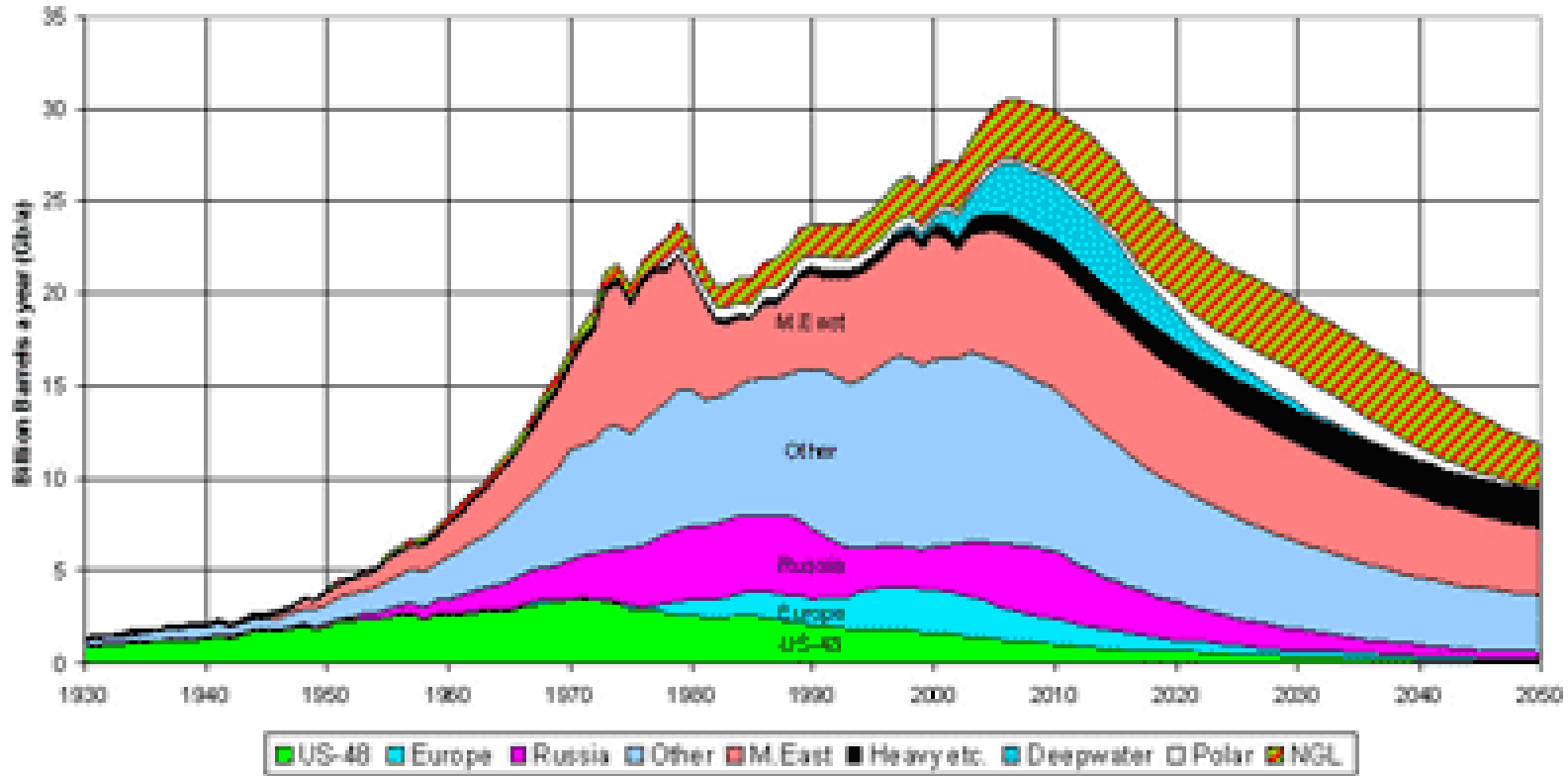


Peak Oil: Inevitable Catastrophe, or Innovation Opportunity?



Prof. Kevin Wehr, CSU Sacramento

Peak Oil

- The concept of “peak oil” is relatively straightforward:
 - As we pump oil we first take the cheap, easy, and high quality crude.
 - As production continues we move from the cheap, through the expensive, to the bottom of the barrel.
 - Through this process, costs rise monotonically at first, then geometrically, and finally exponentially.

Hubbert's peak

- Shell oil geologist and Princeton professor, M. King Hubbert predicted in 1956 that within 20 years domestic US production of oil would “peak” -- meaning that production of the cheap, light, high quality oil at the top of the reserves would be exhausted, leaving only the thick, heavy, expensive oil at the bottom of the fields.



