The Coal Conundrum:
Can We Reconcile the Exigencies of Climate, Growth, and Global Peace?

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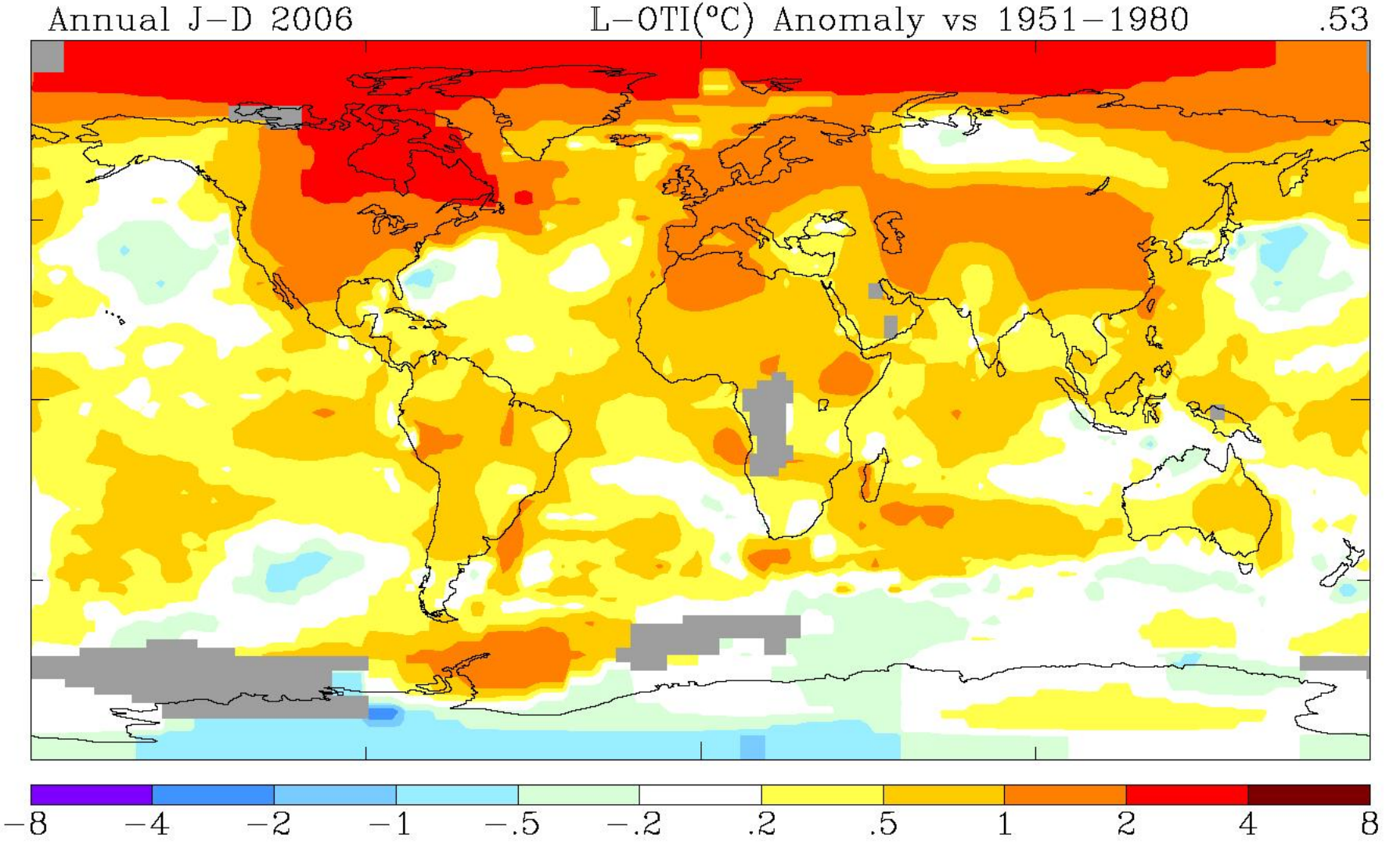
May 10 2007

