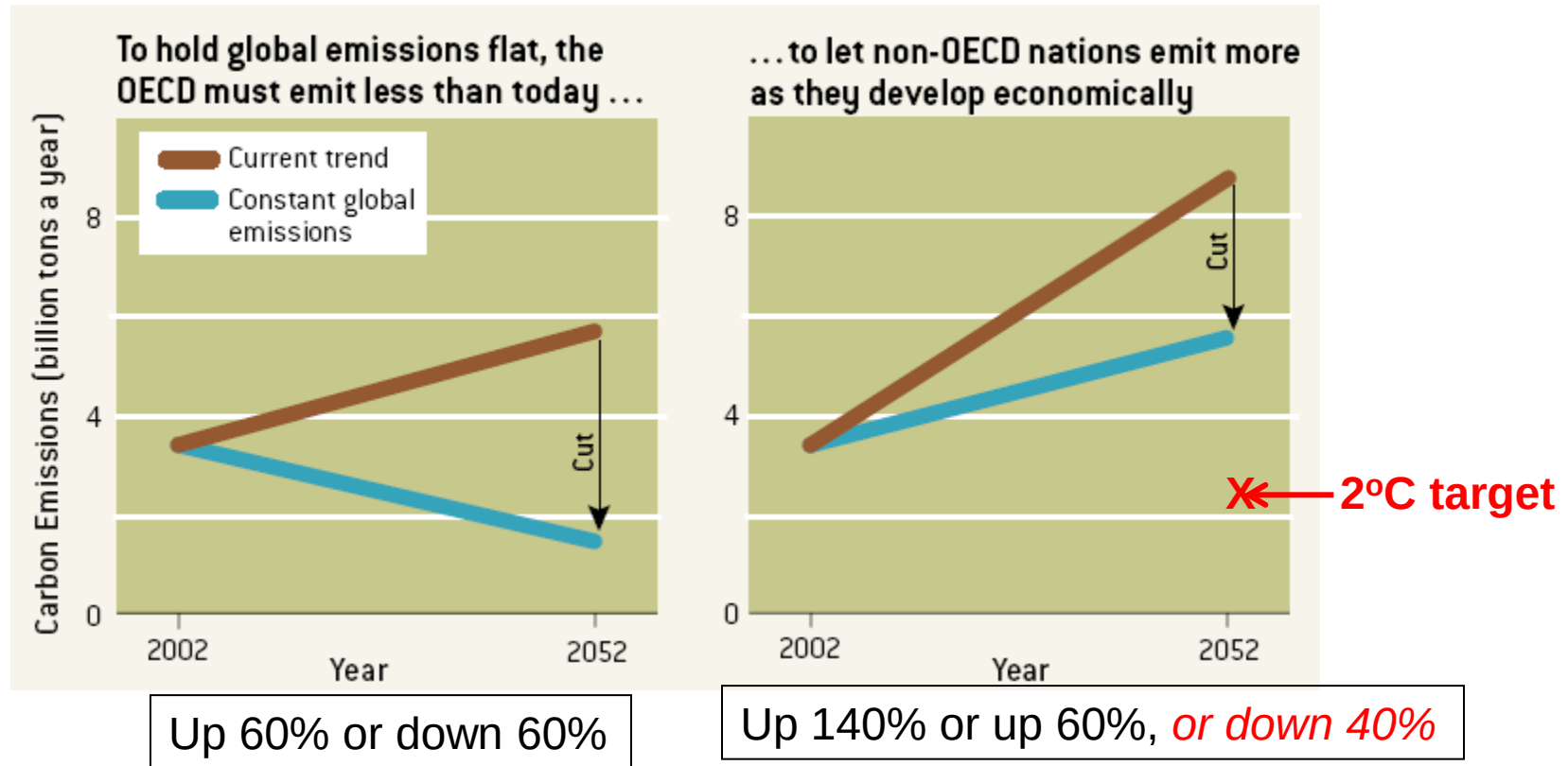


“Flat” vs. “down 50%” is about the developing world’s emissions



Blue: 3°C target, approximately.

Analysis of *low-carbon industrialization* has been far too casual relative to its essential role in reaching a 2°C target.