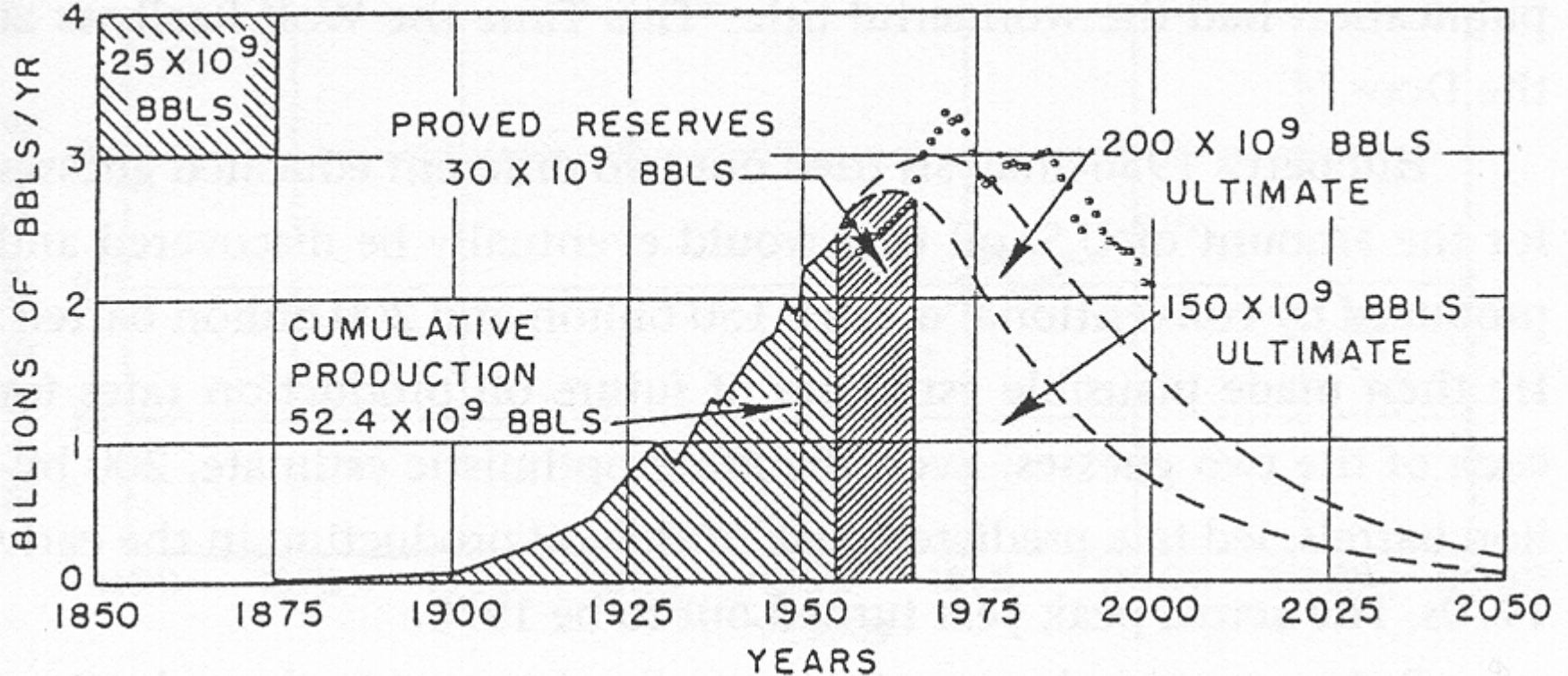
Was Hubbert Right?

- Hubbert's prediction was not taken seriously by anyone outside of the small circle of petroleum geologists and oil company CEOs and CFOs.
- In the eyes of mainstream 1950s and 1960s Americans, oil production seemed to be everlasting, with cheap oil a birthright.

Was Hubbert Right?

- In 1971 his prediction came true: the government agency that regulated pumping of oil quietly announced a “100% allowable for the next month.”
- This meant that fields could be pumped at maximum rates, meaning that subsequent production would steadily decline.

Was Hubbert Right?



- Hubbert's original 1956 projection. Actual production is in small dots above his estimates.

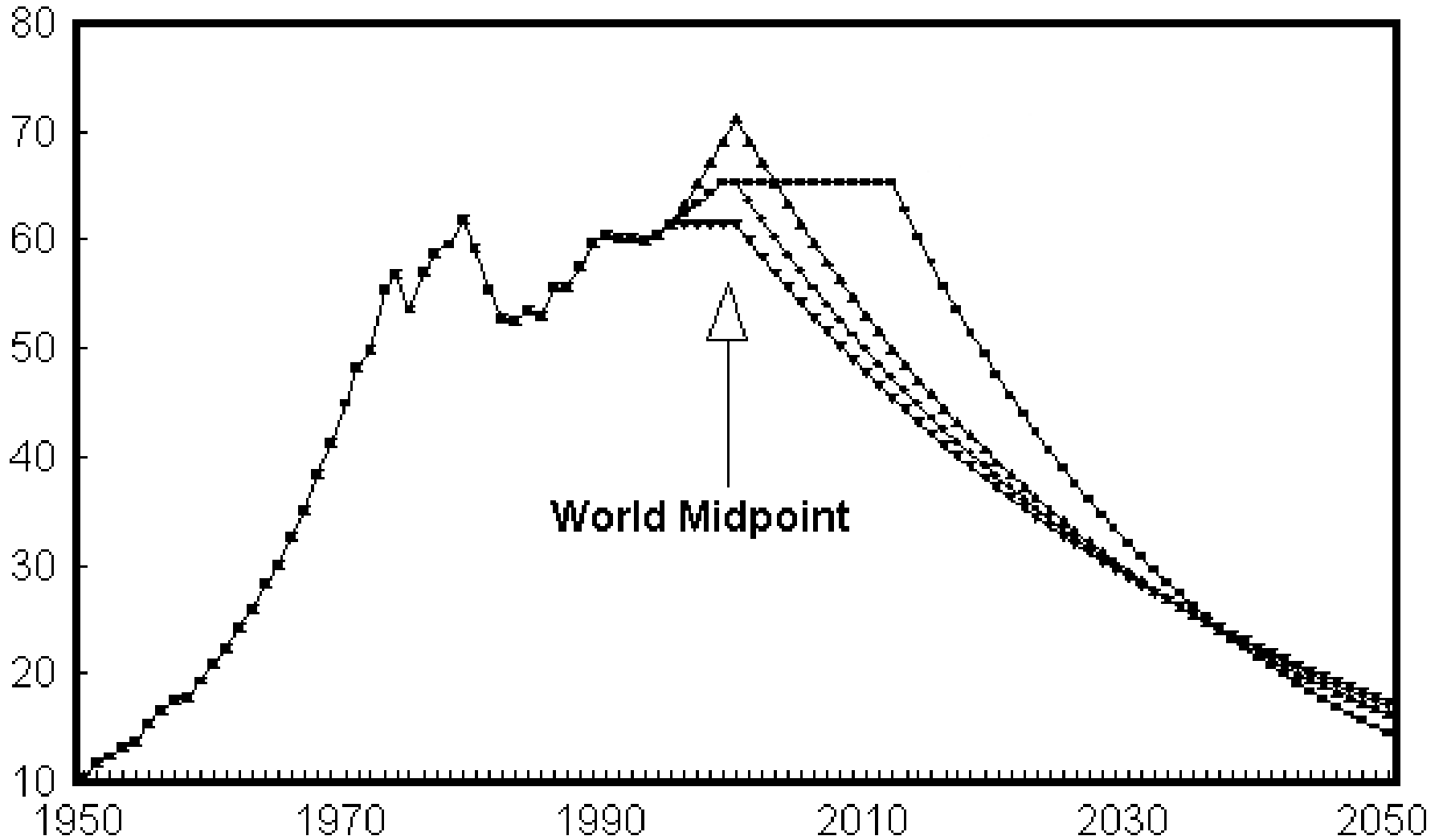
Was Hubbert Right?