Direct Observations of Recent Climate Change

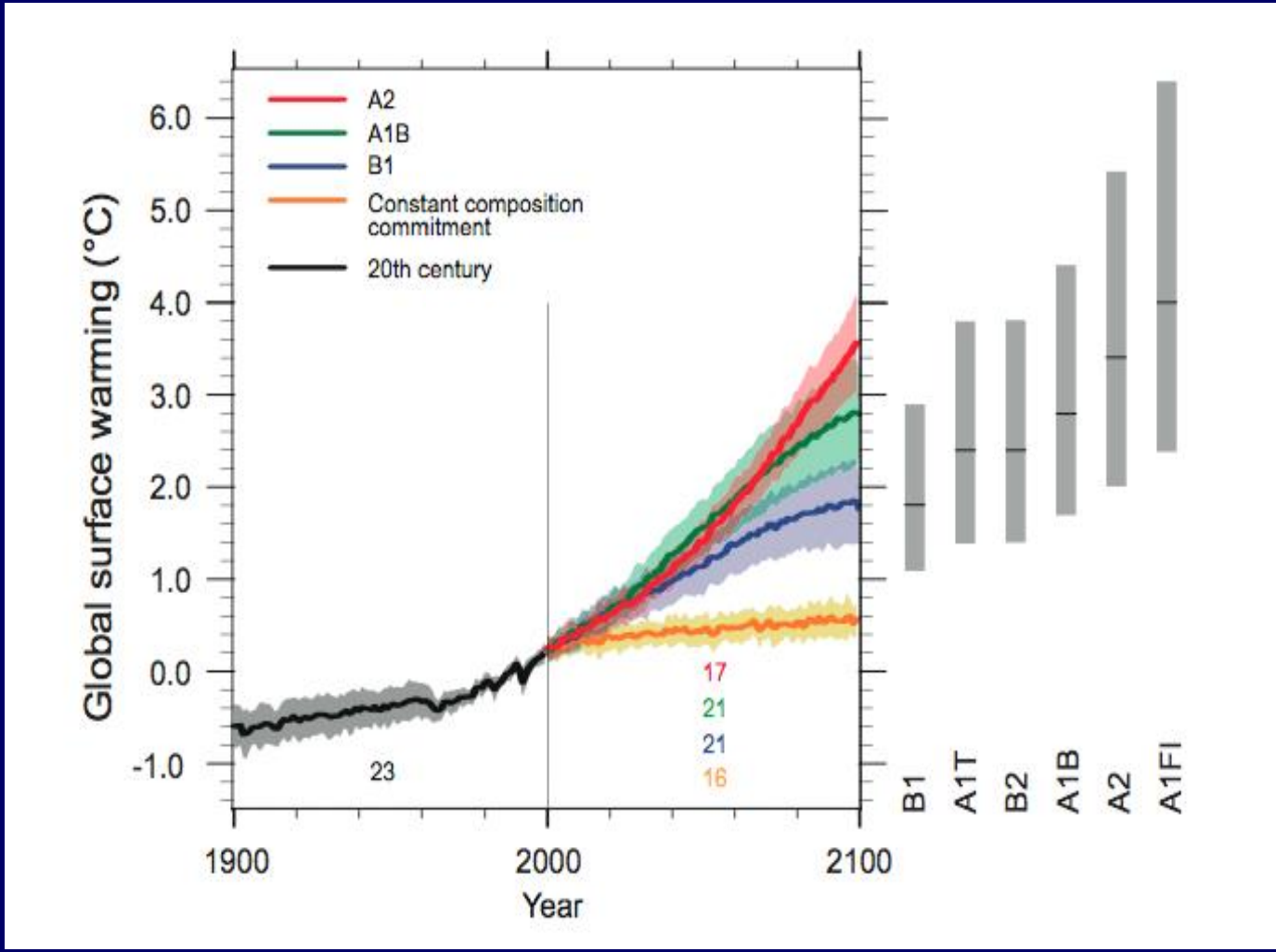
Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level.


Annual J-D 2006
L-OTI(°C) Anomaly vs 1951-1980
.53
-8
-4
-2
-1
-.5
-.2
.2
.5
1
2
4
8

Projections of Future Changes in Climate

Best estimate for low scenario (B1) is 1.8°C (*likely* range is 1.1°C to 2.9°C), and for high scenario (A1FI) is 4.0°C (*likely* range is 2.4°C to 6.4°C).

