World Energy Needs and Fossil Fuel Reserves

AOSC 433/633 & CHEM 433

Ross Salawitch

Class Web Site: http://www.atmos.umd.edu/~rjs/class/spr2015

Topics for today:

- **World Energy Needs: Population and Standard of Living**
- **Fossil Fuel Reserve**

Lay the ground work for rest of the semester

Lecture 17

16 April 2015

Student Projects

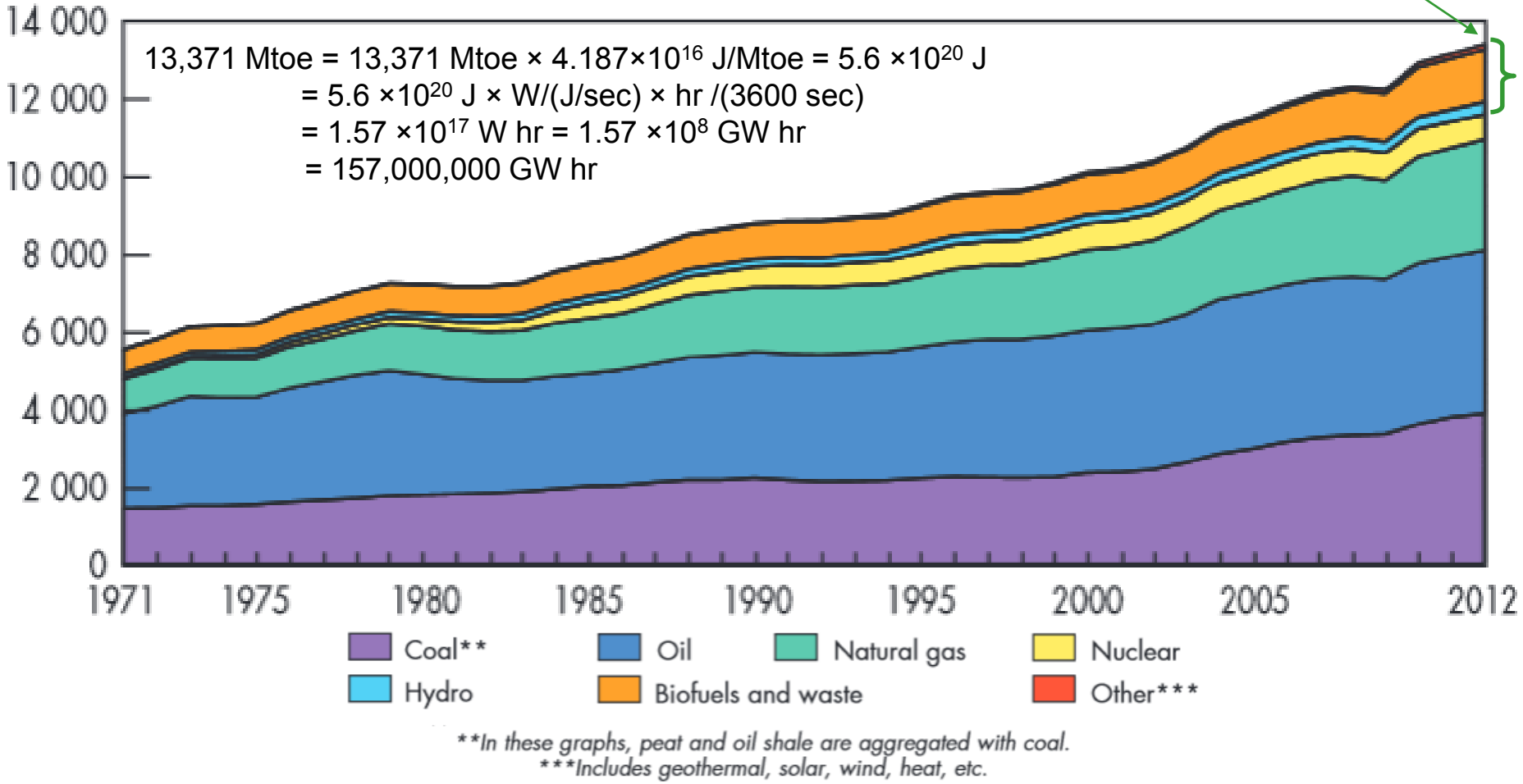
- **Mandatory for 633 students:** project grade will count towards final grade in an amount equal to each exam
- Due Monday, 11 May 2015… you're welcome to complete sooner
- ~8 pages single spaced (not including reference list or figures) on a topic related to class (your choice …we're happy to discuss potential topics)
- Must be ***new work for this class*** but can be related to your dissertation or some other topic in which you've had prior interest
- ~10 min project presentations 6:30 pm, 11 May: everyone encouraged to attend
- **433 students:** may complete a Student Project (same guidelines) and the grade on this project can replace that of a ***single Problem Set*** especially helpful for students who have not turned in a Problem Set
- Request all students who will complete a project to provide a **2 to 3 sentence description as soon as possible** ⇨ **11 May is less than a month away**
- Finally, I am delighted to provide feedback on your project (paper & presentation) if given the opportunity prior to 11 May 2015

World *Energy* Production:

Energy (units: Mtoe)

Mtoe: megatonne of oil equivalent (Mtoe) = 4.187x 10^{16} J
used to describe the energy content of all fuels.
http://www.aps.org/policy/reports/popa-reports/energy/units.cfm

Green Technologies

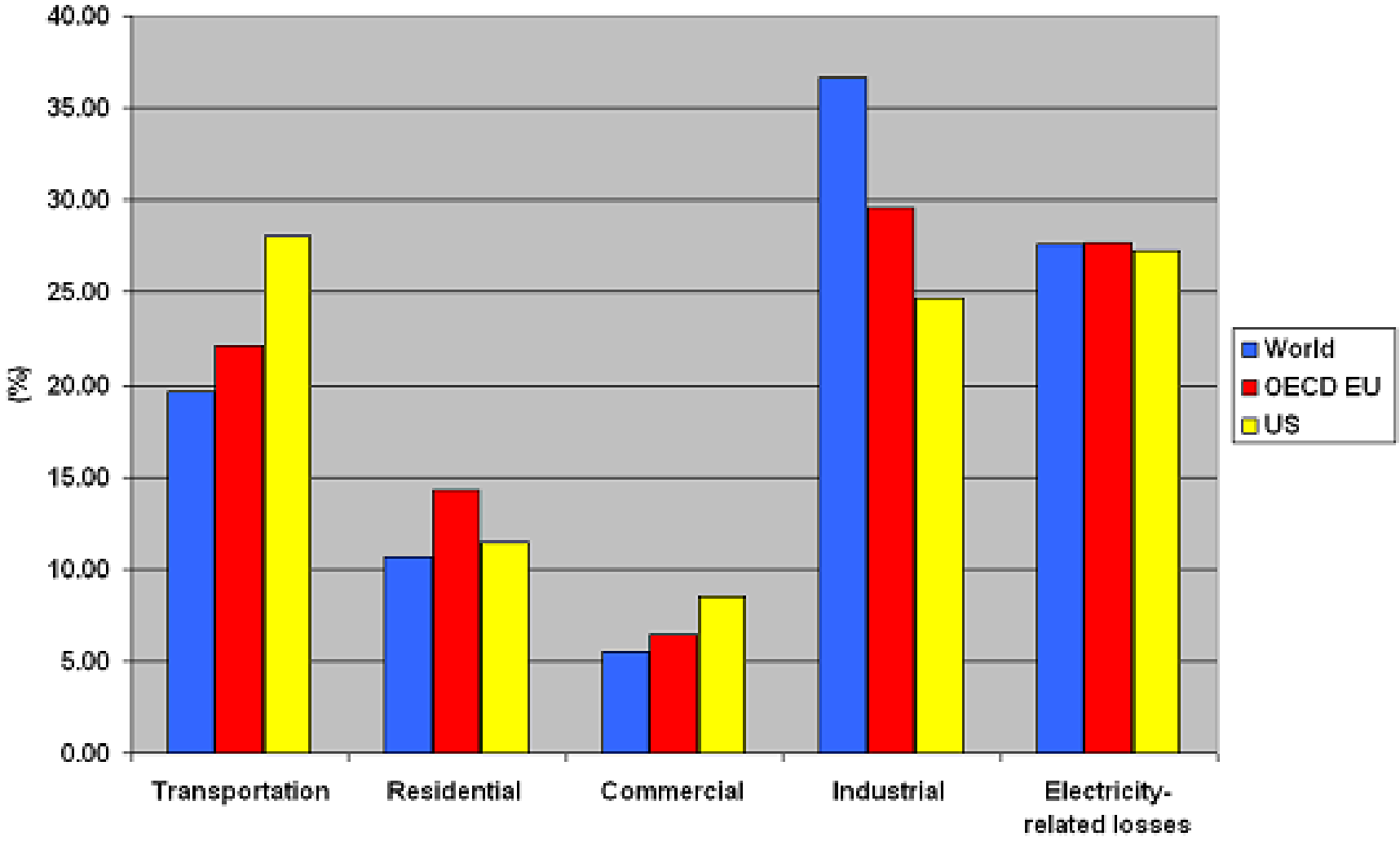


13,371 Mtoe = 13,371 Mtoe × 4.187×10^{16} J/Mtoe = 5.6 ×10^{20} J
= 5.6 ×10^{20} J × W/(J/sec) × hr /(3600 sec)
= 1.57 ×10^{17} W hr = 1.57 ×10^{8} GW hr
= 157,000,000 GW hr

***In these graphs, peat and oil shale are aggregated with coal.*
****Includes geothermal, solar, wind, heat, etc.*

Source: http://www.iea.org/publications/freepublications/publication/keyworld2014.pdf

World *Energy* Consumption:



OECD: Organisation for Economic Co-operation and Development
EU : European Union

Source: http://edro.files.wordpress.com/2007/11/energy-consumption-by-sector-and-region-a.png

World Installed ***Electricity*** Generating ***Capacity***:

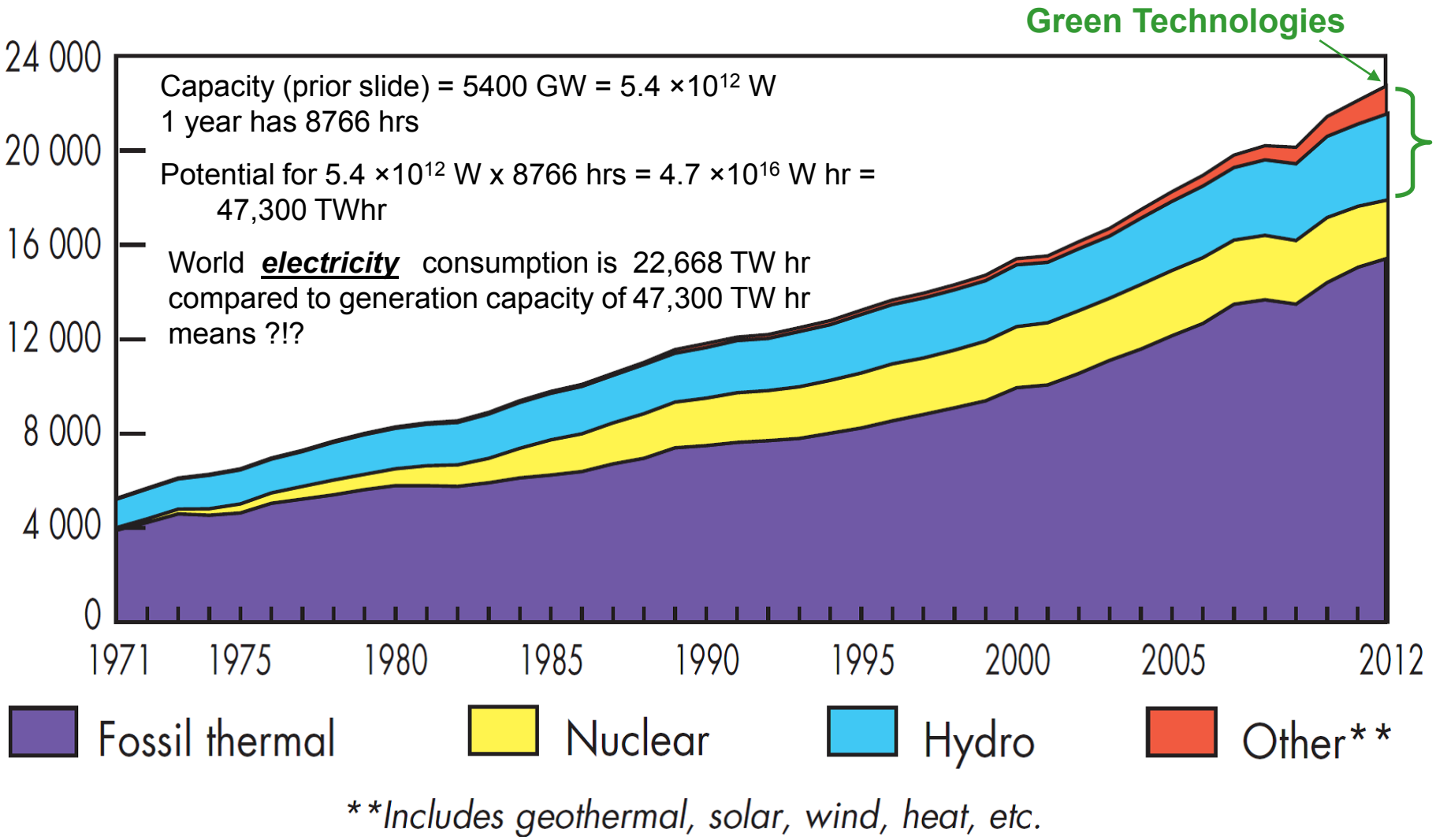
Power (Energy/Time)