- Hubbert was correct, he was just off by 5-10 years in his estimate.
- This was due to:
 - OPEC-induced oil shocks
 - Economic “stagflation”
 - Price-induced consumer conservation
 - New discoveries in Alaska

World Peak Oil

- In the decades since Hubbert's prediction came true, new concerns over Greenhouse Gas Emissions, Global Climate Change, and atmospheric Carbon loading have caused a new generation of scientists and environmentalists to re-examine the concept of Peak Oil on a global context:

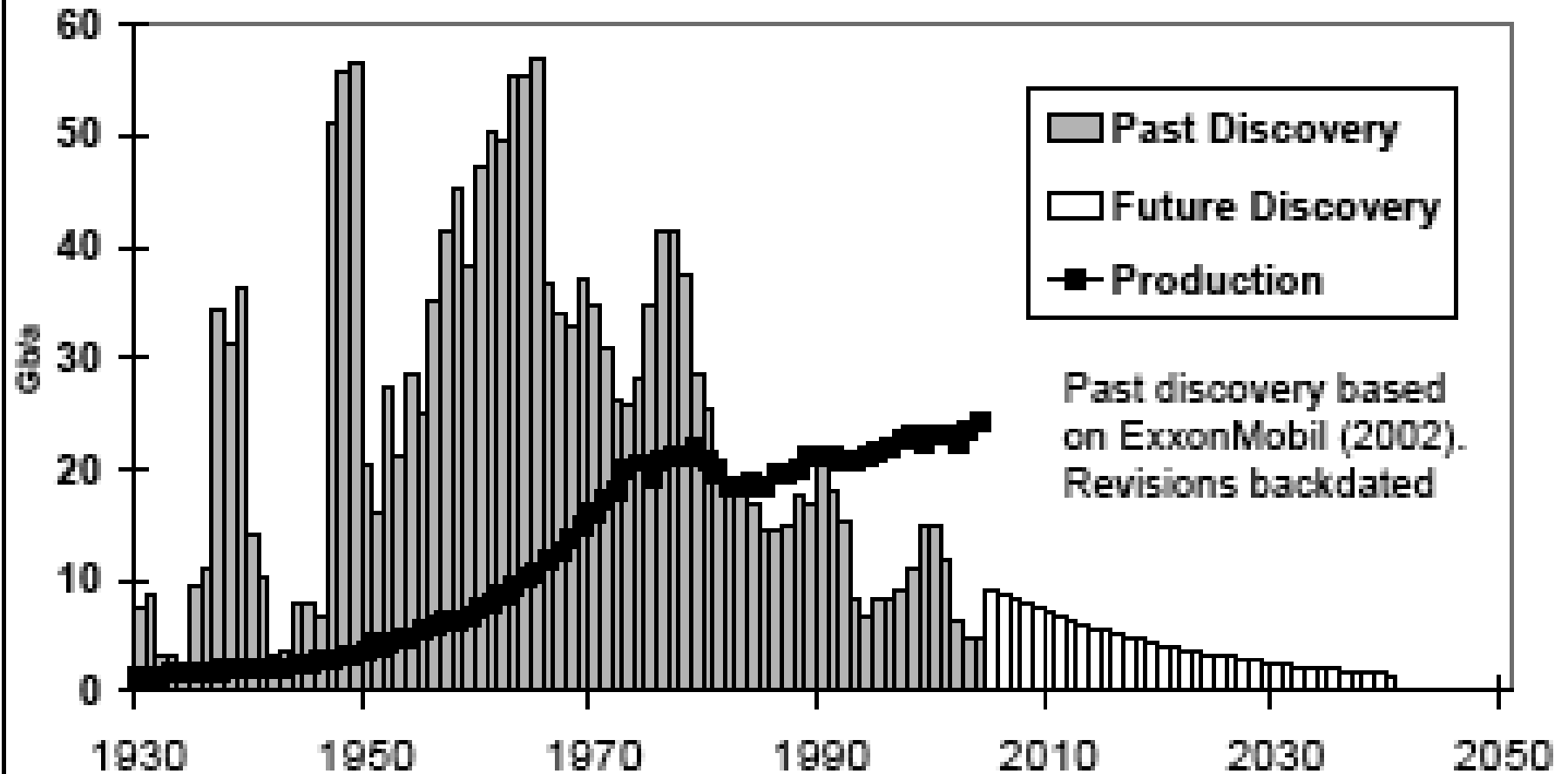
World Peak Oil, 1994



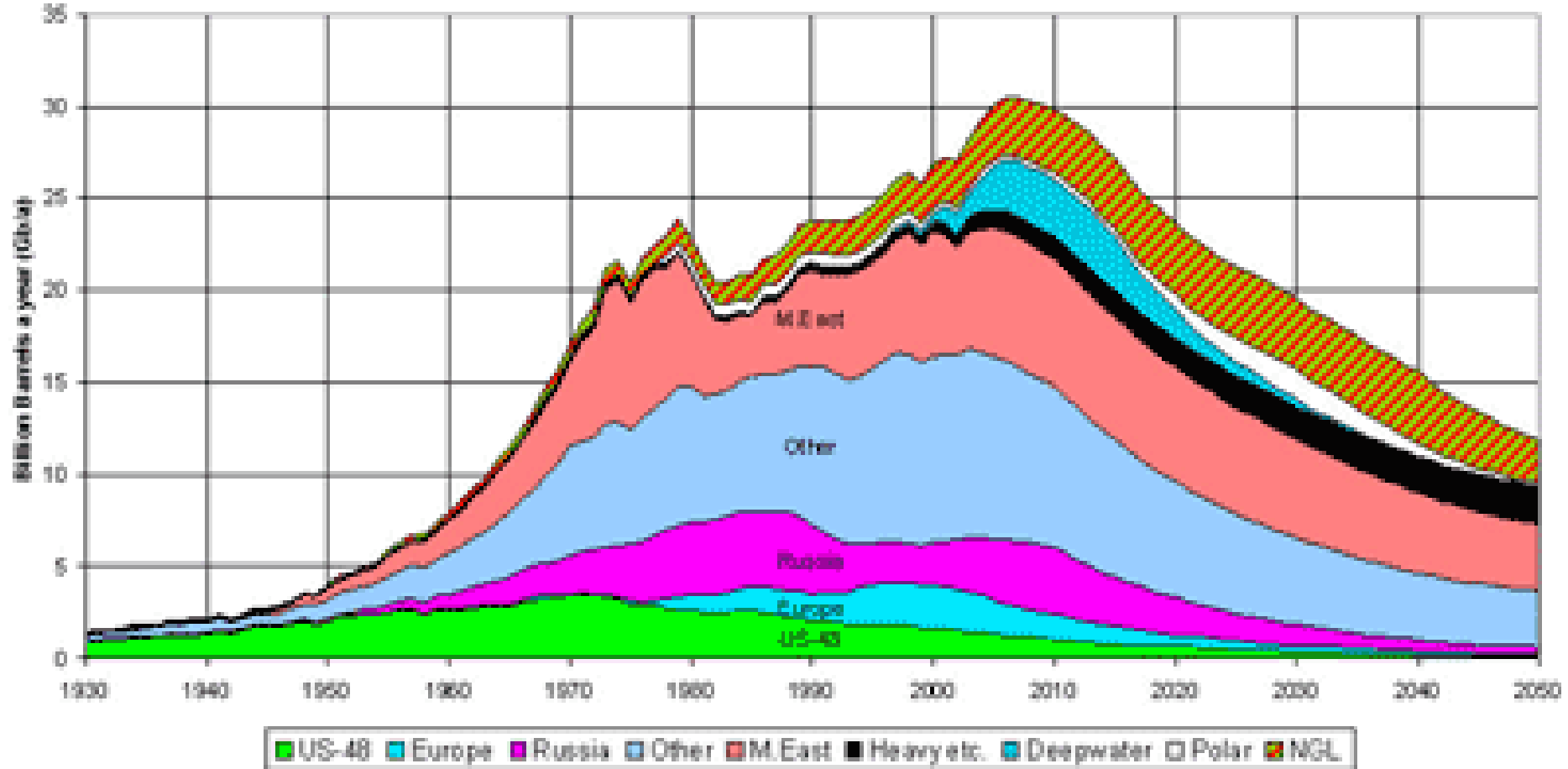
Campbell World Oil Production Plot

World Peak Oil, 1998

THE GROWING GAP
Regular Oil



World Peak Oil, 2000



World Peak Oil, 2003

Matt Simmons, a Bush Administration energy advisor and Oil CEO:

“As I have said, the experts and politicians have no Plan B to fall back on. If energy peaks...it will be a tremendous jolt to our economic well-being and to our health — greater than anyone could ever imagine...The solution is to pray. Under the best of circumstances, if all prayers are answered there will be no crisis for maybe two years. After that it’s a certainty.”

World Peak Oil, 2006

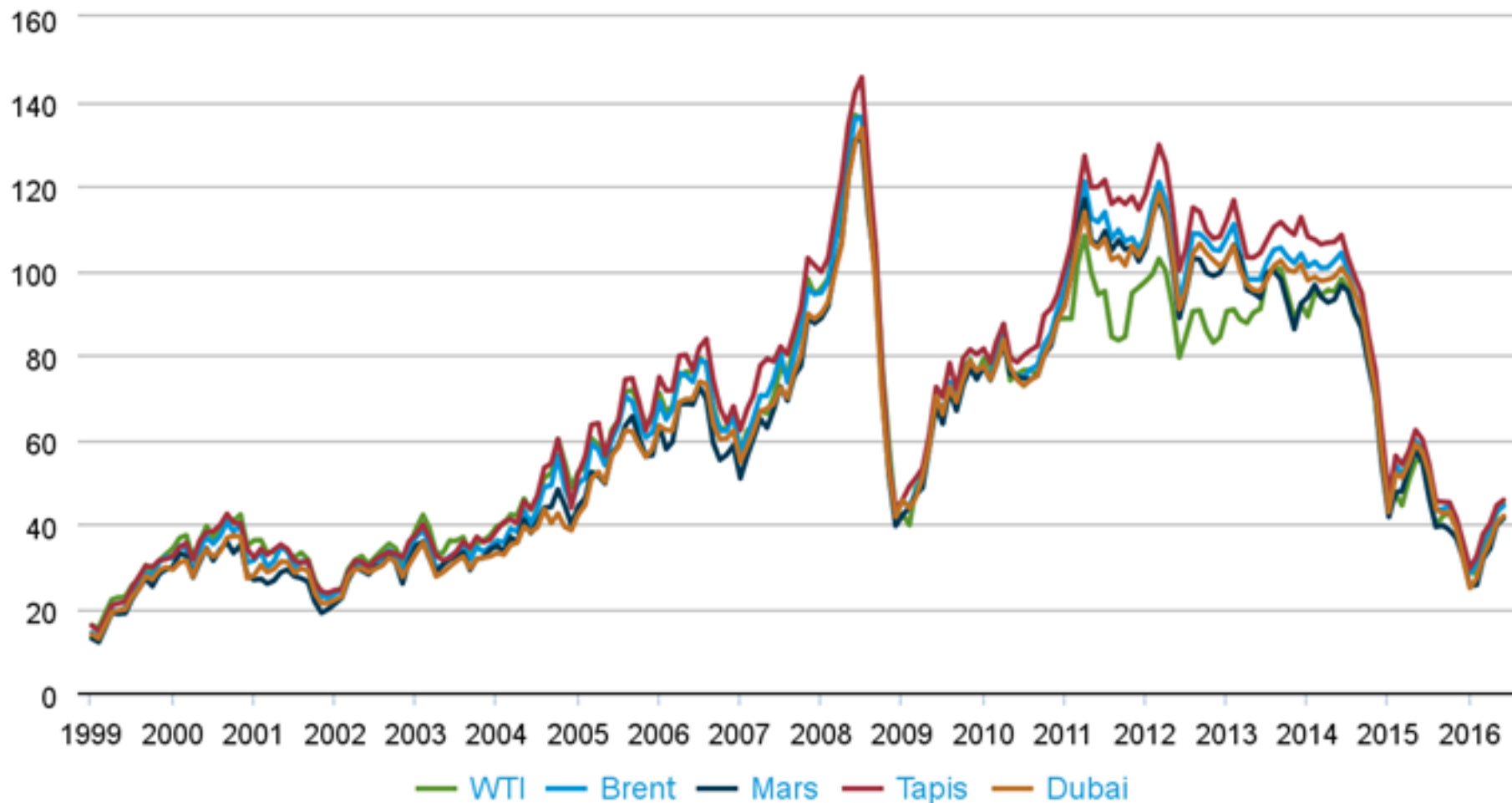
- In the 2006 State of the Union address President Bush warned that Americans are “*addicted to oil.*”
- Solutions included alternative energy and reduction of foreign oil reliance.
- The US became a net importer of oil in 1958, and since then we have spent \$3 trillion importing oil.
- 58% of US consumption was imported in 2006:
 - Mexico and Canada sent the most oil at about 15% of the total each,
 - Saudi Arabia, Nigeria, and Venezuela account for about 10-15% each,
 - The Mid-East accounts for about 20% (almost all of which comes from Saudi Arabia).