Coal-electricity Wedges

700 modern (90% capacity factor, 50% efficient) 1-GW coal plants, with CO₂ vented, will emit 1 GtC each year, if by “modern” we mean that the carbon intensity is:

0.18 kgC/kWh, or 0.66 kgCO₂/kWh.

Electricity-supply wedges result from not building such plants.

Leapfrogging

Robert Socolow

Princeton University

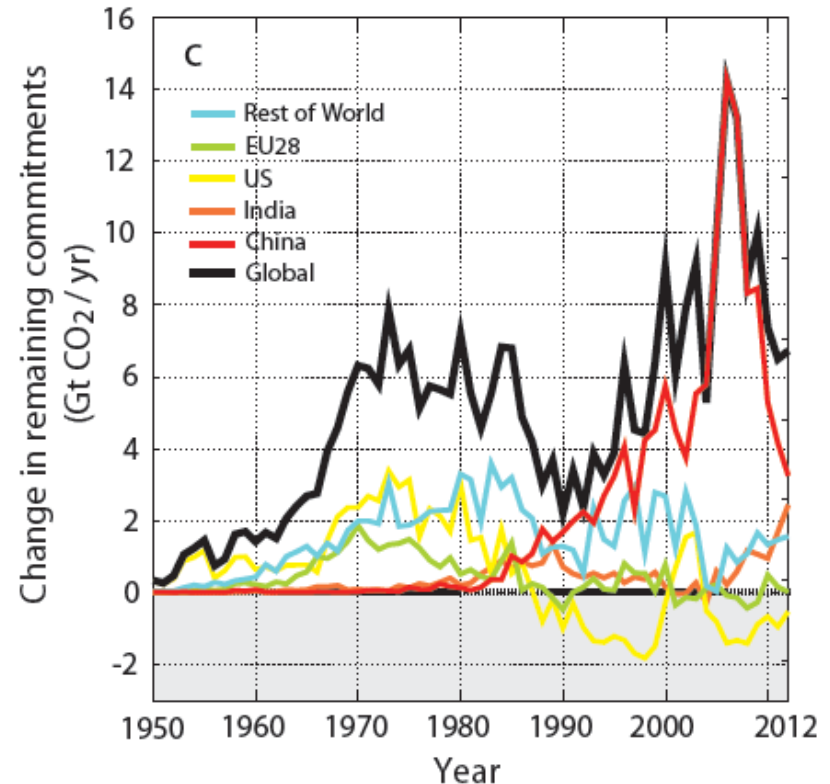
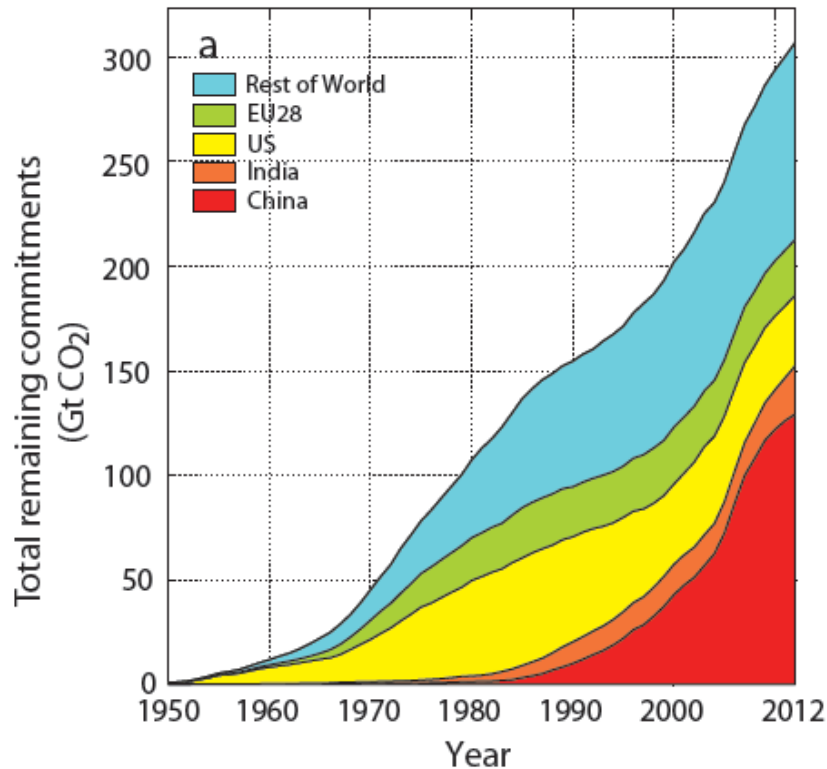
socolow@princeton.edu