Broadly consistent with span quoted for SRES in TAR, but not directly comparable

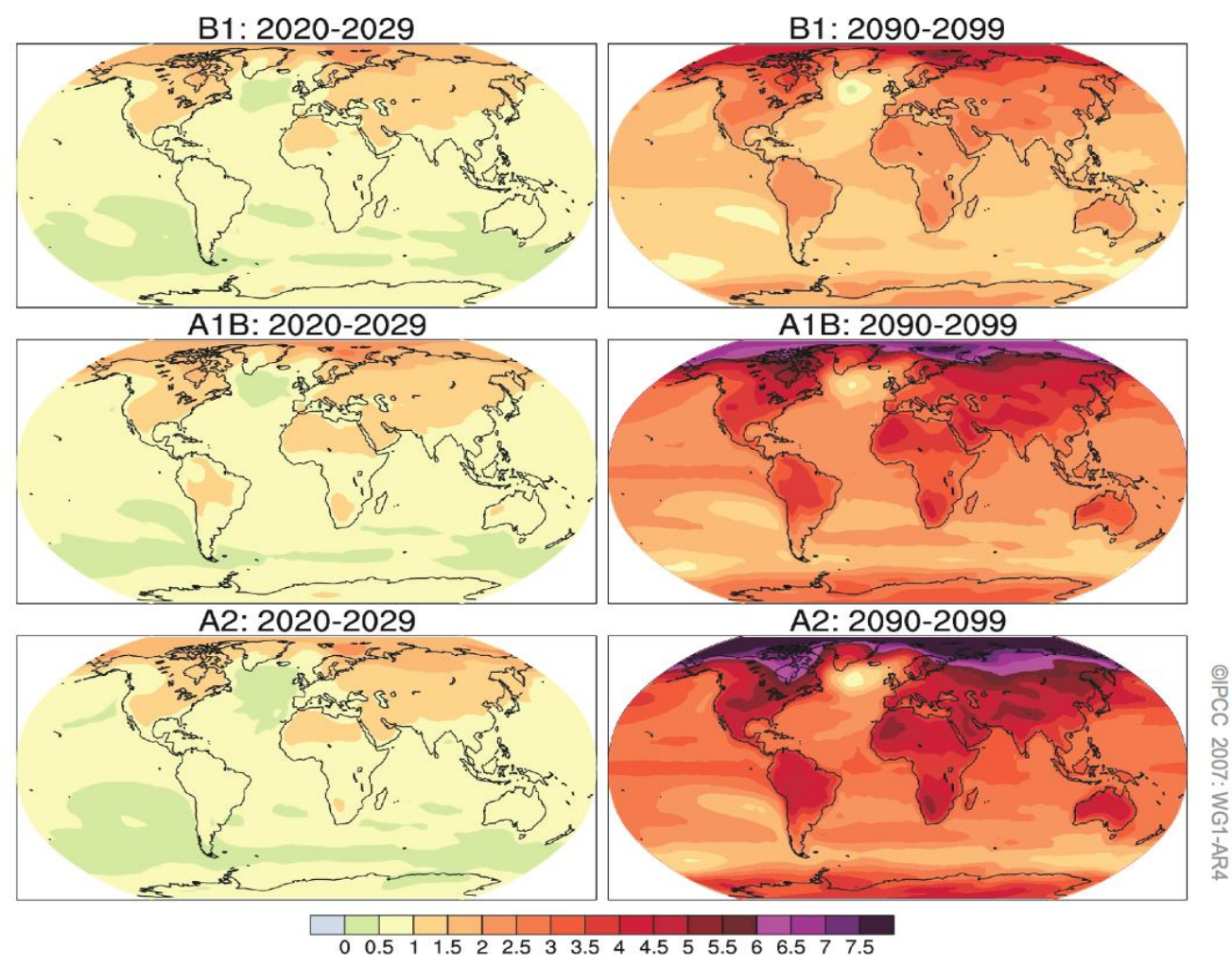


Projections of Future Changes in Climate

Projected warming in 21st century expected to be

greatest over land and at most high northern latitudes

and least over the Southern Ocean and parts of the North Atlantic Ocean



The Challenge: Very soon, humankind must cap—and then ramp down—global carbon emissions

We have very little "room to warm":

Estimated maximum "safe" warming: 2°C

Warming to date: 0.8°C

Warming in pipeline, even if emissions cease: 0.6°C

Room to warm: 0.6°C

So we have very little "room to emit":

Estimated carbon concentration that is likely to produce at least 2°C warming: ~450 ppm

Current concentration: ~380 ppm

Room to emit: ~ 70 ppm

Incremental annual increase: ~2 ppm and rising

Years to 450 ppm: ~ 30

Will the Decarbonization Trend Continue?

"Decarbonization essentially defines the future of energy supply.

Globally we are destined to use about 50-80 billion tons more coal. This is about one-third what humans have mined in all our earlier history, and about 30 years at present levels of production, so all the participants in the coal industry have a generation or so in which to remodel themselves. We should squeeze the maximum electricity from the black rocks with the minimum fallout of nasties, but coal is not our primary concern because its use will fade anyway."

Jesse Ausubel, Rockefeller University, 2003

Historical Trend: From low-quality solid fuel to higher-quality liquids that can be transported globally

Coal	14 to 33 megajoules per kg.
Oil	42 megajoules per kg.
Natural gas	54 megajoules per kg.

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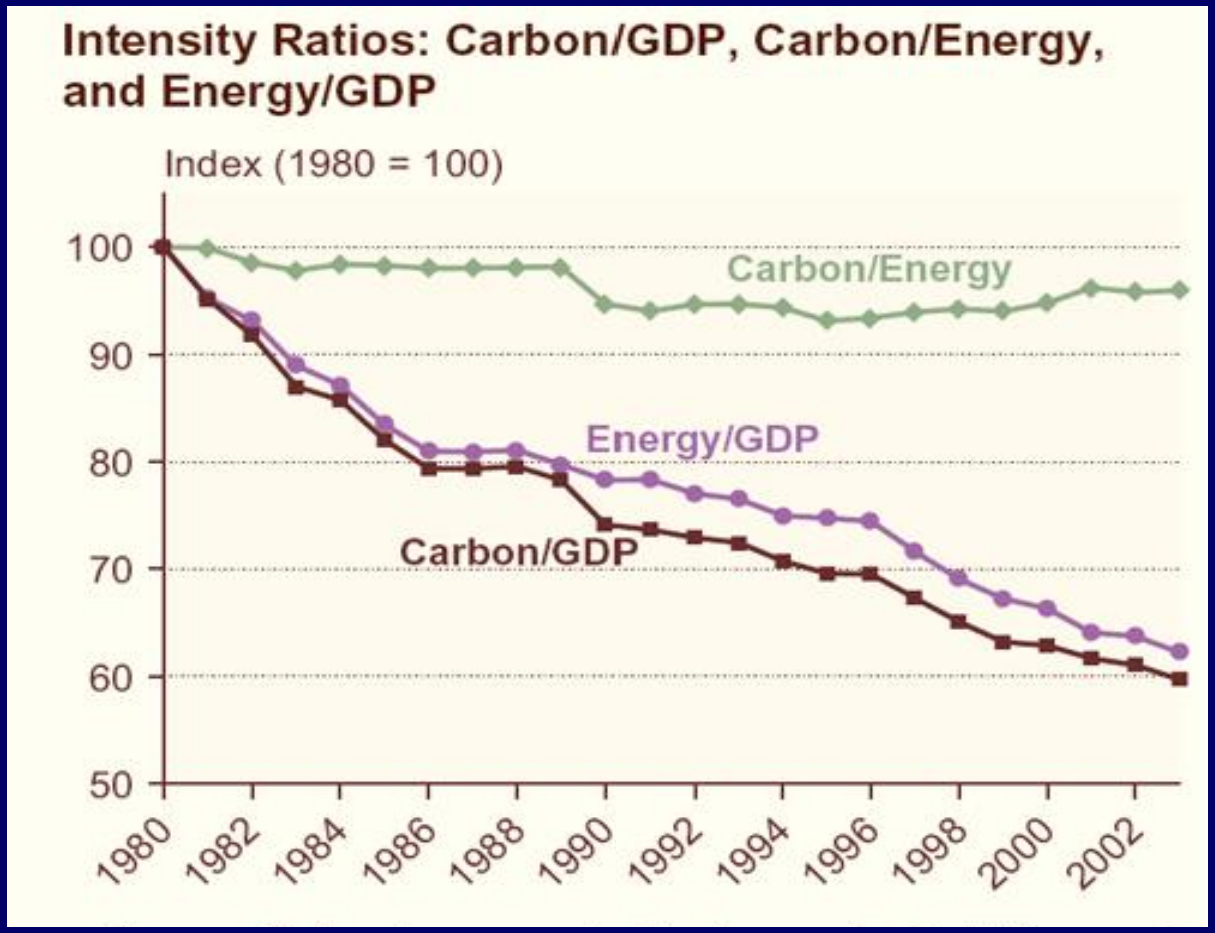