World Peak Oil 2000-2010

- The estimates in the late 20th Century equivocated, each successive scenario pushing the world peak off a few years.
- Questionable Middle East “new discoveries” and “proven reserves” kept pushing out the peak date (while expanding pumping rates kept prices even).
- And then came 2008...

World crude oil prices

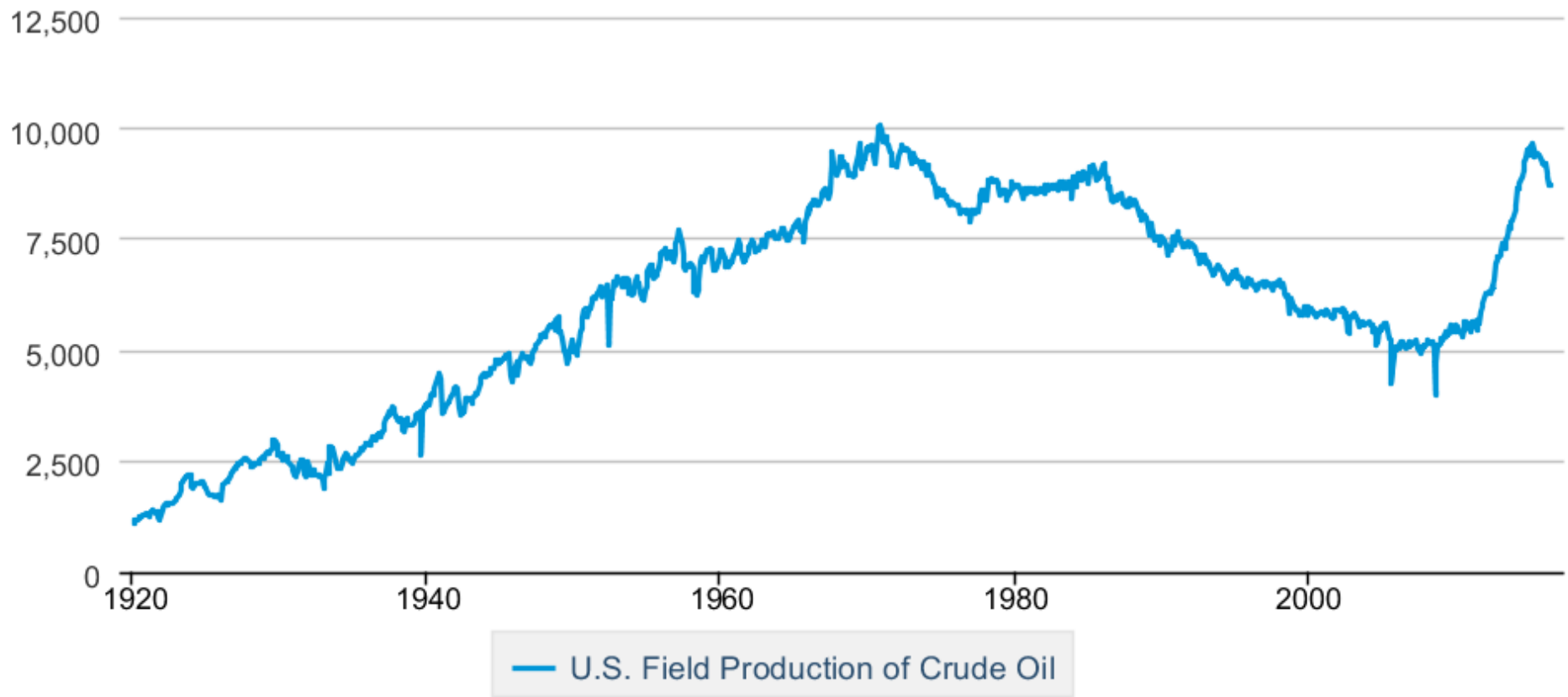
\$/bbl (real 2010 dollars, monthly average)



Sources: Bloomberg, Thomson Reuters. Published by: U.S. Energy Information Administration.
Updated: Monthly | Last Updated: 06/30/2016