Panel Discussion on Innovation: China Energy Group

Princeton University

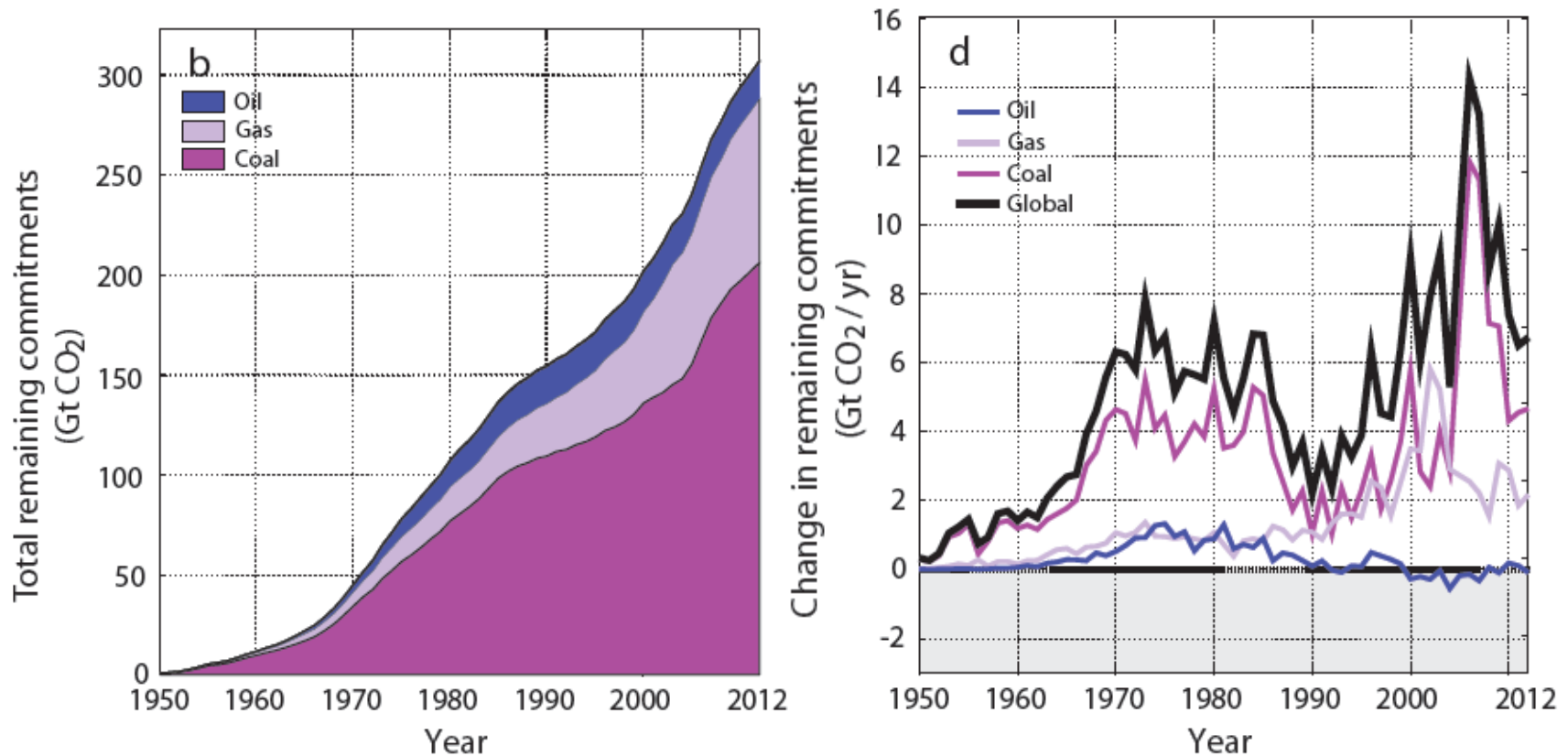
November 24, 2014

Committed emissions as of each year, 1950-2012, by region, power sector only



In 2012 China had half of the world's commitments, other developing countries had more than half, and the U.S. was disinvesting. Note the U.S. "rush to gas," 1998-2002.