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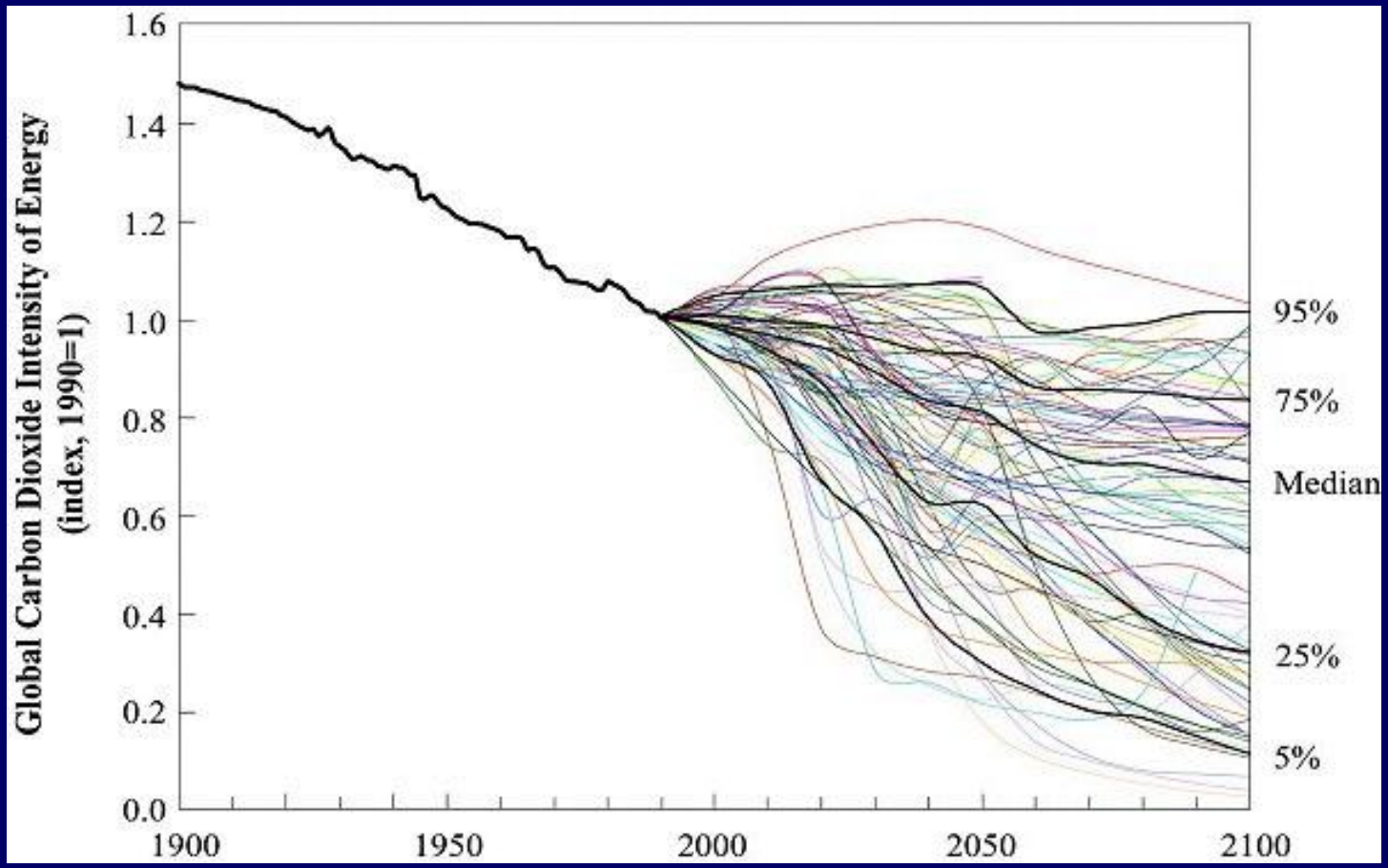