Total Source	GW (year 2012)
Coal	1,810
Natural Gas	1,391
Hydro-electric	979
Liquid Fossil Fuel	388
Nuclear	373
Wind	268
Solar, Tidal	94
Biomass	87
Geothermal	10
Total	5400

Source: http://www.eia.doe.gov/forecasts/ieo/ieo_tables.cfm

World ***Electricity Consumption***:

Energy (units: TW hr)



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Capacity

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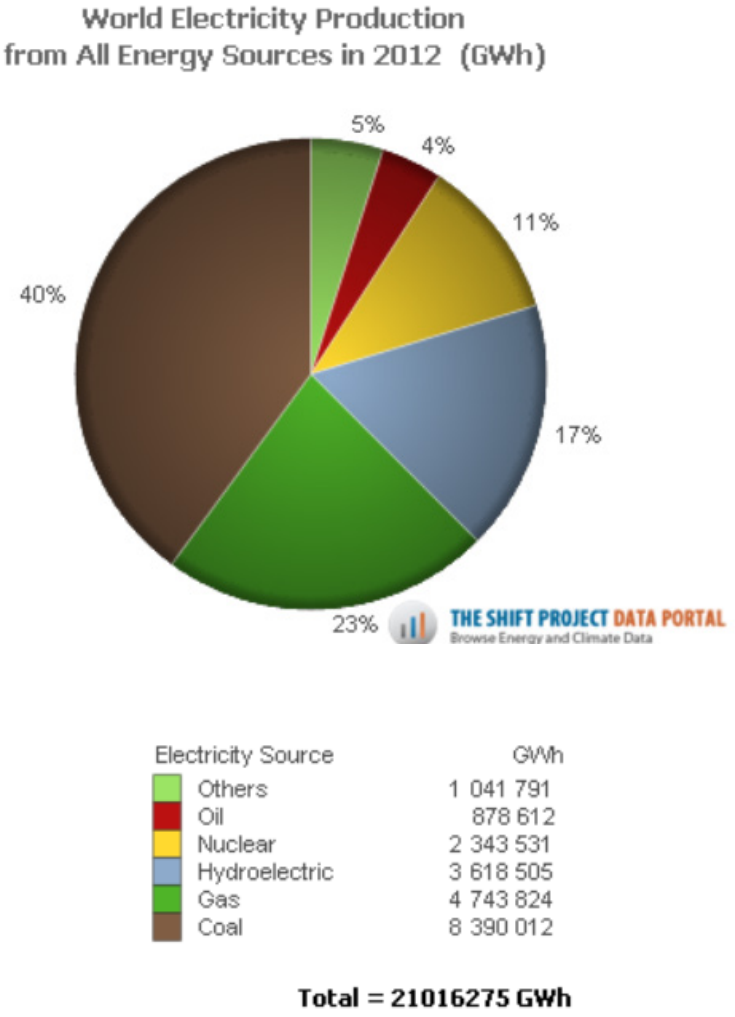
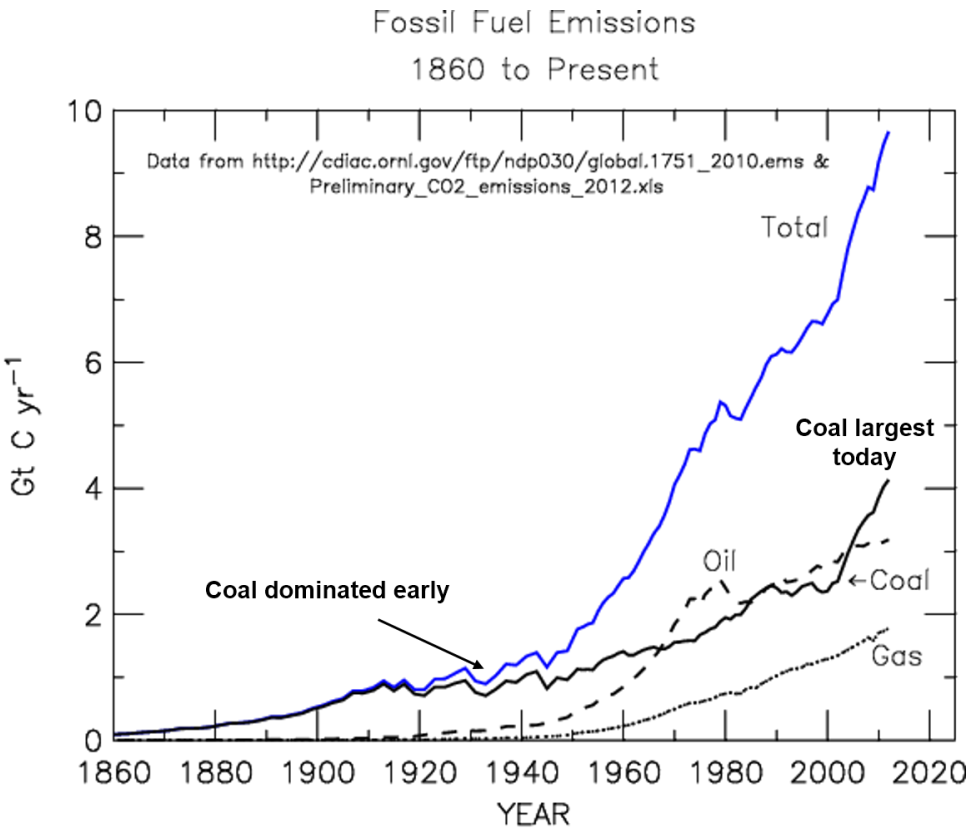


http://www.tsp-data-portal.org/Breakdown-of-Electricity-Generation-by-Energy-Source#tspQvChart

Fossil Fuel Emissions and Reserves



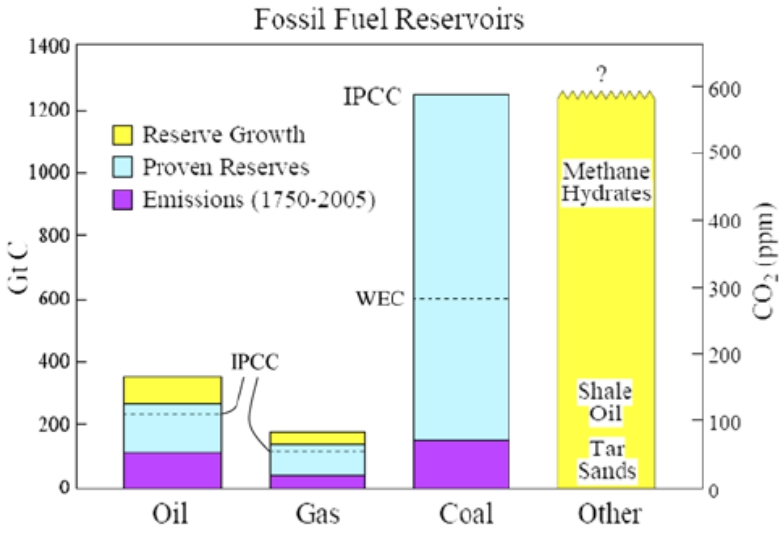


Figure 1. Fossil fuel-related estimates used in this study. Historical fossil fuel CO_2 emissions from the Carbon Dioxide Information Analysis Center [CDIAC; *Marland et al.*, 2006] and British Petroleum [*BP*, 2006]. Lower limits for current proven conventional reserve estimates for oil and gas from *IPCC* [2001a] (dashed lines), upper limits and reserve growth values from US Energy Information Administration [*EIA*, 2006]. Lower limit for conventional coal reserves from World Energy Council [*WEC*, 2007; dashed line], upper limit from *IPCC* [2001a]. Possible amounts of unconventional fossil resources from *IPCC* [2001a].

Kharecha and Hansen, *GBC*, 2008.

CO_2 is long lived: society must reduce emissions soon or we will be committed to dramatic, future increases!

Curve that levels off at ~560 ppm has emissions peaking ~2030
Less than 20 years from now !