Committed emissions as of each year, 1950-2012, by fuel, power sector only



The China-coal peak in 2005 is distinctive, but annual net new commitments of 6 to 10 GtCO₂ are seen throughout 2000-2102.

“The Warsaw Communiqué”

The World Coal Association and the Polish Ministry of Economy issued the Warsaw Communiqué, dated Nov 18-19, 2013, in the lead up to the UNFCCC negotiations in Warsaw. Its key points:

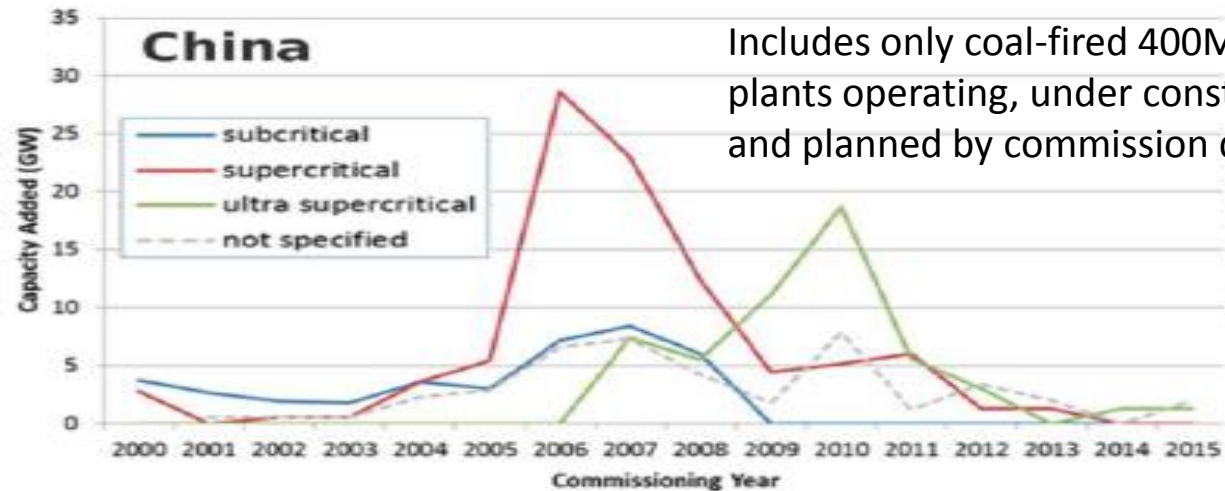
- 1) Call for “immediate use of high-efficiency low-emissions coal combustion technologies” and “carbon capture utilisation and storage technologies once demonstrated and commercialised.”
- 2) Support R&D and set goals to move “global average efficiency of coal-fired power generation plants to current state of the art levels.”
- 3) Call on “development banks to support developing countries in accessing clean coal technologies.”

Higher power-plant efficiency now, CCS at some future time.