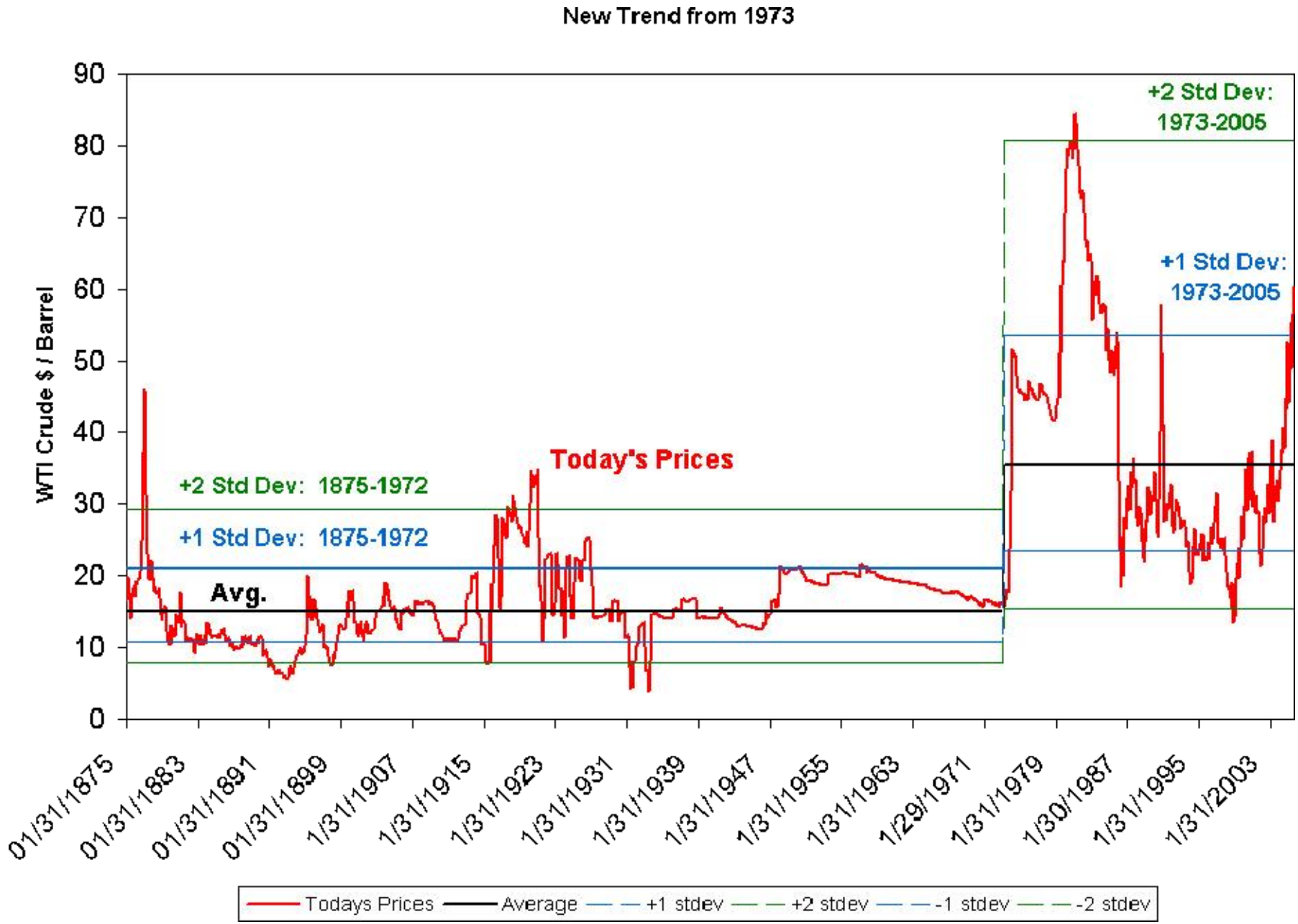
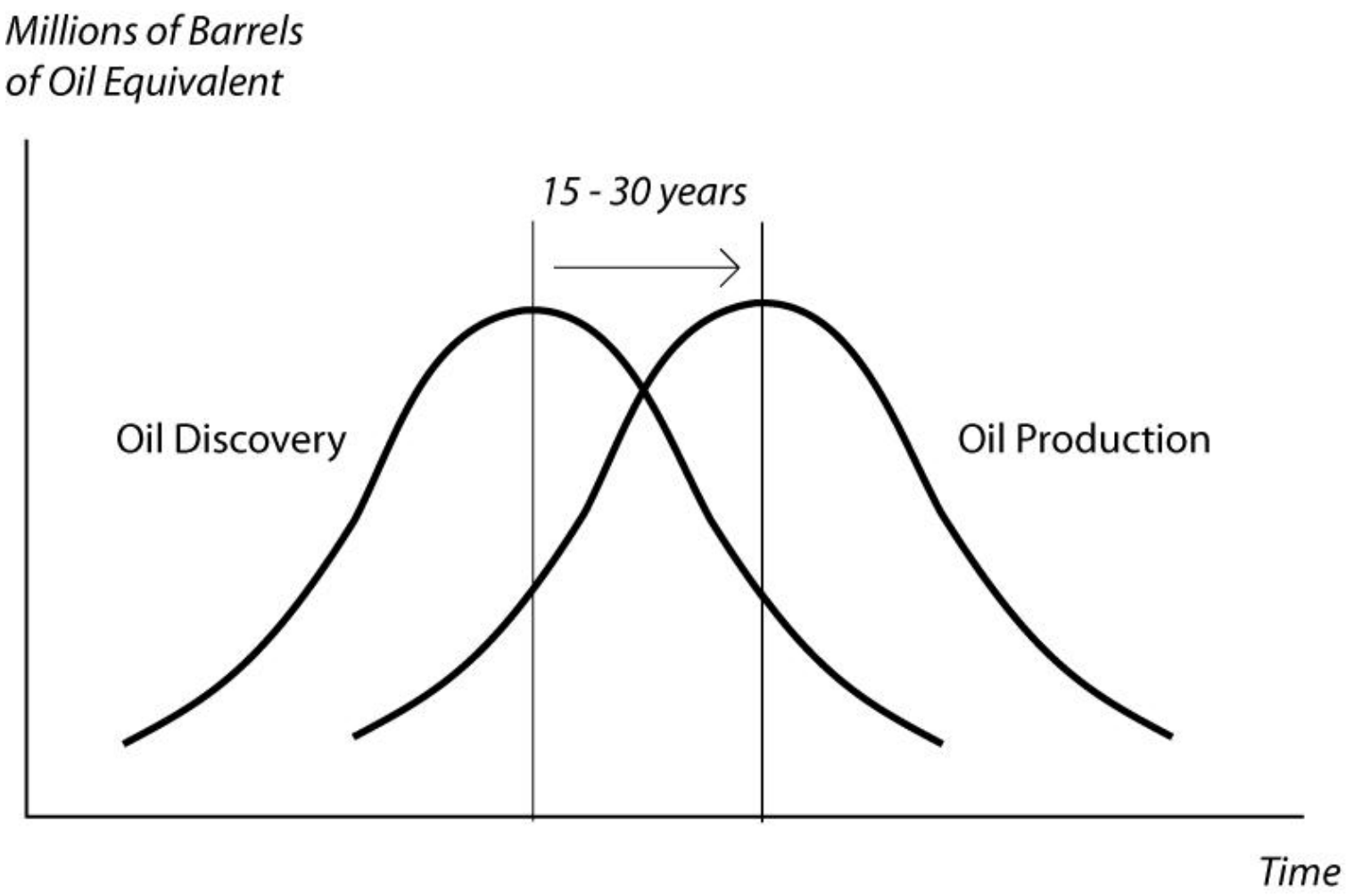