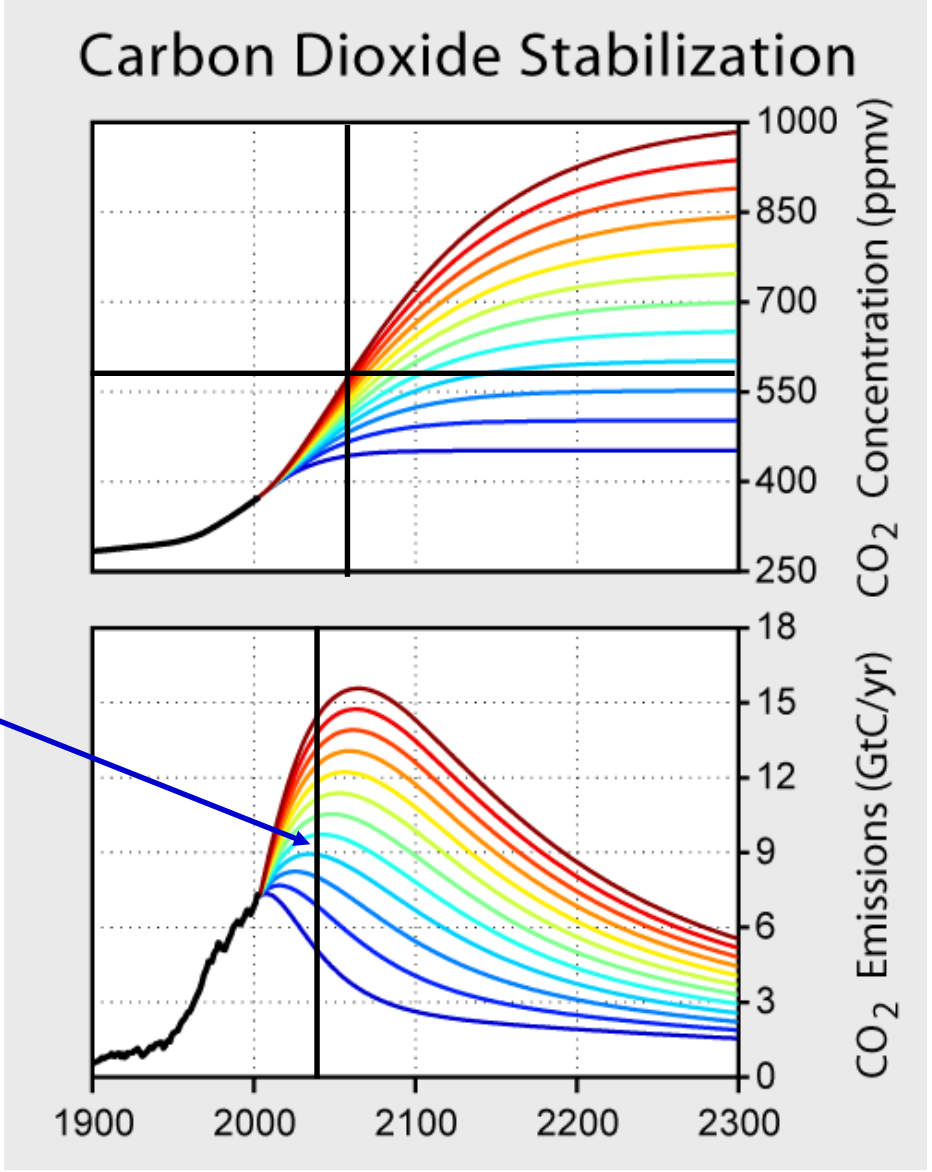
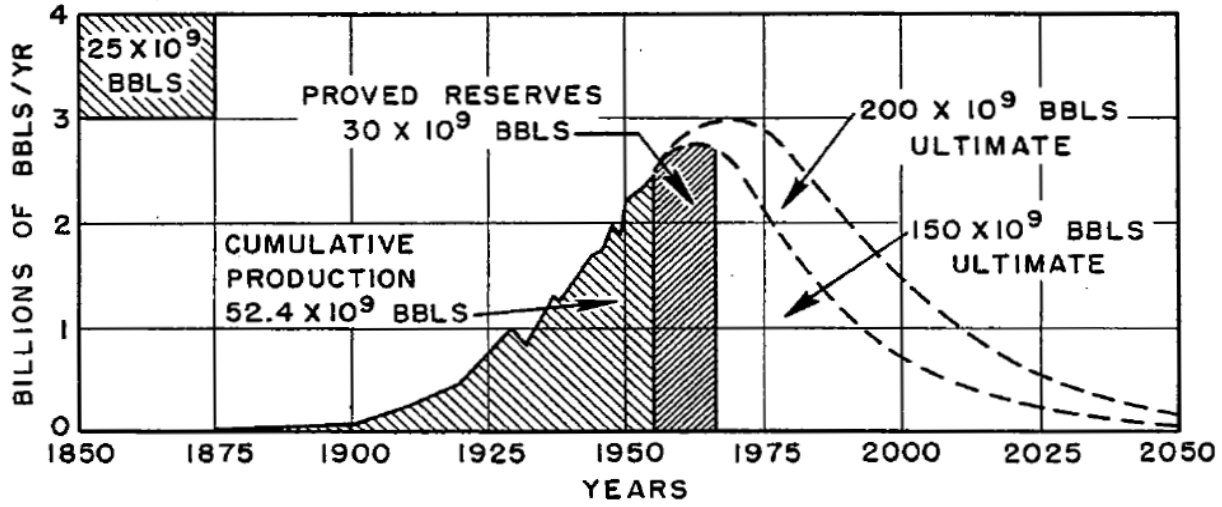
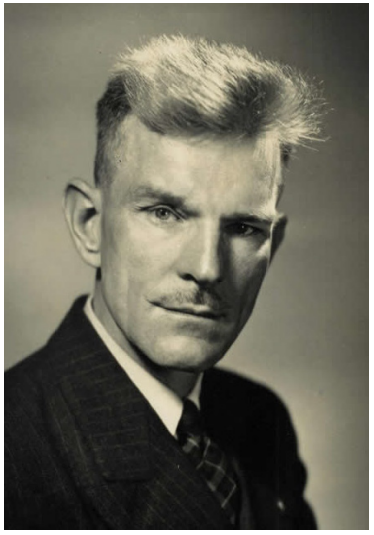


Image: "Global Warming Art" : http://www.globalwarmingart.com/wiki/Image:Carbon_Stabilization_Scenarios_png

Hubbert's Peak

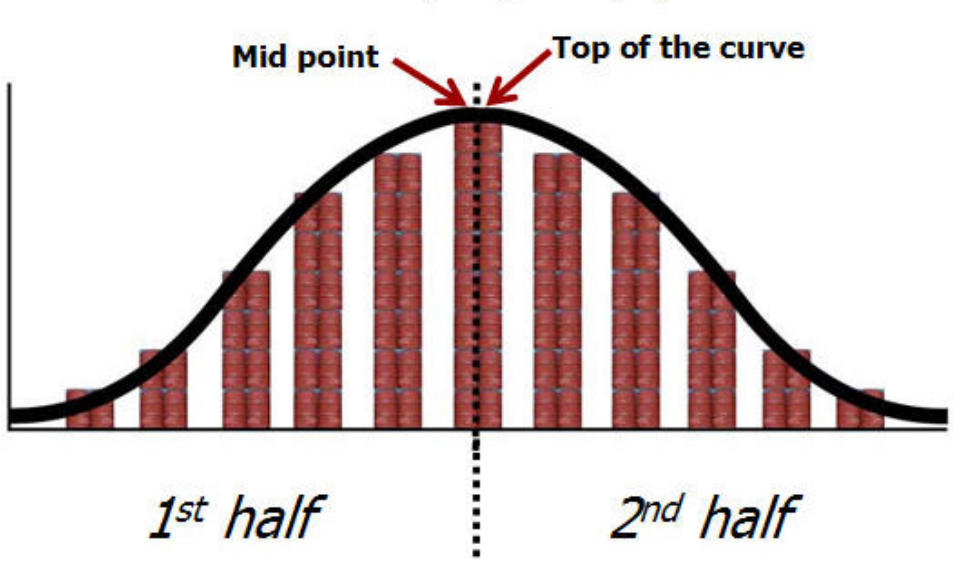


- **M. King Hubbert: Shell geophysicist**
- **1956 : presented a paper "Nuclear Energy and Fossil Fuels" that predicted US oil production would peak in 1970**
- **Paper was met with skepticism & ridicule**
- **But: *<u>this prediction was remarkably accurate</u>* !**



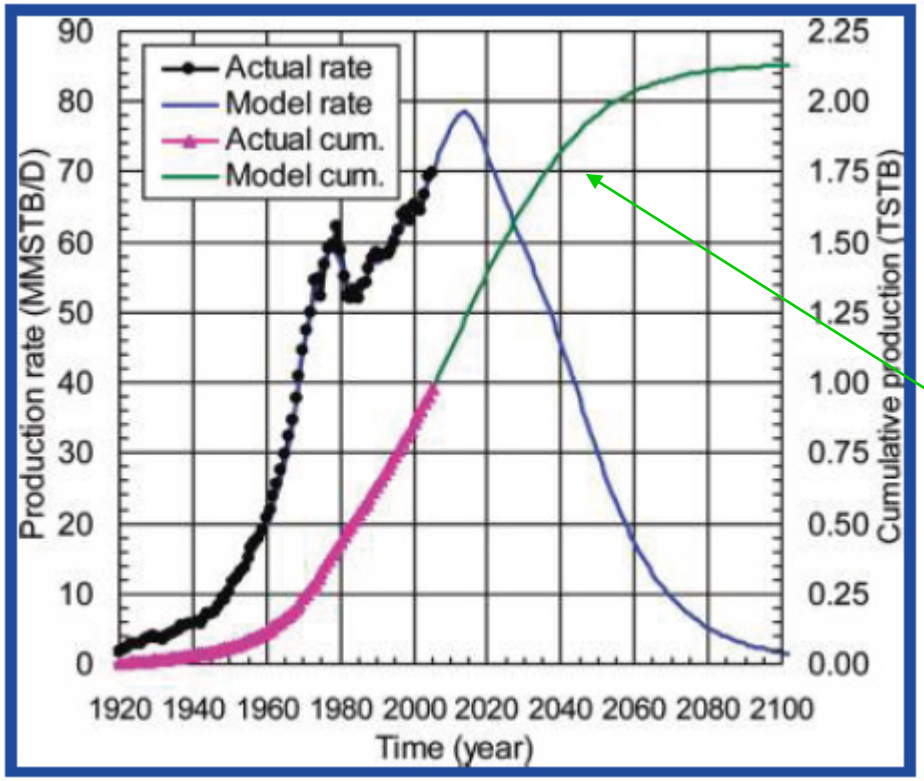
Mathematics of Resource Use

It is unlikely that an industry will go from full production of a resource to zero production the next year. It is reasonable to assume that production will follow an exponential growth while a resource is easy to find and relatively cheap to produce. As the resource becomes harder to find, prices rise, production rates peak, and then begin to decrease.



The area beneath this curve is the total amount of resource available.

Global *Oil* Production Predicted to Peak Next Decade !



Hubbert-like analysis applied to 47 major oil producing countries led to conclusion that global production of oil will peak near 2014.

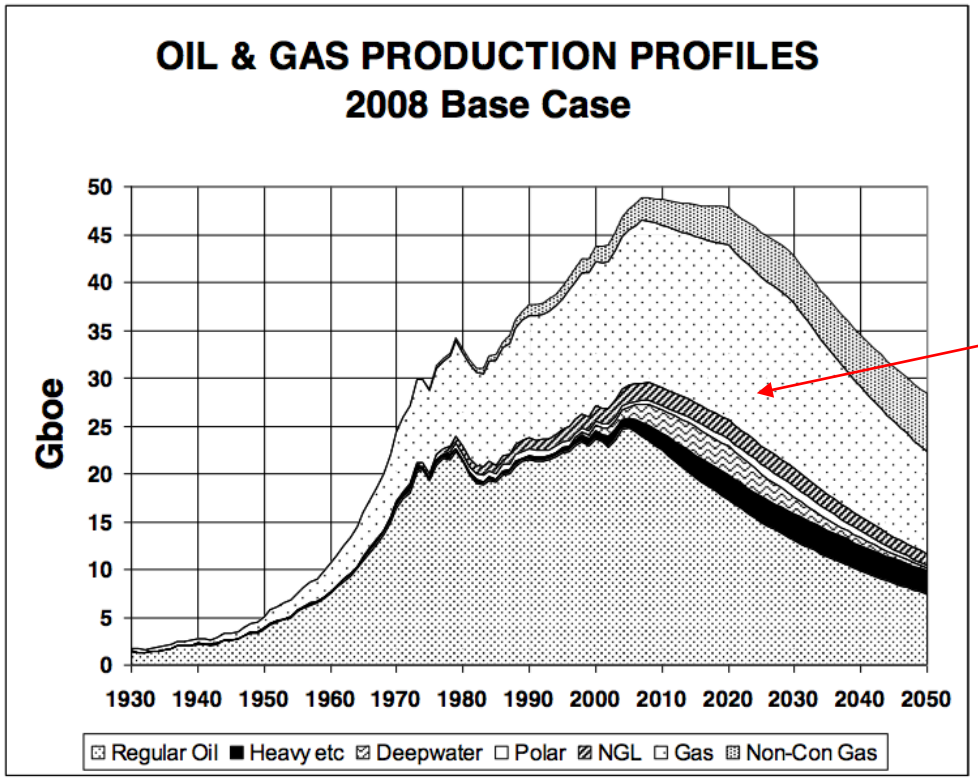
Actual production curve shows effects of economic and geo-political events

Cumulative (cum.) production curve indicates known oil reserves are ~ 2.1 TSTN (trillion stock tank barrels), **half of which have been produced**