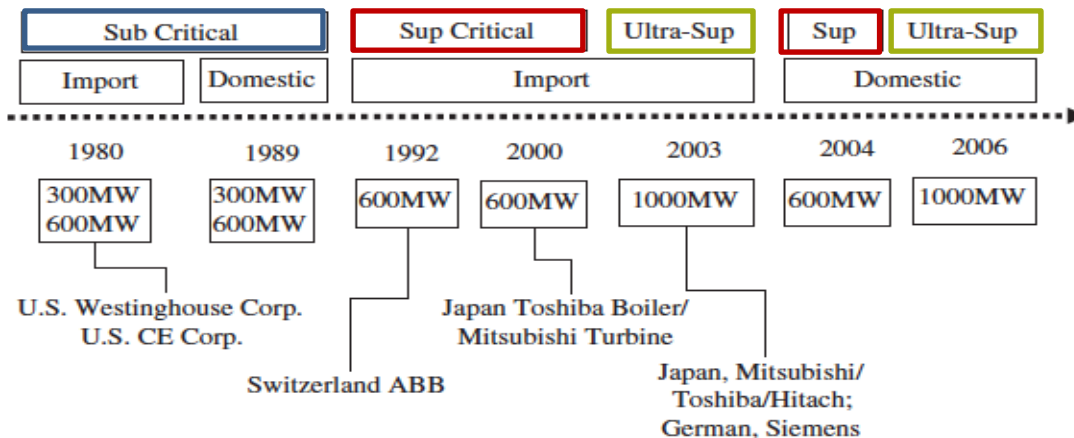
That's not good enough.

Source: <http://www.worldcoal.org/extract/the-warsaw-communicue/>

Achievements: high efficiency, domestic technology



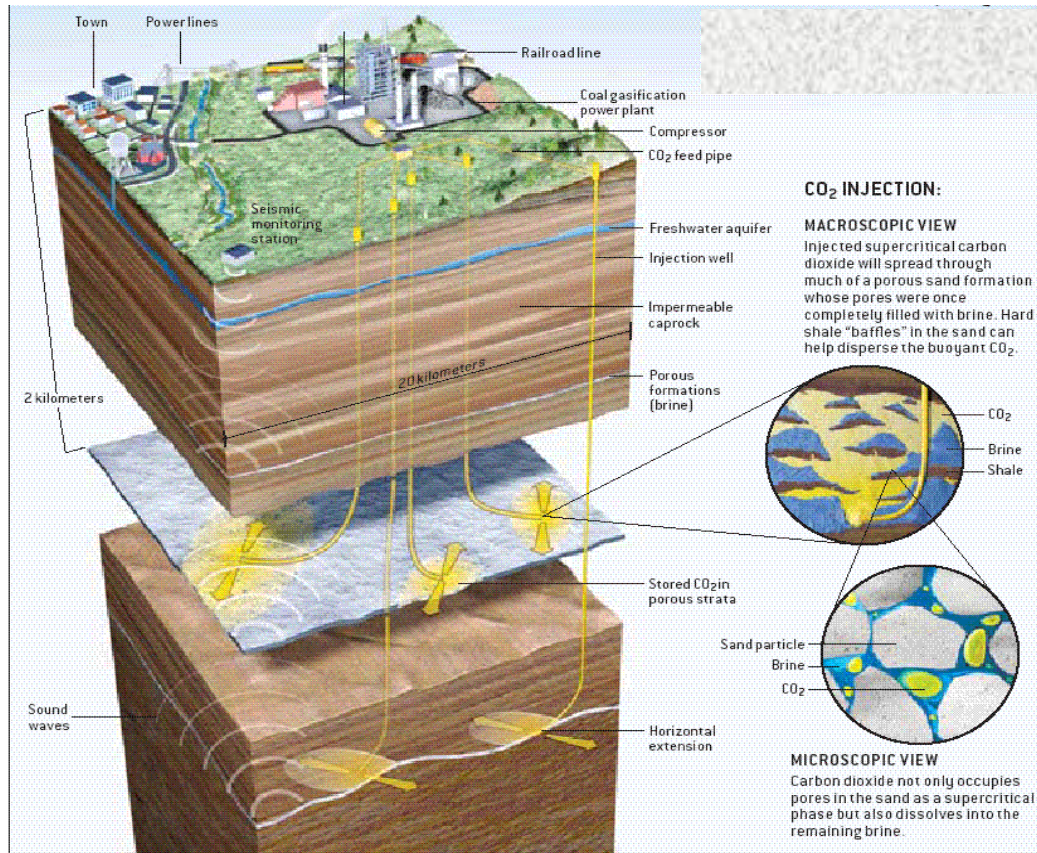
Includes only coal-fired 400MW+ plants operating, under construction and planned by commission date.



Note: Not a linear scale in calendar time.

Source: Hannam, unpublished. Top: Lazarus and Chandler 2010. Bottom: Zhai 2008, in Yue 2012.