CO2 concentrations, Jubany Station, Antarctica

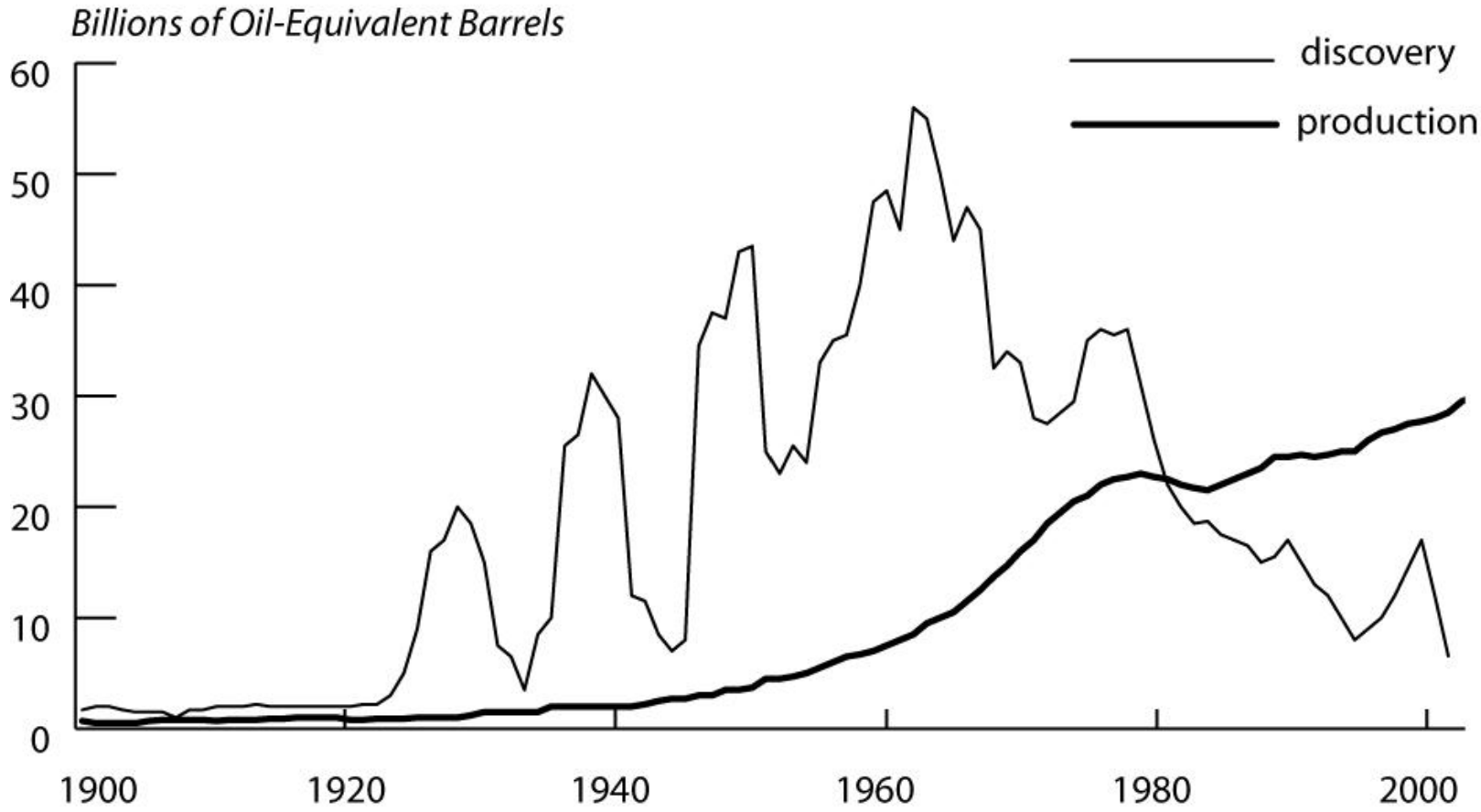
Year	ppm	Δ	
1994	356.75		
1995	358.18	1.43	
1996	360.33	2.15	
1997	361.81	1.48	
1998	363.95	2.14	1.64
1999	365.65	1.70	
2000	366.69	1.04	
2001	368.22	1.53	
2002	370.47	2.25	
2003	372.19	1.72	
2004	374.87	2.68	2.10
2005	376.73	1.86	
2006	378.74	2.01	