U.S. Field Production of Crude Oil

Thousand Barrels per Day

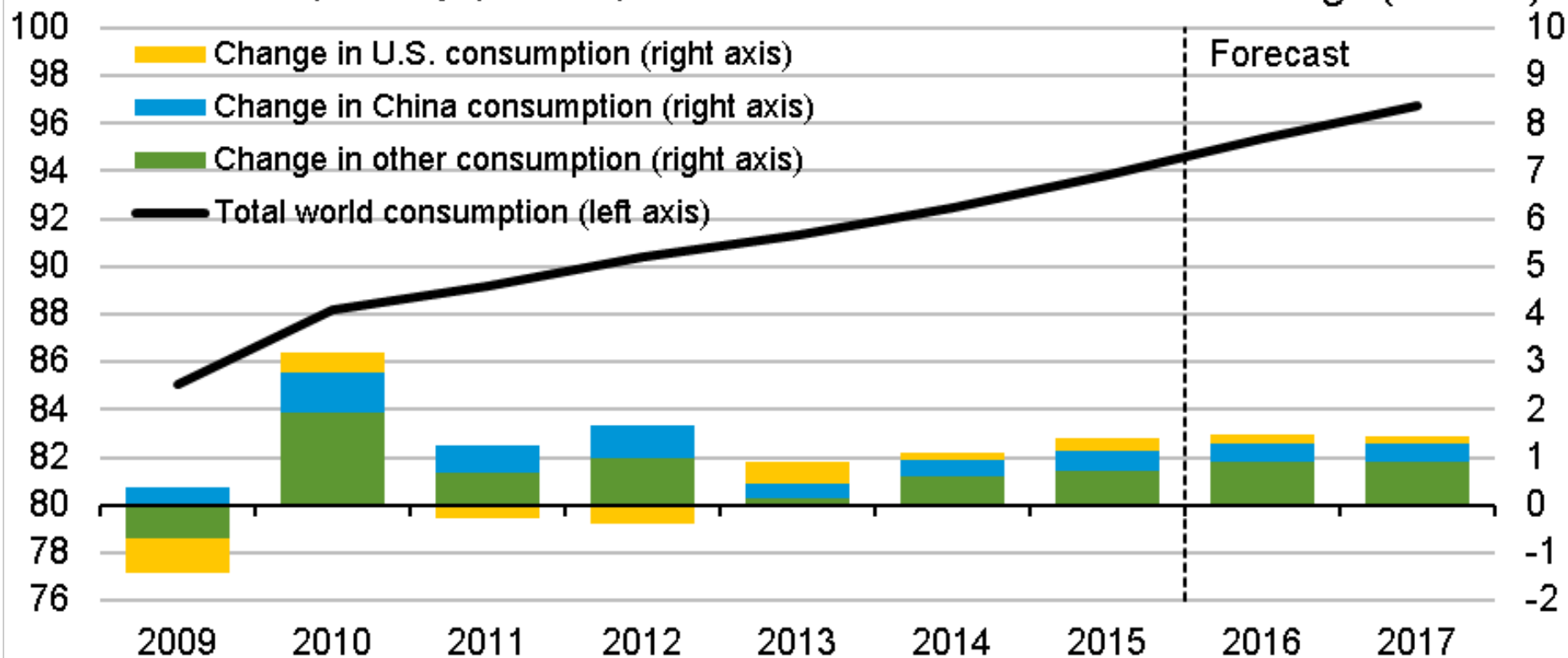


World liquid fuels consumption

million barrels per day (MMb/d)



annual change (MMb/d)



Source: Short-Term Energy Outlook, September 2016.

World Peak Oil 2000-2010

- Several processes interrelate:
 - War drives up oil prices through increased consumption (DoD is the single biggest user of oil), and due to increased risk and market uncertainty.
 - Contracting economies use less oil, driving prices down through reduced demand
 - Production contracted in response, driving prices back up.

World Peak Oil 2010-2015

- And then came the revolutionary technology of hydro-fracturing:
 - Lowers the cost of production, even for thick heavy crudes
 - Offers replacement by natural gas for some applications, but not all.
 - Importation rates for oil in the US is now just 24% --the lowest since 1970.

Peak Oil Perspectives

- From a conservation/environmentalist point of view, this a story of inevitable catastrophe, perhaps delayed momentarily, but the chickens will come to roost.
- For the techno-optimist, this is a story of new discovery and technological innovation in the face of impending scarcity.

Peak Oil Perspectives

- This is a replay of the Ehrlich-Simon debates of the 1970s:
 - Paul Ehrlich, conservation biologist, said that the age of oil was coming to an end, and the cost of energy would soon skyrocket, causing recession.
 - Julian Simon, economist, argued that human ingenuity (the “ultimate resource”) would innovate due to cost increases from scarcity.

Peak Oil Perspectives

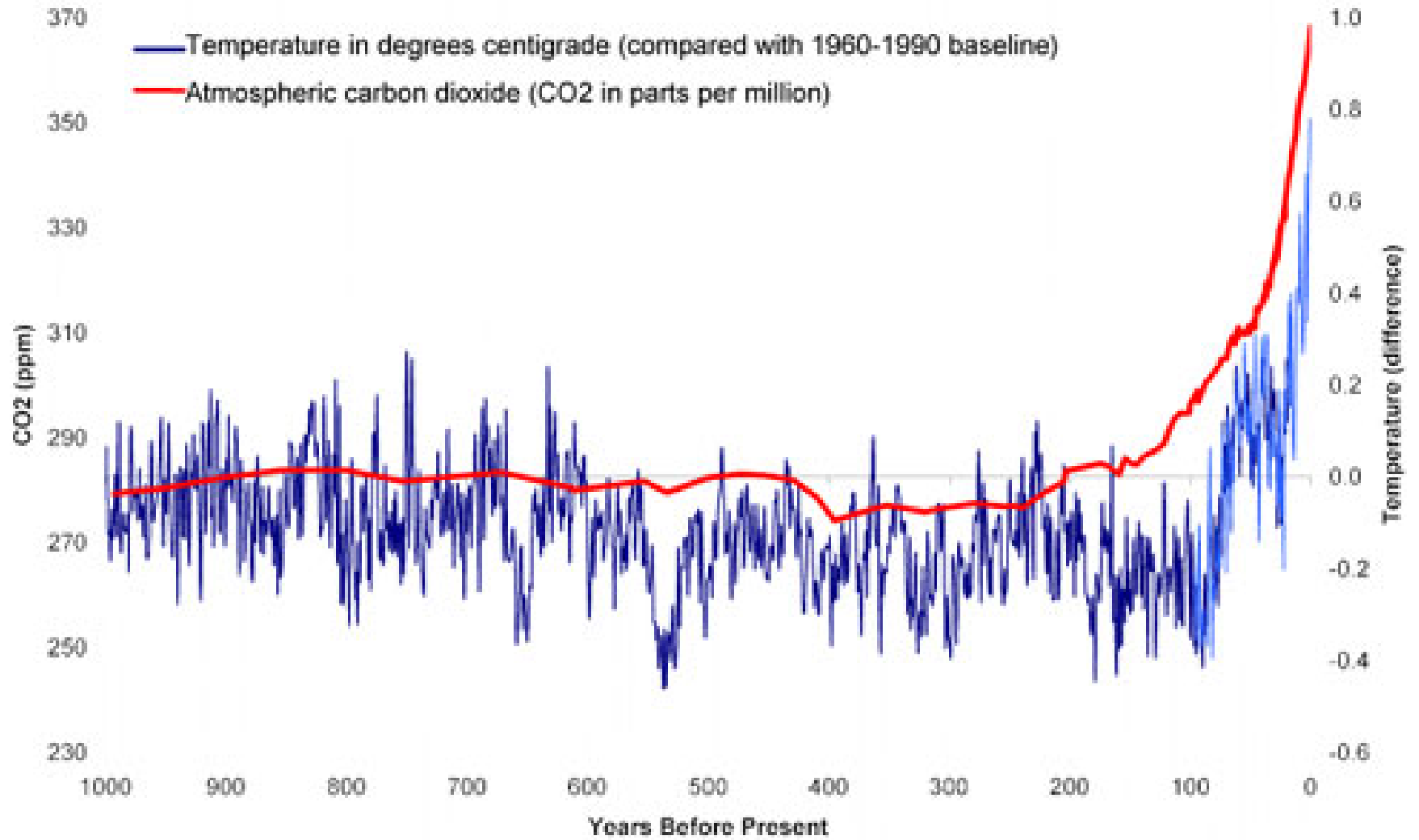
- Sadly, there is no clear way to adjudicate this debate:
 - Costs rise and fall with the market, war, and production, but Simon was right about trends.
 - Despite cost variability, the increasing use of fossil fuels does drive destructive climate change—if these externalities were included, the costs would be astronomical, so Ehrlich is right, too.