Nashawi *et al.,* Energy Fuels, 2010

http://pubs.acs.org/doi/abs/10.1021/ef901240p

Natural Gas

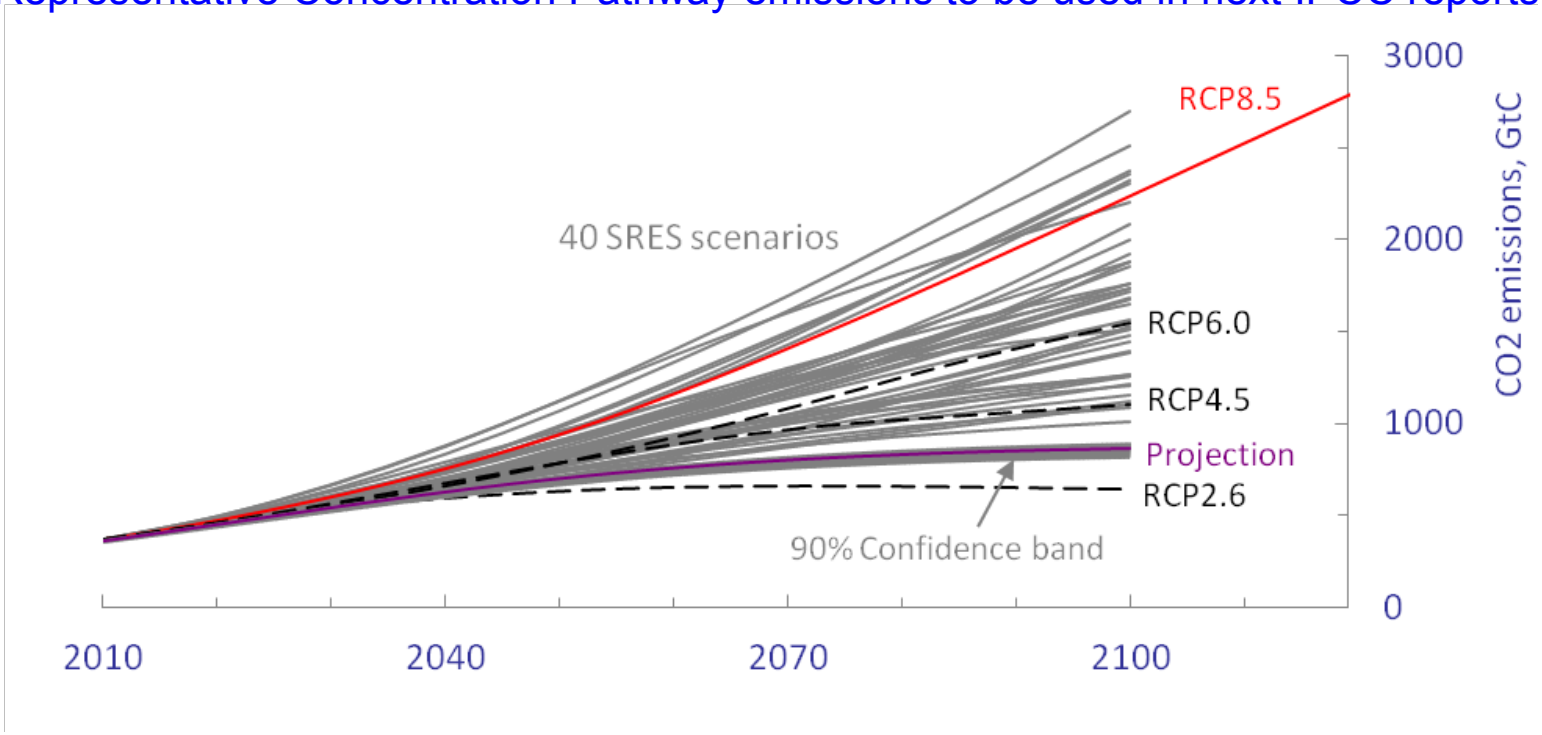


- Most reserves in Middle East & Russia.
- Hubbert analysis indicates peak of gas production around 2020

http://gailtheactuary.files.wordpress.com/2010/11/colin-campbell-april-2009-forecast.png

One analysis suggests CO_2 emissions will fall far short of "doom and gloom" scenarios due to shortfall in supply

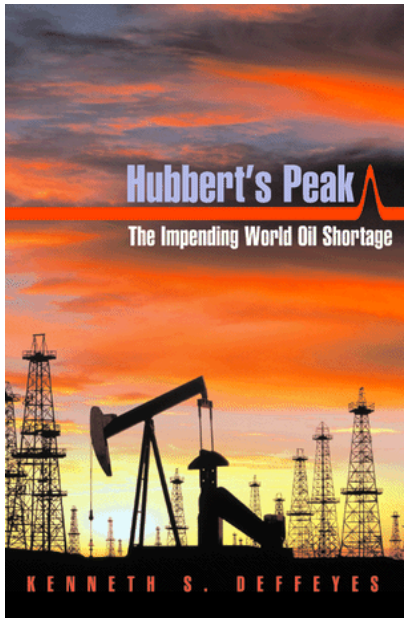
SRES: Special Report on Emission Scenario used in past IPCC reports
RCP: Representative Concentration Pathway emissions to be used in next IPCC reports

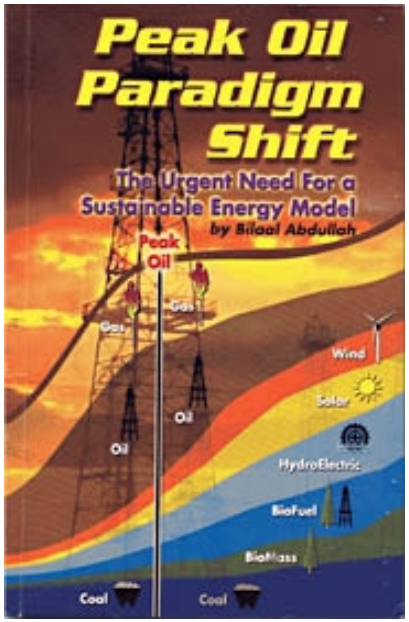


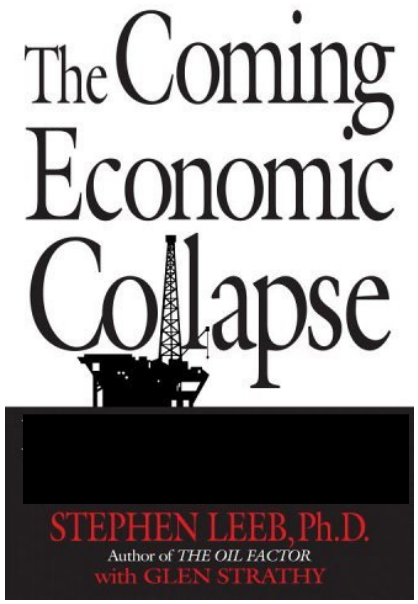
- Trend Analysis results in lower emissions than any of the 40 IPCC emission scenarios !
- **Good news: atmospheric CO_2 will peak at only ~470 ppm according to this estimate**
- **Bad news: world will have to find a new way to power its economy**

Source : David Rutledge, Caltech
http://www.its.caltech.edu/~rutledge/Energy%20Supplies%20and%20Climate.ppt

Extensive Literature on This Subject

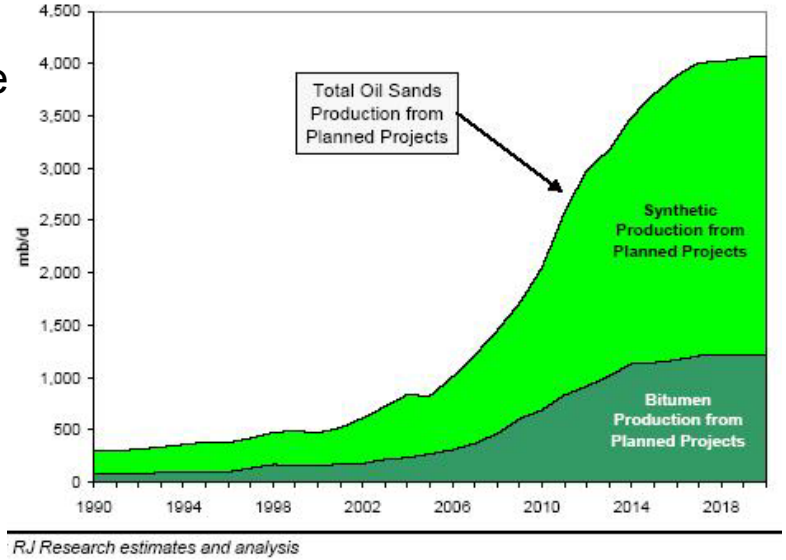






Canadian oil sands (tar sands)

- May represent 2/3 of world's total petroleum resource
- Not considered in many estimates of fossil fuel reserve
- Because of oil sands production, **Canada is largest supplier of oil to US**
- "Gold rush" like economic boom in Alberta Canada
- Fossil fuel extraction energy and water intensive: forests flattened and large waste water lakes created



RJ Research estimates and analysis

See http://en.wikipedia.org/wiki/Tar_sands and http://oilsands.alberta.ca/ for more info.

Future Use of Fossil Fuels

- If society decides to continue to reply on fossil fuels, we will become increasingly reliant on **coal** (in the short term) and **oil sands** (in the long term)

Why is this a concern?

Future Use of Fossil Fuels

- If society decides to continue to reply on fossil fuels, we will become increasingly reliant on **coal** (in the short term) and **oil sands** (in the long term)

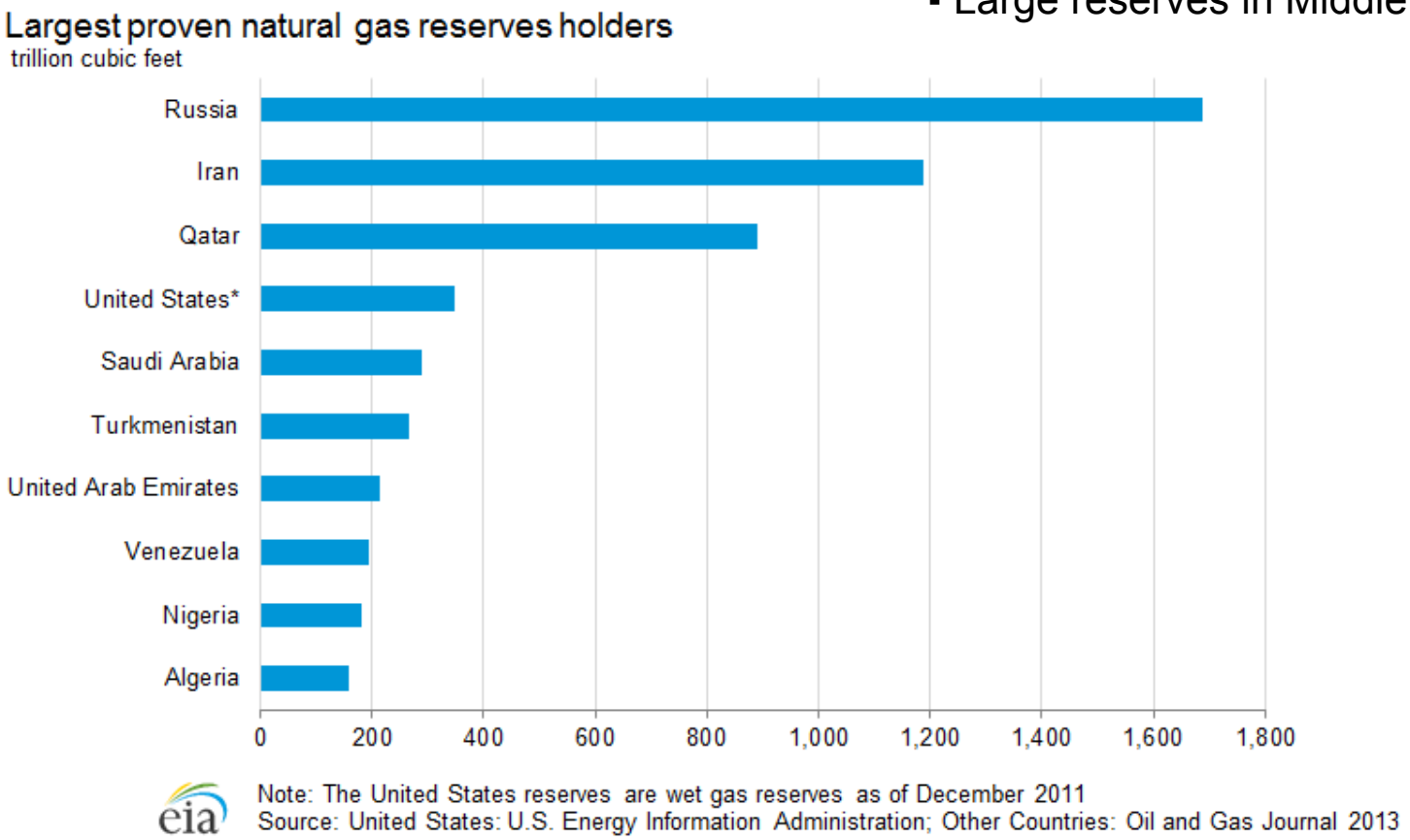
Why else might reliance on coal and oil sands be a concern?