New Trend from 1973
WTI Crude $ / Barrel
90
80
70
60
50
40
30
20
10
0
+2 Std Dev: 1973-2005
+1 Std Dev: 1973-2005
Today's Prices
+2 Std Dev: 1875-1972
+1 Std Dev: 1875-1972
Avg.
01/31/1875
01/31/1883
01/31/1891
01/31/1899
1/31/1907
1/31/1915
1/31/1923
1/31/1931
1/31/1939
1/31/1947
1/31/1955
1/31/1963
1/29/1971
1/31/1979
1/30/1987
1/31/1995
1/31/2003
Todays Prices
Average
+1 stdev
+2 stdev
-1 stdev
-2 stdev

Difference between discovery peak and output peak



Global oil discovery peaked in the early 1960s



Source: Harry Longwell, "The Future of the Oil and Gas Industry: Past Approaches, New Challenges," World Energy 5 3 (2002): 100-4, and Colin Campbell, personal correspondence.

The First Bottom Line:

The decarbonization trend is unlikely to continue, as the world shifts back to coal

The Dirt on Coal

Coal provides >25 percent of world's primary energy

It provides 40 percent of world's electricity

Coal extraction grew at ~5 percent between 2000 and 2005 (doubling time of 14 years)

Ninety percent is consumed in country of origin

Coal produces nearly 40 percent of world's greenhouse gas emissions, mainly CO2

How Much Do We Have?

Total world reserves at end of 2002 (World Energy Council)

