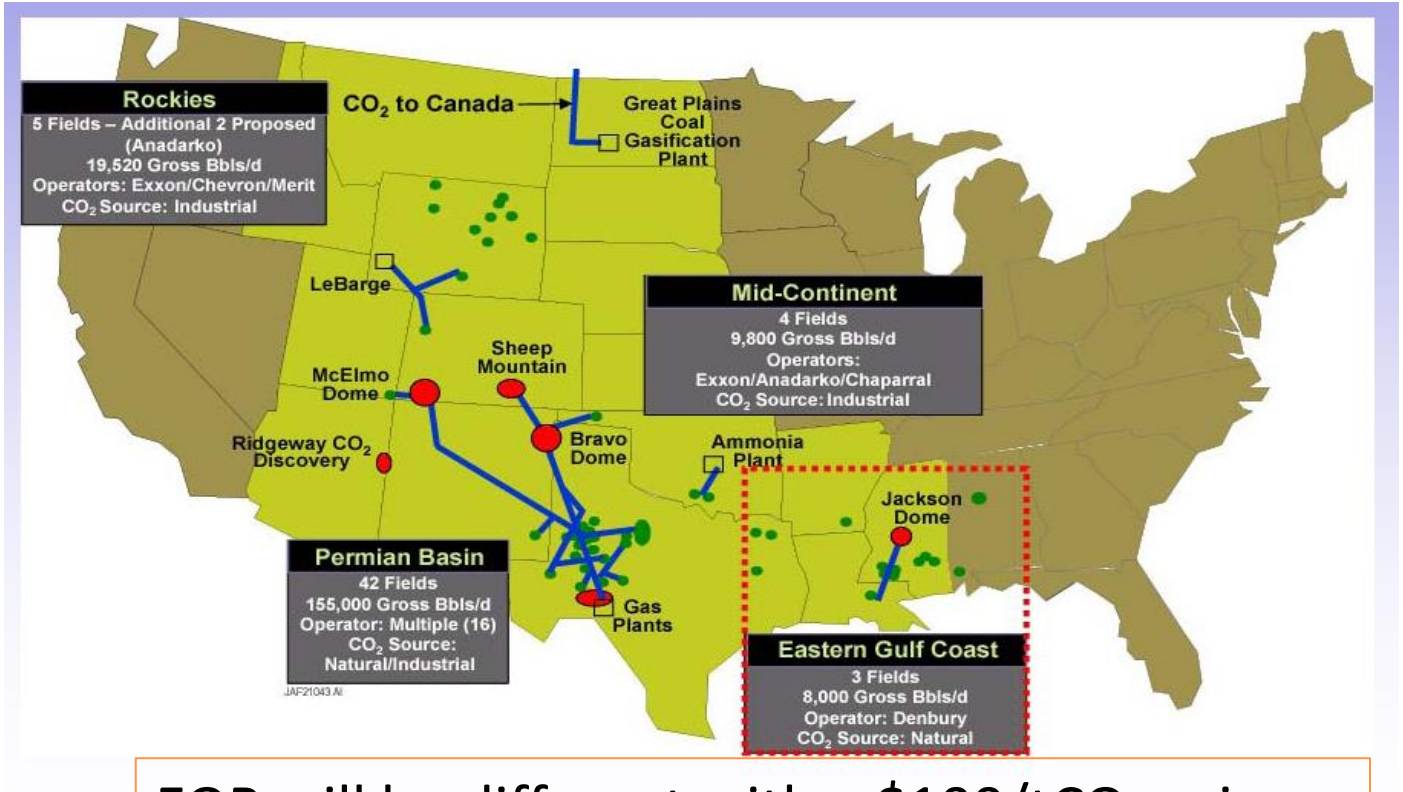
10% porosity

1/3 of pore space is CO_2

Result: Horizontal footprint is 40 km^2.

How long does the CO_2 need to stay down?

U.S. CO_2 pipeline infrastructure



EOR will be different with a \$100/tCO_2 price.

$100/tCO$_2$

How will various industries respond to a specific economy-wide carbon price whose objective is to induce new investments?

For the sake of argument, consider **$100/tCO$_2$**.