Fossil Fuel	GHG Output (pounds CO_2 per kWh)
Oil Sands	
Coal	
Oil	
Gas	

http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2report.html
http://www.iop.org/EJ/abstract/1748-9326/4/1/014005

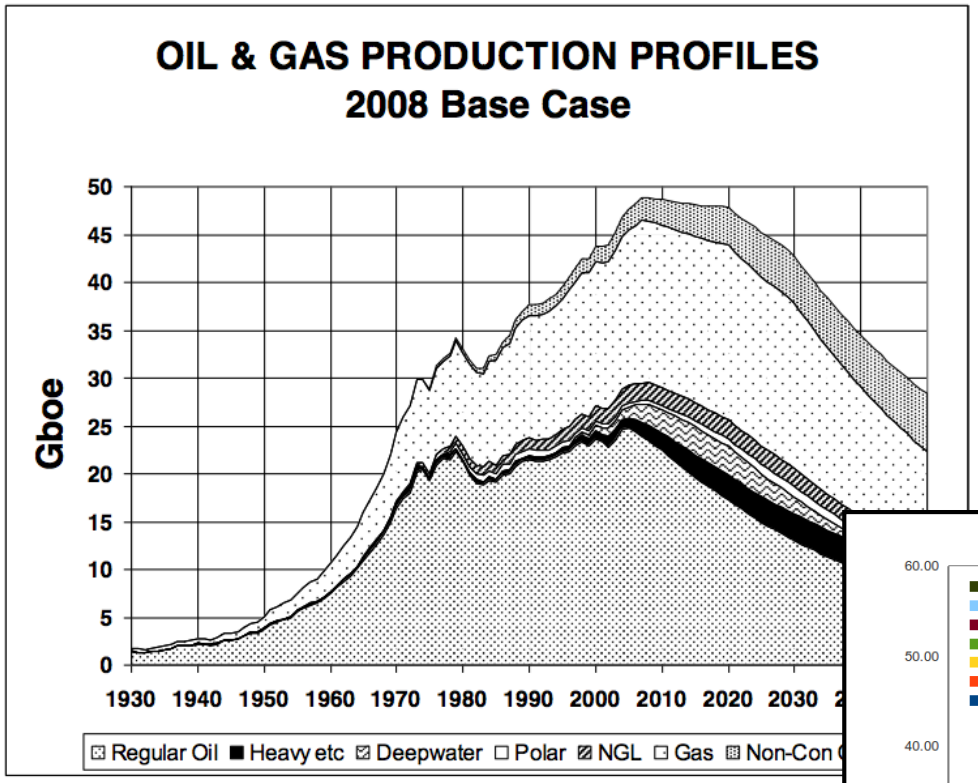
Natural Gas

- Large reserves in Middle East & Russia.



http://www.eia.gov/countries/cab.cfm?fips=rs

Natural Gas



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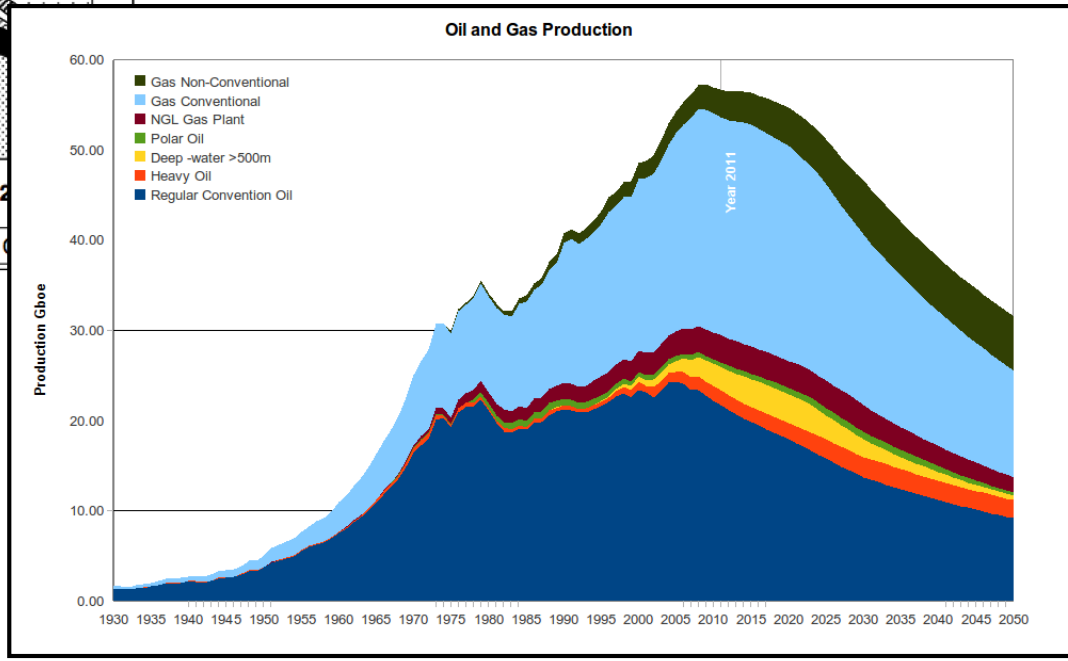
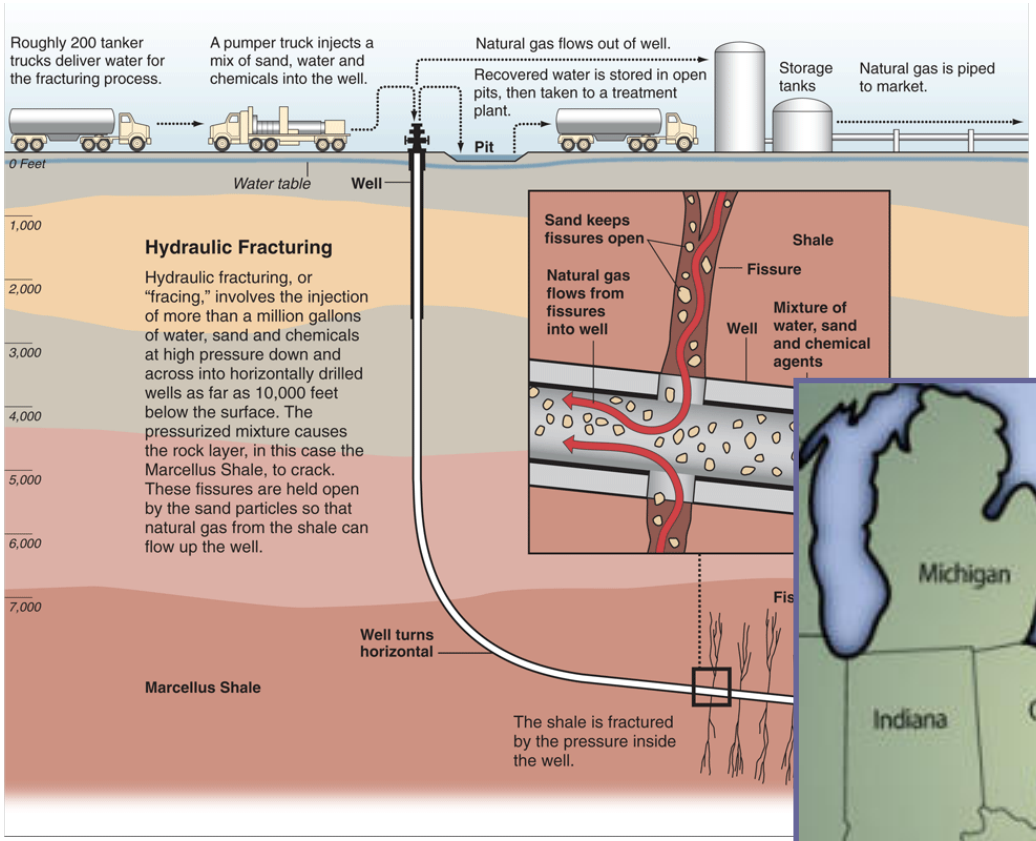
Another Projection

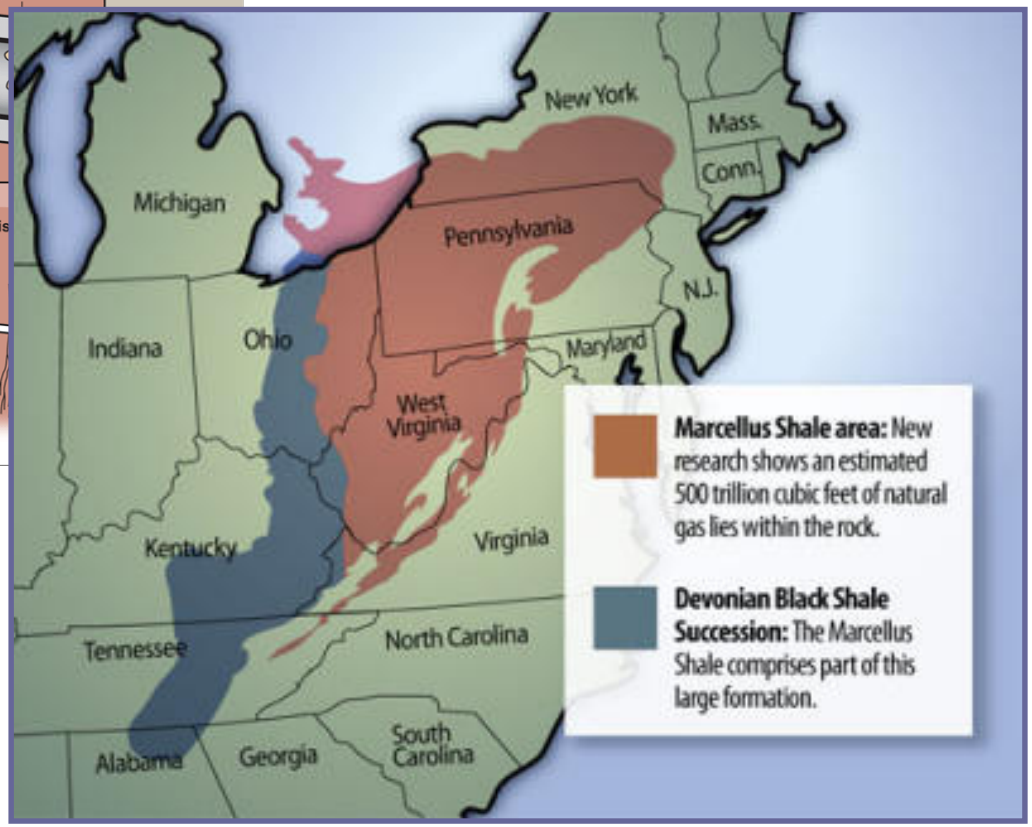


http://aspoireland.files.wordpress.com/2011/05/aspo-oil-and-gas-production-profiles1.png