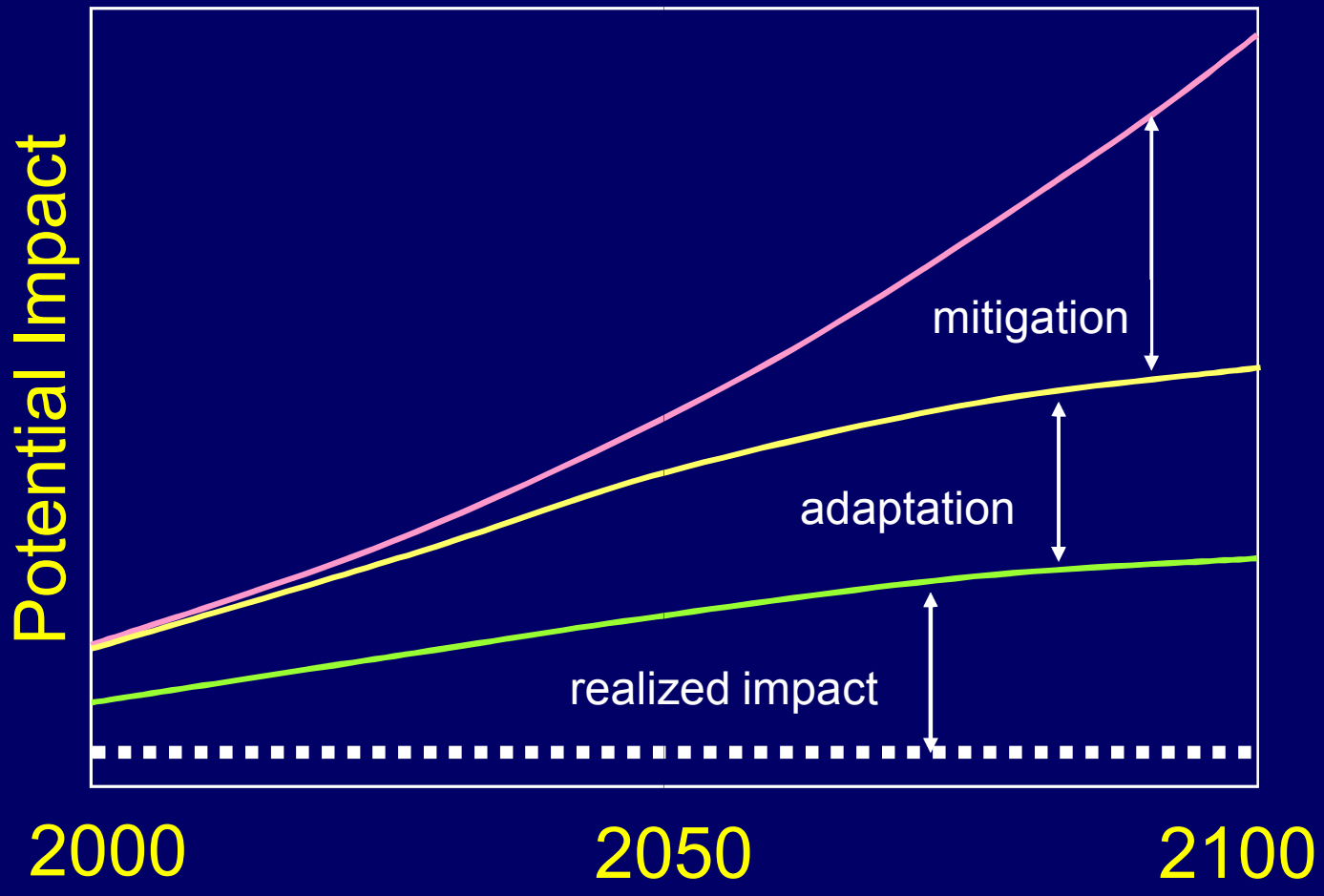
Bituminous and Anthracite (18-30 MJ/kg)	479 billion tons
Sub-bituminous (8-25 MJ/kg)	272 billion tons
Lignite (5-14 MJ/kg)	158 billion tons

At current production levels, current coal reserves will last 155 years (World Coal Institute). This may be a significant overestimate.

The Second Bottom Line:

Carbon capture and storage (CCS) is a "critical enabling technology" if economic growth is to continue and if humankind is to avoid catastrophic climate change

Impact, Mitigation, and Adaptation



Chris Milly (USGS/NOAA-GFDL, 2007)

The Future of Coal (MIT,2007)

"Today, and independent of whatever carbon constraints may be chosen, the priority objective with respect to coal should be the successful large-scale demonstration of the technical, economic, and environmental performance of the technologies that make up all of the major components of a large-scale integrated CCS system – capture, transportation and storage.

Such demonstrations are a prerequisite for broad deployment at the gigatonne scale in response to adoption of future carbon mitigation policy . . . ."

The Third Bottom Line:

Those countries and regions that prepare for this transition now will do better later

The Future of Coal (MIT,2007)

"At present, government and private sector programs to implement on a timely basis the required large-scale integrated demonstrations to confirm the suitability of carbon sequestration are completely inadequate. . . .

The scale of CCS required to make a major difference in global greenhouse gas concentrations is massive. For example, sequestering one gigatonne of carbon per year requires injection of about 50 million barrels per day of supercritical CO2 from about six hundred 1000 MW of coal plants."

China

Coal accounts for two-thirds of China's primary energy supply

Output rose from 1.3 billion tonnes in 2000 to 2.23 billion tonnes in 2005 (nearly one-third of world coal output)

Over half of this coal is used to generate electricity, and 80 percent of China's electricity comes from coal. About 70,000 MW of new generating capacity was brought online in 2005

Nearly 50 percent of China's railway capacity is dedicated to moving coal

The Future of Coal (MIT,2007)

"What many outsiders see as the deliberate result of Chinese national 'energy strategy' is in fact better understood as an agglomeration of *ad hoc* decisions by local governments, local power producers, and local industrial concerns. These local actors are primarily motivated by the need to maintain a high rate of economic growth and few, if any, have the national interest in mind. They are rushing to fill a void left by the absence of a coherent national energy strategy."

The Future of Coal (MIT,2007)

"The Chinese government's capacity to achieve targets for reducing hydrocarbon consumption or pollutant releases, or Kyoto-like limits on greenhouse gas emissions, is in practice quite limited. . . .

The many players, diffuse decision making authority, blurred regulatory and commercial interests, and considerable interest contestation in the energy sector combine to make dramatic, crisp changes unlikely. It is illusory to expect that the world's carbon problem can somehow be solved by wholesale changes in Chinese energy utilization trends."

The Future of Coal (MIT,2007)

"[Although the diverse energy players in China] are not well coordinated, and often represent competing interests themselves, they are frequently looking outside, particularly to the advanced industrial economies, for guidance and models to emulate. . . .

In short, there may be significant opportunities, especially through commercial channels, for foreign involvement in China's pursuit of sustainable energy development."