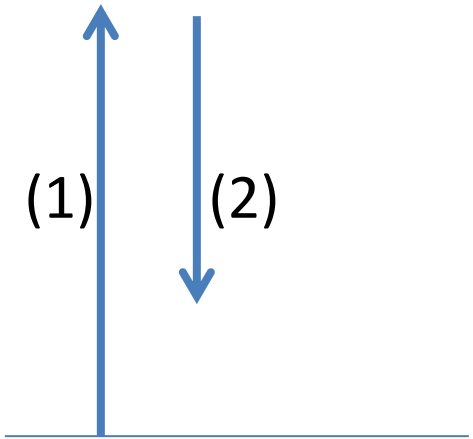
- *Upstream*, the impacts are particularly dramatic upstream. **$100/tCO$_2$** is:
  $40/barrel of oil
  $5/million Btu of natural gas
  $200/ton of high-quality coal.

- *Downstream*, if price-independent distribution costs are added, retail price increases are smaller, in percent. **$100/tCO$_2$** is:
  $0.80/U.S. gallon of gasoline
  $0.08/kWh electricity from coal
  $0.04/kWh electricity from natural gas.

“Stranded asset” and investments in new reserves

Step 1: An asset is *created* by adding value to something. What minimum amount of activity turns a thing into an asset? Investment is necessary, not just discovery.

Step 2: An asset is *stranded*. Stranding requires a) immobility, plus b) an external imposition that reduces the asset’s value.



The next Investments that expand fossil fuel reserves and build new infrastructure and power plants could create “stranded assets”: these investments presume 20-60 years of “business as usual.”

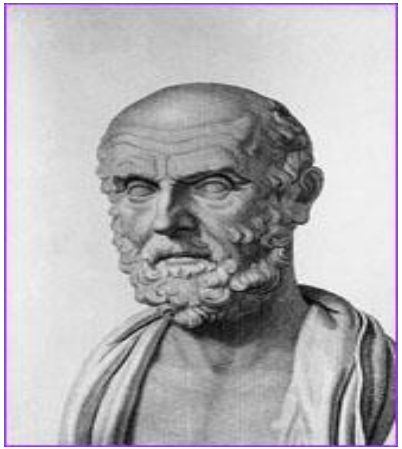
“Solutions” can bring serious problems of their own.

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 consider the risks of disruption from climate change *and* the risks of disruption from mitigation.

Patient Earth



"I will apply, for the benefit of the sick, all measures that are required, avoiding those twin traps of overtreatment and therapeutic nihilism."

Hippocrates

*** Modern version of the Hippocratic oath, Louis Lasagna, 1964, http://www.pbs.org/wgbh/nova/doctors/oath_modern.html**

Recommendation #1
Address your core activities.

1. *Upstream CO_2*: Lead in curtailing flaring, promote CCS where gas is processed, redesign EOR for when CO_2 storage becomes a revenue stream.
2. *Upstream fugitive CH_4:* Demonstrate best practices – minimal release, fast response to carelessness. Beyond safety.
3. *Gas for coal:* Work out the limits on how much and how fast, e.g., to restrain the coal juggernaut in Asia.
4. *Gas for "firming":* Provide dispatchable power via partnerships where gas backs up intermittent renewables.

Recommendation #2
Engage policymaking proactively.

1. *Be real and helpful about carbon pricing*. What should we expect to see happen at \$5/tCO_2? What about at \$100/tCO_2, reached by a ramp that is credible?
2. *Identify yourselves with carbon efficiency*. *Examples*:

    A. When bringing gas to new cities, assure efficient buildings/appliances.

    B. Help your industrial and power-plant customer to use your fuel efficiently (the customer's side of the meter).

Pace of change: Minimally explored

How quickly change can occur? History is useful: How quickly did automobiles displace horses, and why neither faster nor slower?

Looking ahead:

How quickly will science provide key insights into how the earth works?

How quickly can a technology gain market share?

How will human values change (diet, consumerism)?

What goes wrong when change is attempted too quickly?

Grounds for optimism

1. The world today has a terribly inefficient systems for using carbon.

2. Carbon emissions have just begun to be priced.

3. Most of the 2065 global infrastructure is not yet built.

4. **Very smart scientists and engineers now find energy problems exciting.**