Natural Gas: Fracking



- Pumping of chemical brine to loosen deposits of natural gas from shale
- Marcellus Shale in Penn, NY and NJ is major source region



http://akrondave.files.wordpress.com/2011/01/marcellus-shale.jpg

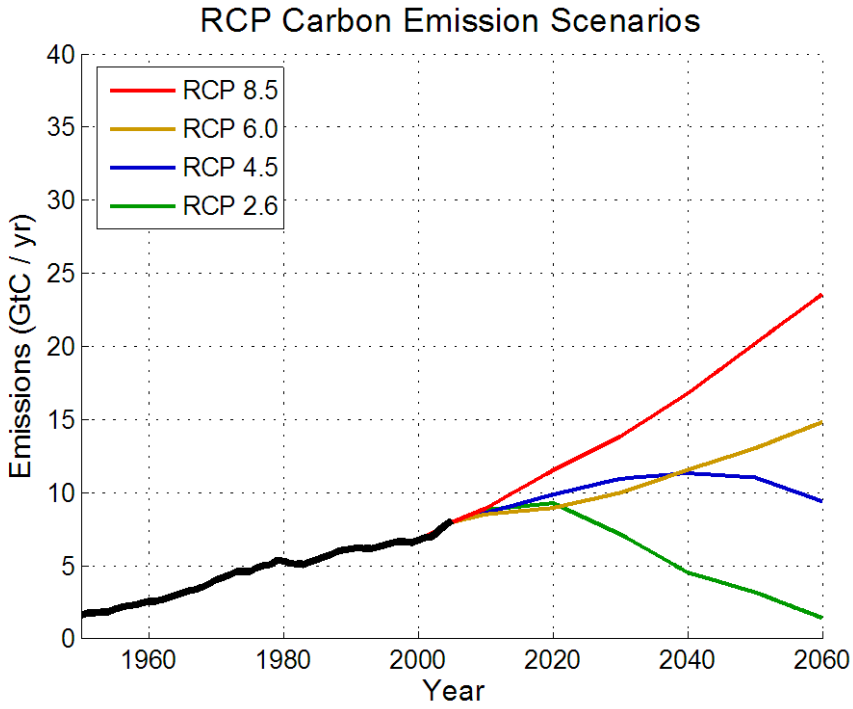
Obama – Xi Accord

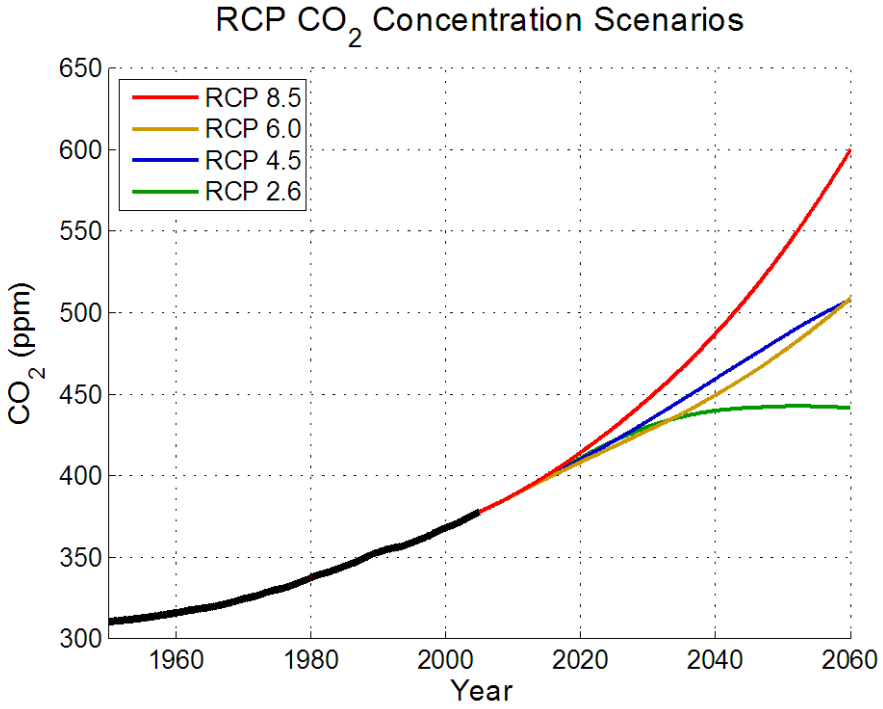
• The Presidents of the United States and China announced their respective post-2020 actions on climate change, recognizing that these actions are part of the longer range effort to transition to low-carbon economies, **mindful of the global temperature goal of 2°C**. The **U.S.** intends to achieve an economy-wide target of **reducing emissions by 26% to 28% below its 2005 level in 2025** ; **China** intends to achieve **peaking of CO_2 emissions around 2030** and make best effort to peak early & intends to increase share of non-fossil fuels in primary energy consumption to ~20% by 2030.

• The United States and China hope that by announcing these targets now, they can inject momentum into the global climate negotiations and inspire other countries to join in coming forward with ambitious actions as soon as possible, preferably by the first quarter of 2015 … to reach a successful global climate agreement in Paris in late 2015.

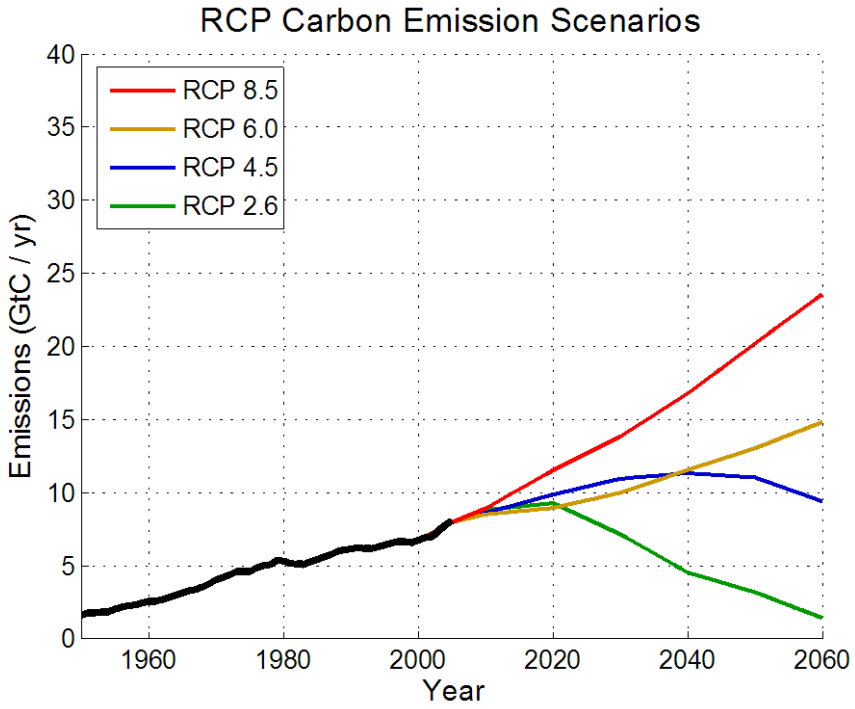
• The two sides have among other things:
  – established the U.S.-China Climate Change Working Group (CCWG), under which they have launched initiatives on vehicles, smart grids, carbon capture, energy efficiency, GHG data management, forests and industrial boilers;
  – agreed to work together towards the global phase down of hydrofluorocarbons (HFCs)
  – created the U.S.-China Clean Energy Research Center, which facilitates collaborative work in carbon capture and storage technologies, energy efficiency in buildings, and clean vehicles; and
  – agreed on a joint peer review of inefficient fossil fuel subsidies under the G-20.

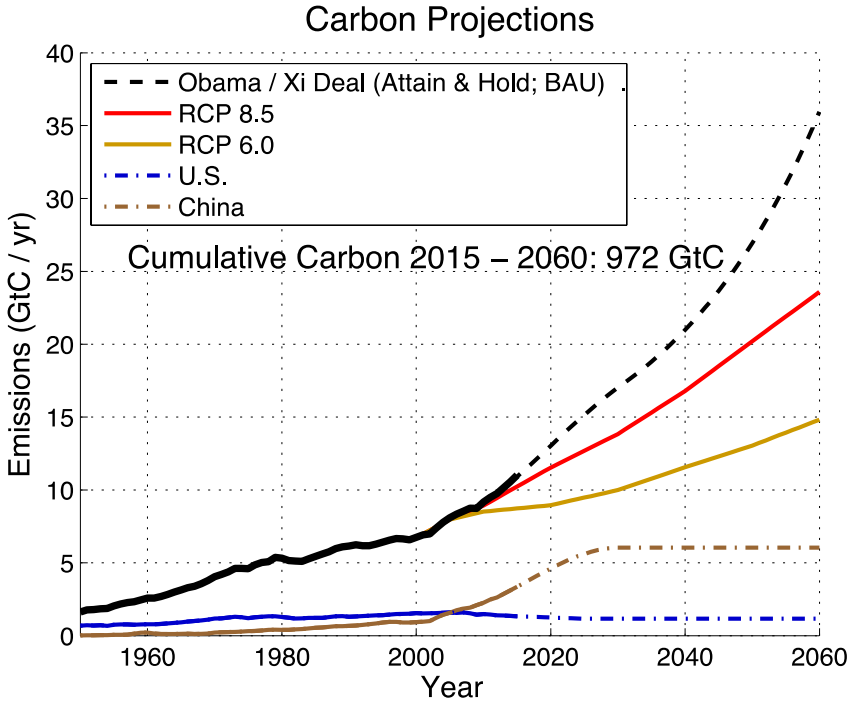
Text: http://www.whitehouse.gov/the-press-office/2014/11/11/us-china-joint-announcement-climate-change
Image: http://www.asianews.it/news-en/China-and-the-United-States-agree-to-climate-agreement-by-2030-32676.html





Tribett et al., in prep, 2015





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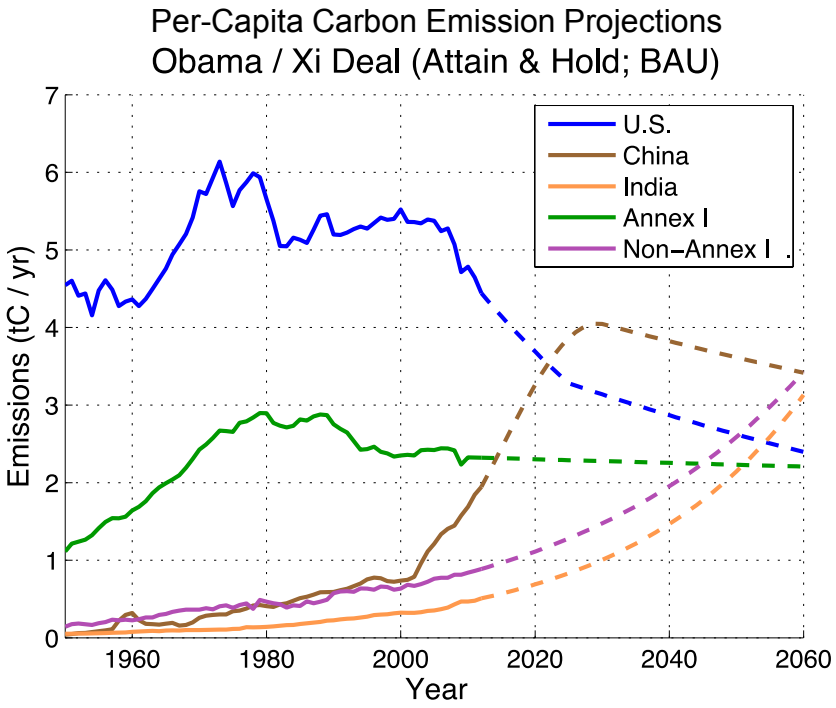