Oil Externalities

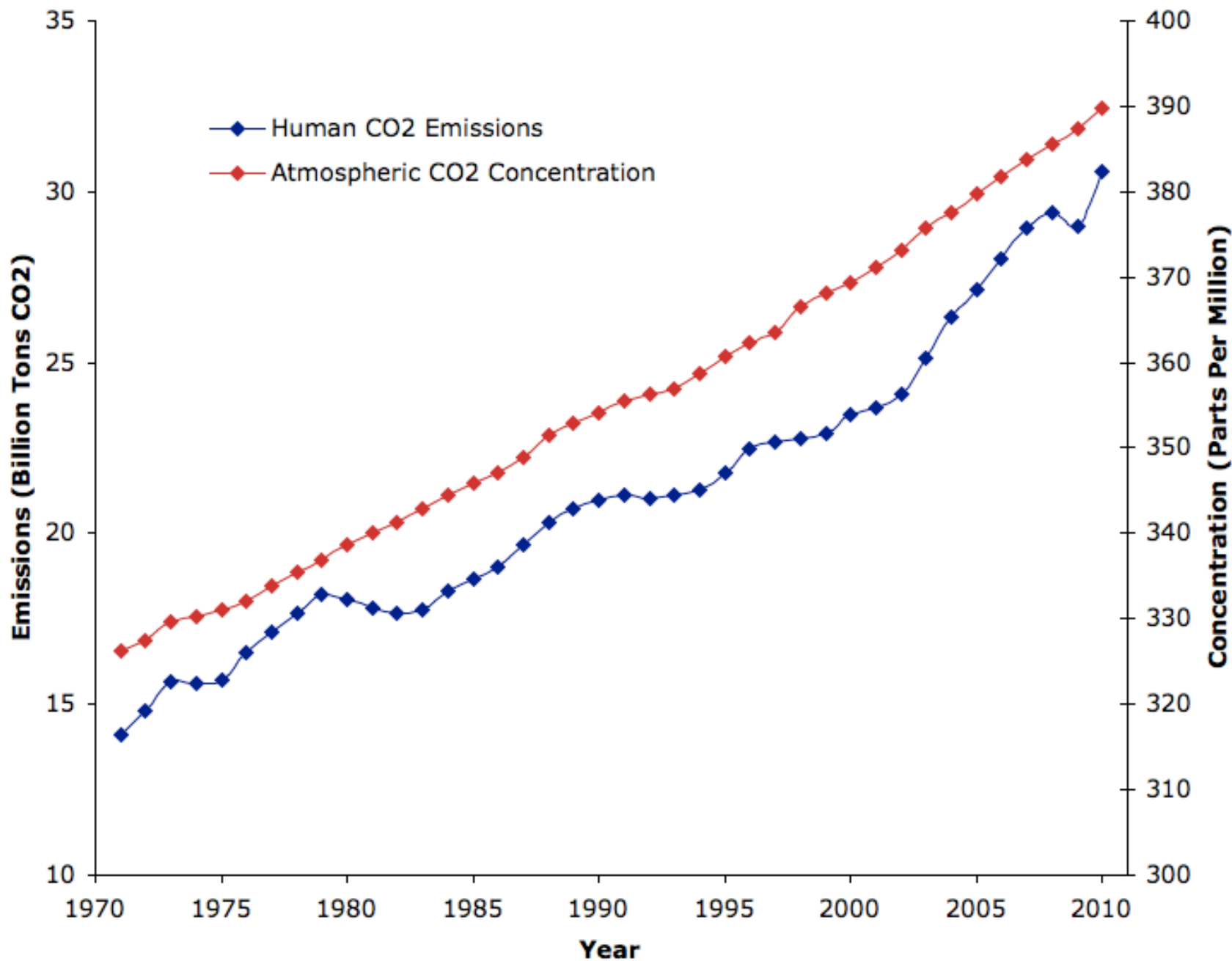
- NAS initiated climate change study in 1979
 - “If CO₂ continues to increase [there] is no reason to doubt that climate changes will result and no reason to believe that these changes will be negligible.”
- Temperatures could increase by 2°-8° F and could play out over several decades
 - “We may not be given a warning until the CO₂ loading is such that an appreciable climate change is inevitable.”