The Future Coal or Natural Gas Power Plant



Shown here: After 10 years of operation of a 1000 MW coal plant, 60 Mt (90 Mm³) of CO₂ have been injected, filling a horizontal area of 40 km² in each of two formations.

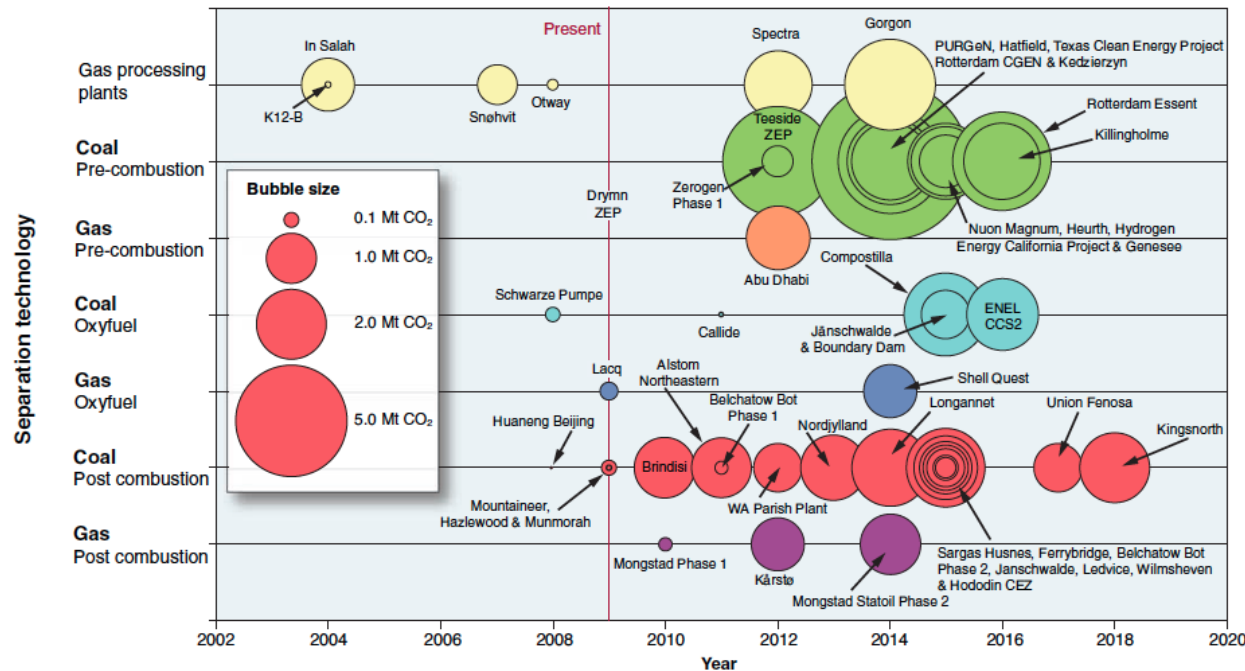
Assumptions:

- 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(CO₂)/day, or 300 million standard cubic feet/day (scfd). That's 3 billion barrels, or 6 trillion standard cubic feet, over 60 years.