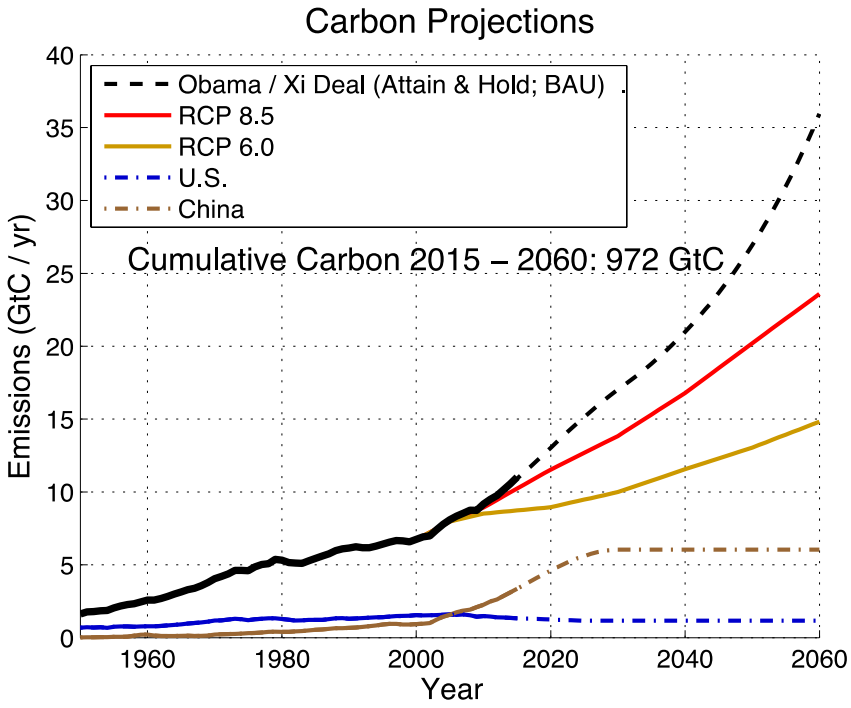

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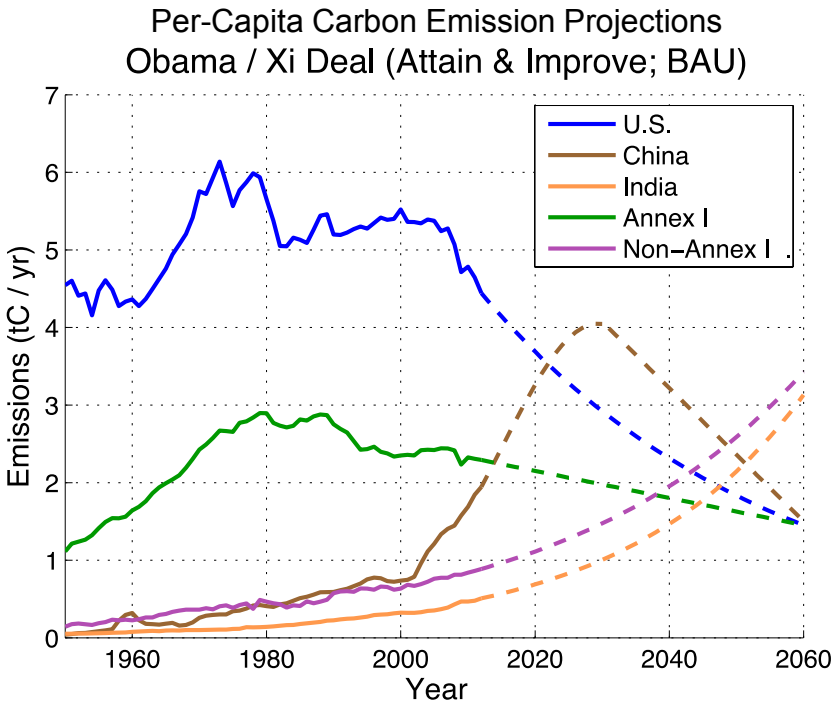

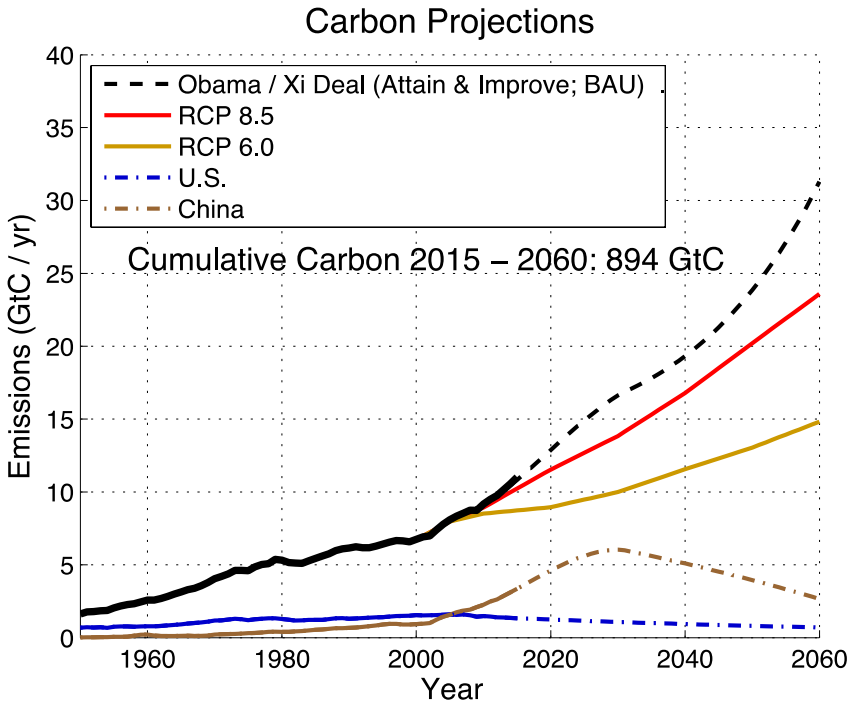

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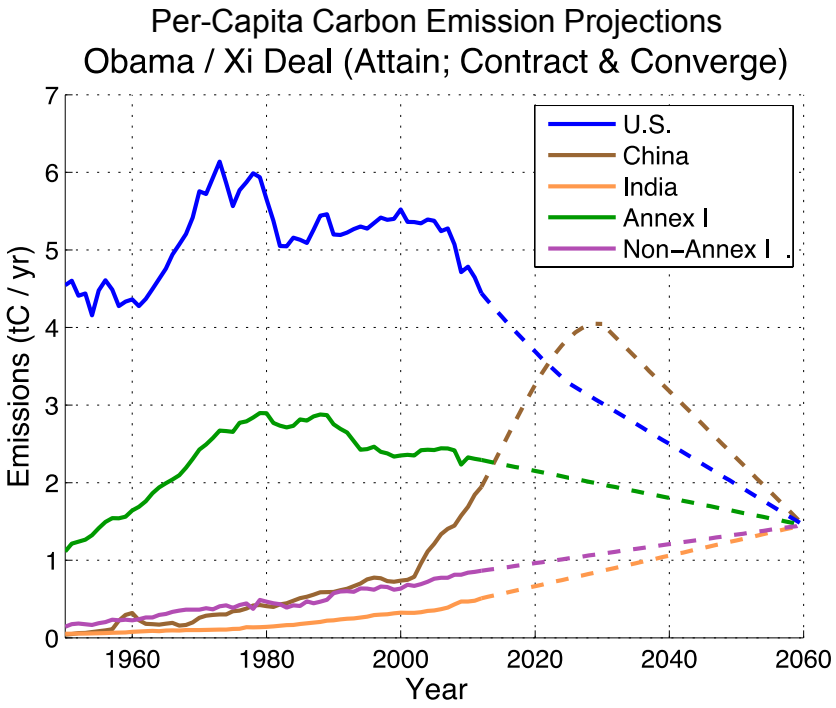