Oil Externalities

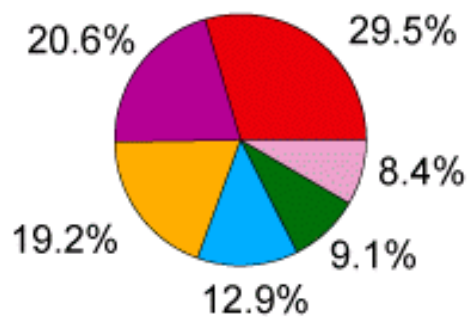
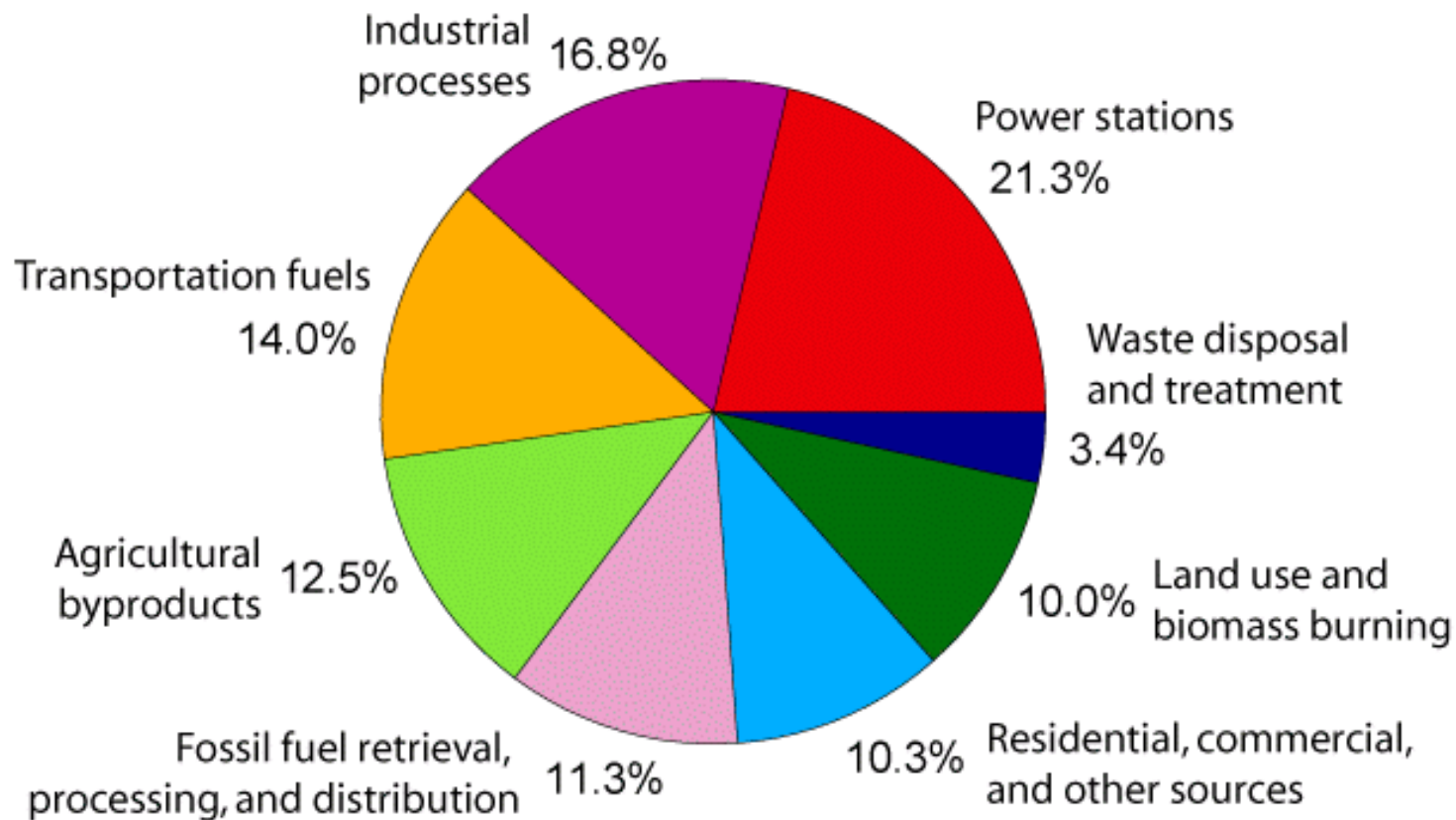
- Carbon loading of the atmosphere is largely responsible for global warming.
- Warming of just a few degrees will have massive impacts on our way of life, from the reduction of farming in the temperate zones, to destructive storms, to lowland flooding, to climate refugees.



Human CO2 Emissions vs. Atmospheric Concentration

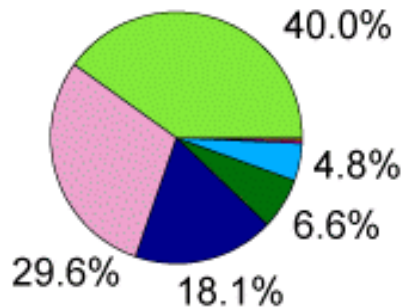


Annual Greenhouse Gas Emissions by Sector



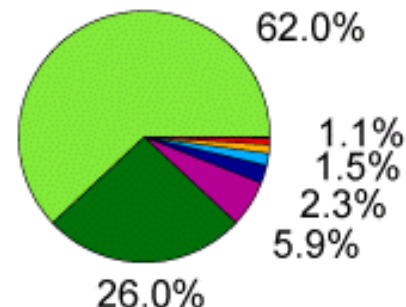
Carbon Dioxide

(72% of total)



Methane

(18% of total)



Nitrous Oxide

(9% of total)

What is to be done?

- Some suggest that we are no longer in the middle-late *Holocene*...we are actually in an era that should be called the *Anthropocene*: an era characterized by the effect of humans on the climate.

What is to be done?

- If you are a pessimist, the party is coming to an end, and Ehrlich (Cassandra) was right.
- If you are an optimist (Simon), this challenge is simply an opportunity:
 - As costs go up, there emerge new pressures towards innovation, and greater incentives for research and development
 - A cost-side crisis will drive R&D to yield new technologies that will offset losses

What is to be done?

- Concentrated Solar farms
- Carbon Capture and Storage
- Space-based Solar Power
- Wind power, especially VAWT
- Nuclear?
- Hydrogen?

What is to be done?

- Alternative technology: yes!
- But we also need to step off of this treadmill:
 - Force institutional and organizational change,
 - Buy smarter, but also buy less,
 - Vote, and vote with your dollars,
 - Use your voice and take action:

“Never doubt that a small group of committed citizens can change the world. Indeed, it’s the only thing that has.”

Margaret Meade