We have lost five years for CCS demonstrations



In Salah terminated.
ZeroGen canceled before construction

Boundary Dam *has opened*

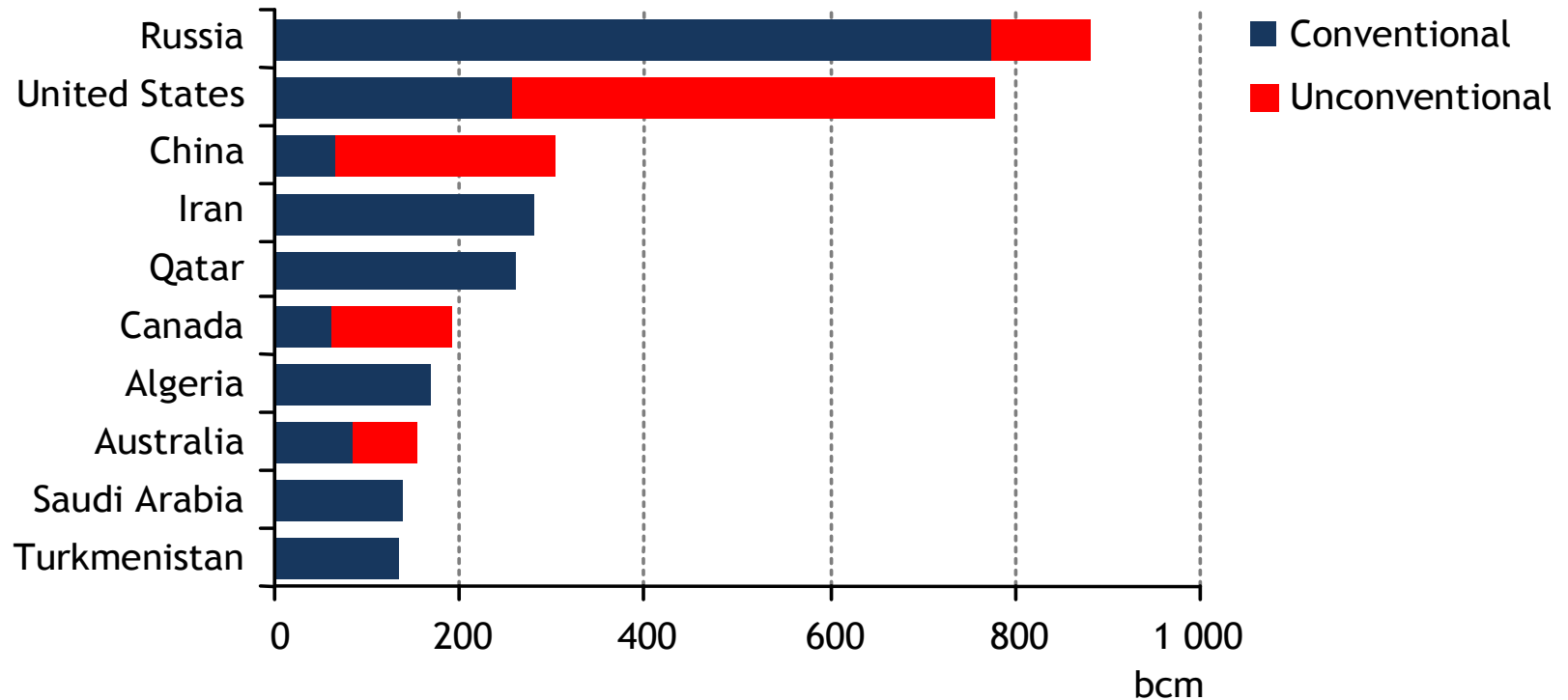
Fig. 4. Chart of large CCS demonstration projects planned worldwide, plotting calendar year against capture type and fuel. Coal and postcombustion power plants dominate. There is typically a 5-year lead time on design and construction (Fig. 2), so to operate these plants on schedule requires that projects

commence spending on design now. Few of these projects have certain funding to assist construction, and even fewer have systems to enable commercial operation. National CCS targets with worldwide coordination and exchanges of learning are needed. [Compiled by Y. Bushby (15)]

Very few of the projects slated for 2009-2014 have happened.
China now has some projects. Are any listed here?

Shale gas: A new class of buried hydrocarbons

Figure 1.8 ▶ Largest gas producers by type in the GAS scenario, 2035



Source of Figure: IEA, 2011. “Are We Entering a Golden Age of Gas?”

Nov 2014: Only three years have passed, and my guess is that IEA now expects shale gas production to become significant in many more countries.

Source of slide (with permission): David McCabe (Clean Air Task Force), Princeton lecture, 1 October 2012.

“Carbon budgets”

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

The IPCC connected the carbon-budget idea to a 2°C target. The idea is more general.

The budget concept leads inexorably to choices:

When?

Better options someday?

Whose?

Geopolitical stability

Used where?

“Fairness”

For what purpose?

Who judges?

Which fossil fuels?

Those with the highest H/C ratio?

Carbon dioxide capture and storage (CCS) expands the budget.

Are there precedents for leaving hydrocarbons in the ground?

END OF TALK