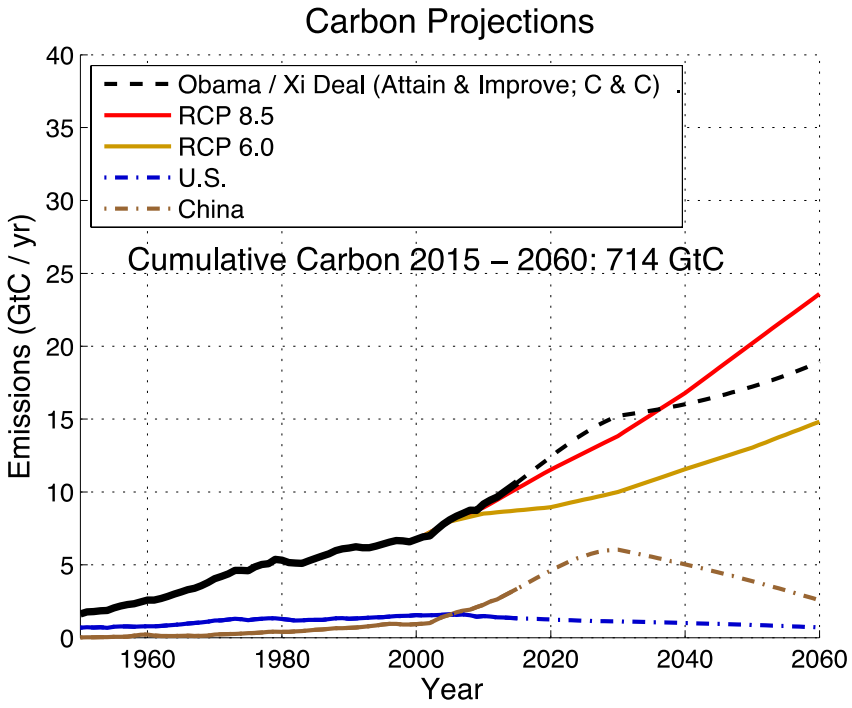

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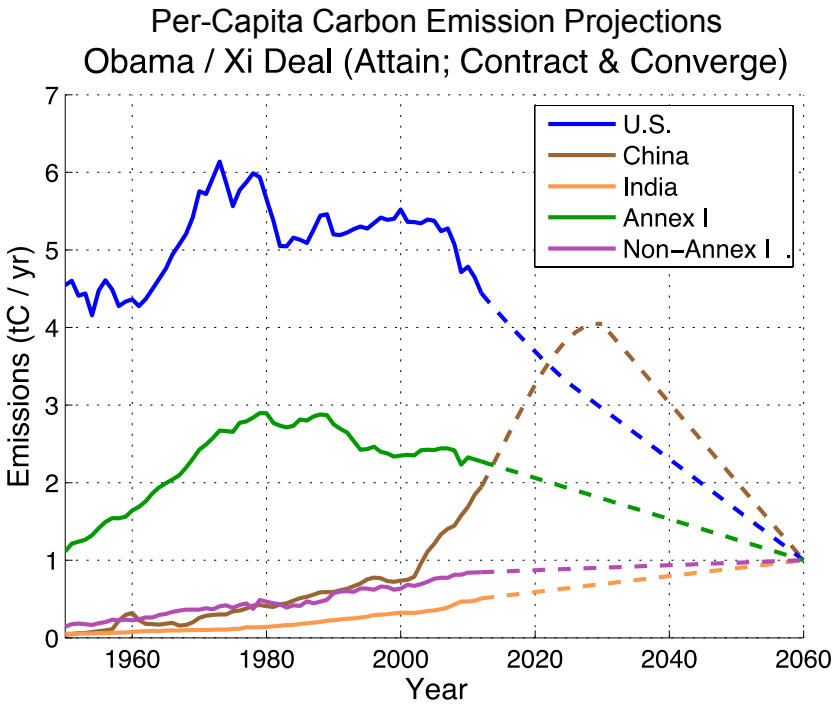
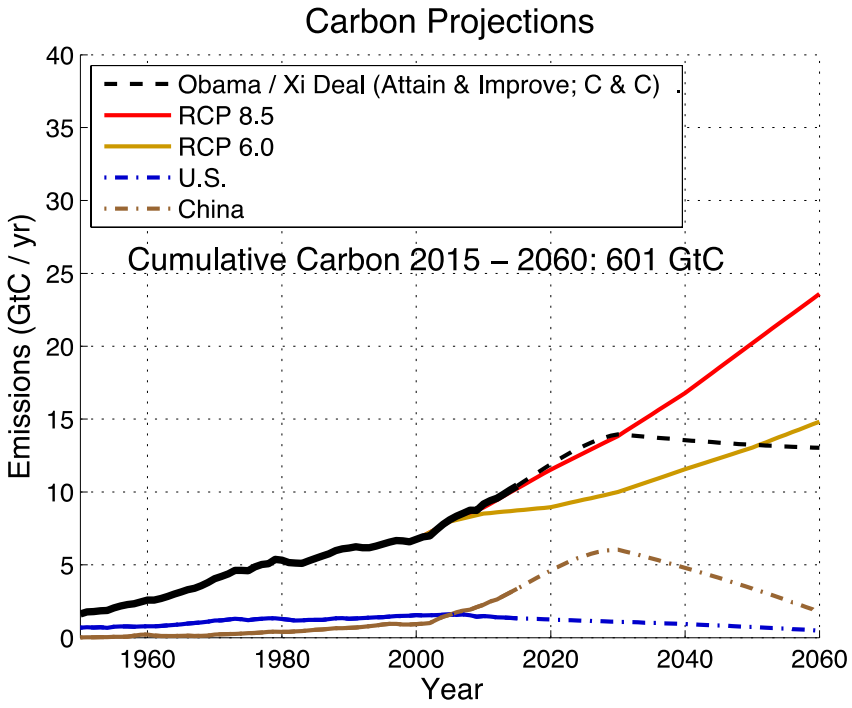
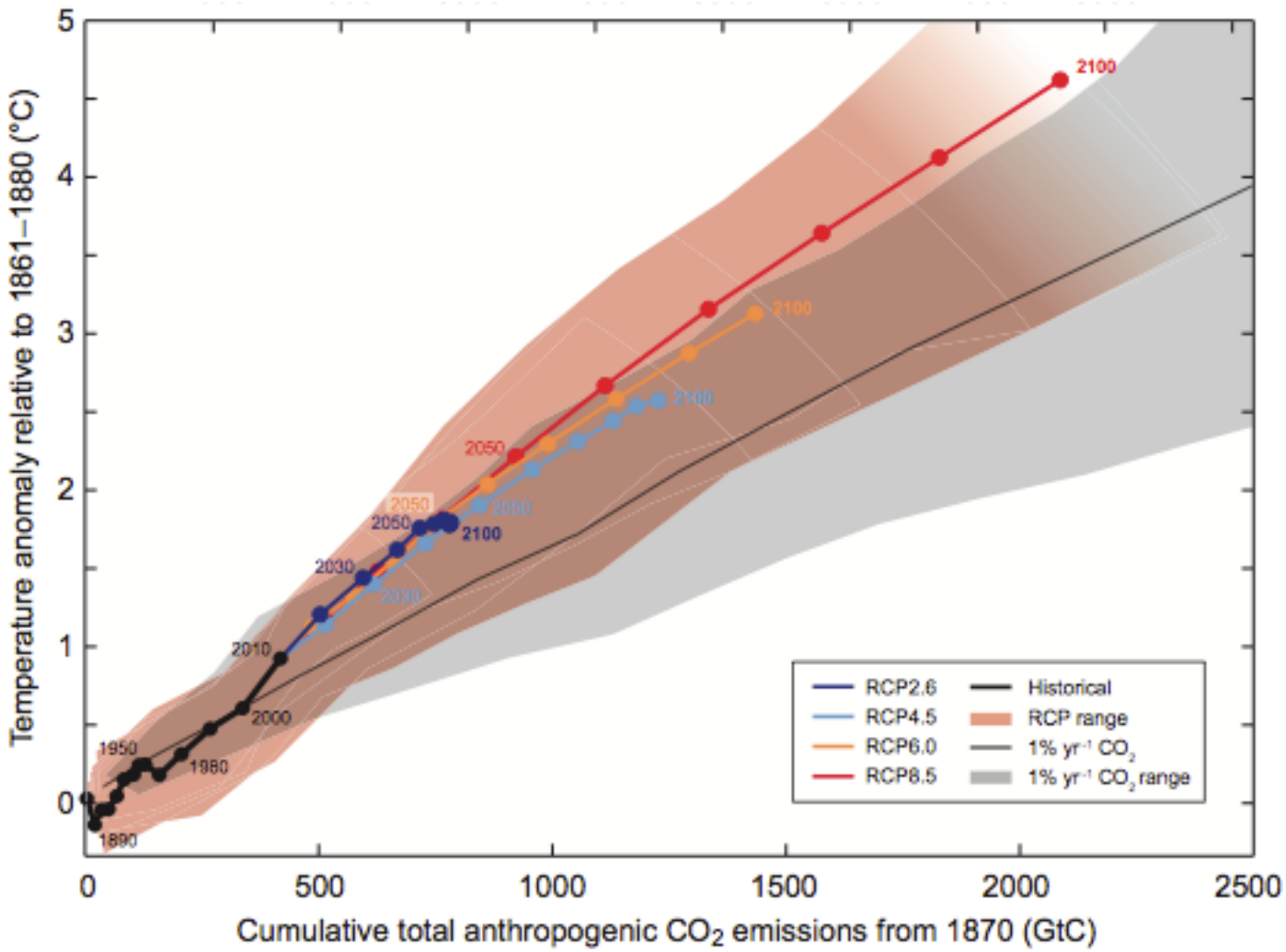




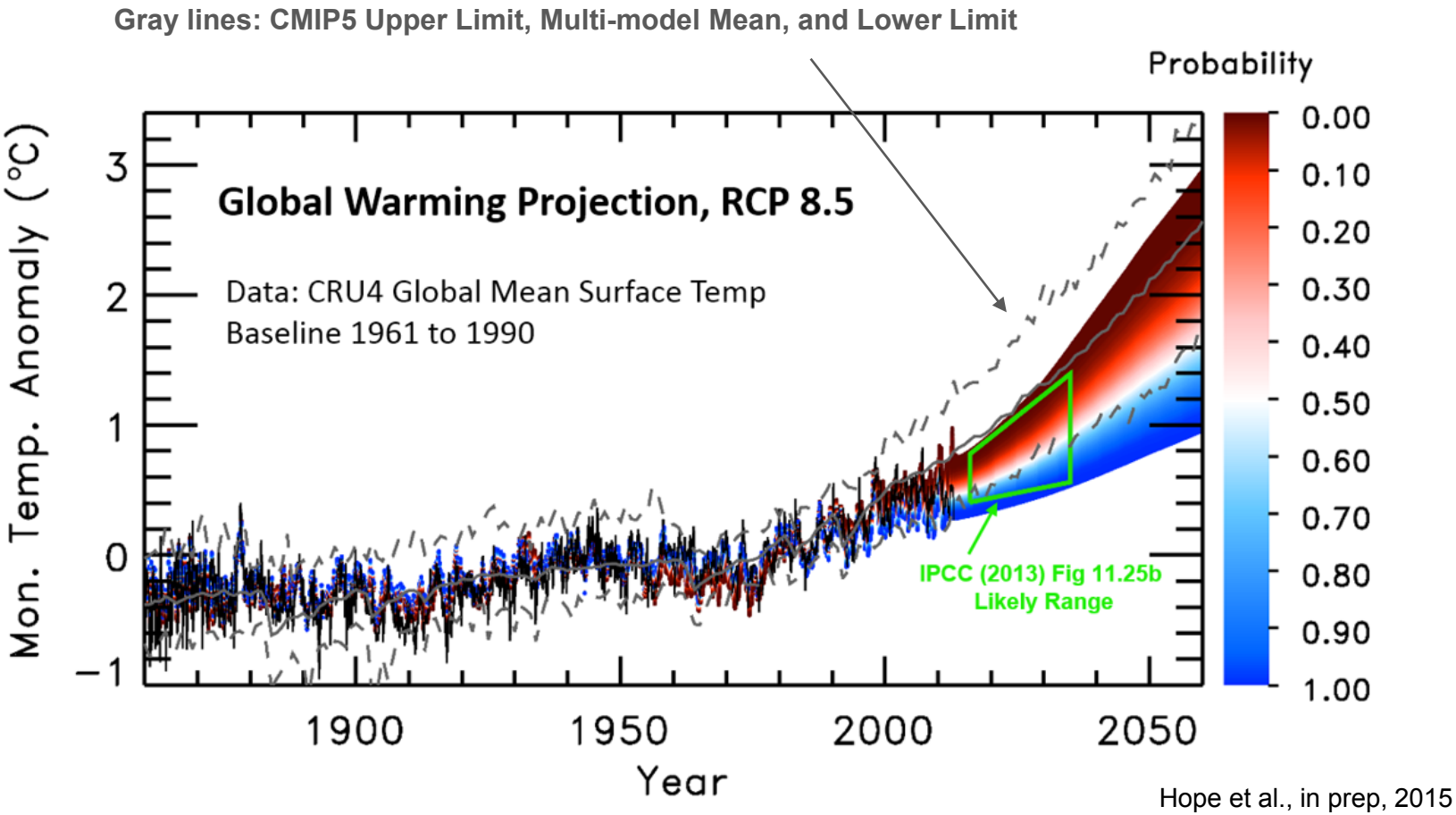
Tribett et al., in prep, 2015

IPCC (2013) Links Rise in GMST to Total Cumulative C Emissions



IPCC AR5 SPM.10

IPCC (2013) Links Rise in GMST to Total Cumulative C Emissions using models that likely warm too fast



Hope et al., in prep, 2015

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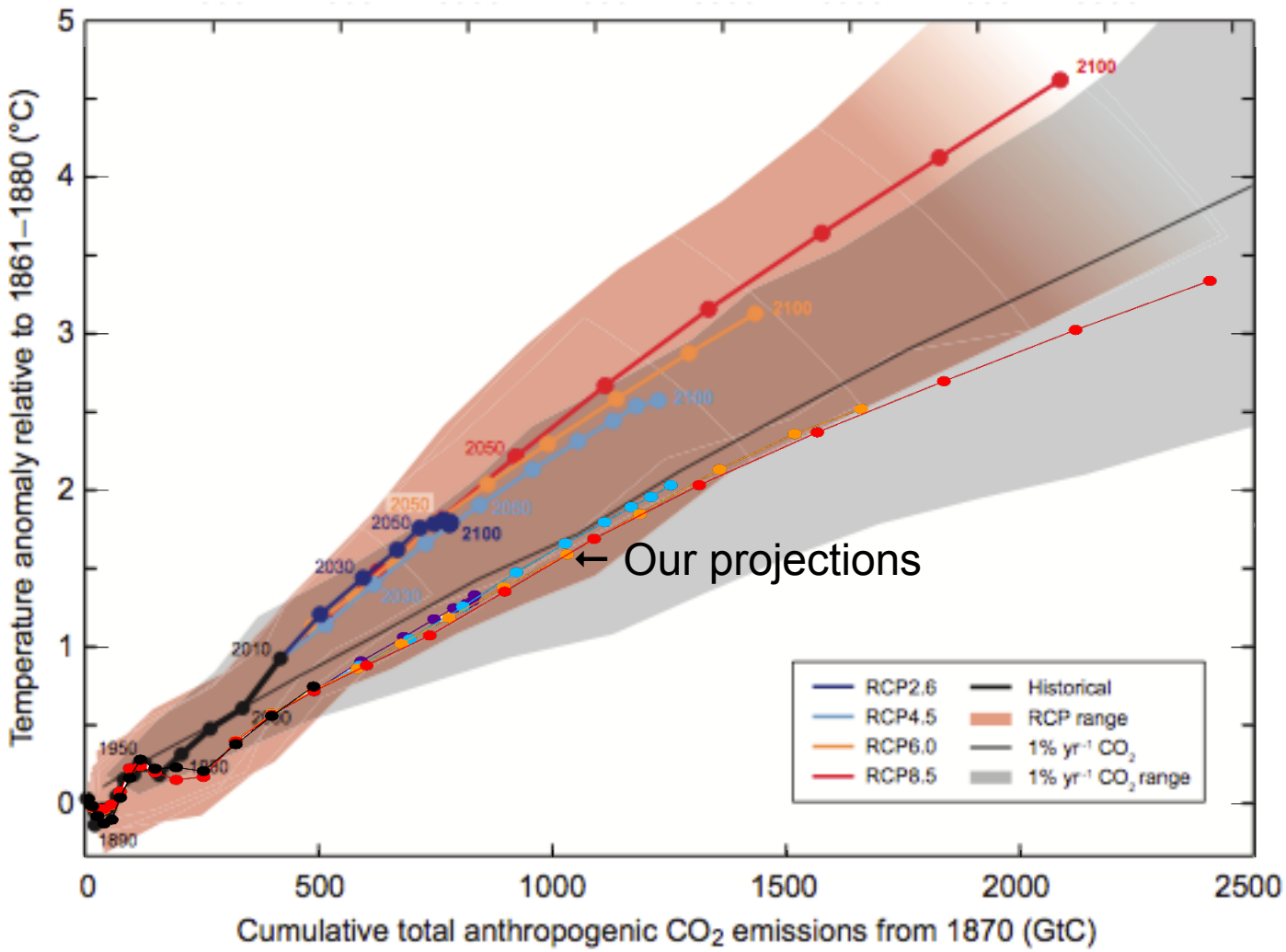

Hope et al., in prep, 2015

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