World Energy Needs and Fossil Fuel Reserves

AOSC 433/633 & CHEM 433

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Class Web Site: http://www.atmos.umd.edu/~rjs/class/spr2017

Topics for today:

- **World Energy Needs**
- **Fossil Fuel Reserves**
- **Need for Renewable Energy, Sooner Rather Than Later !**

Lay the ground work for rest of the semester

Lecture 17

18 April 2017

World Energy Consumption: Total

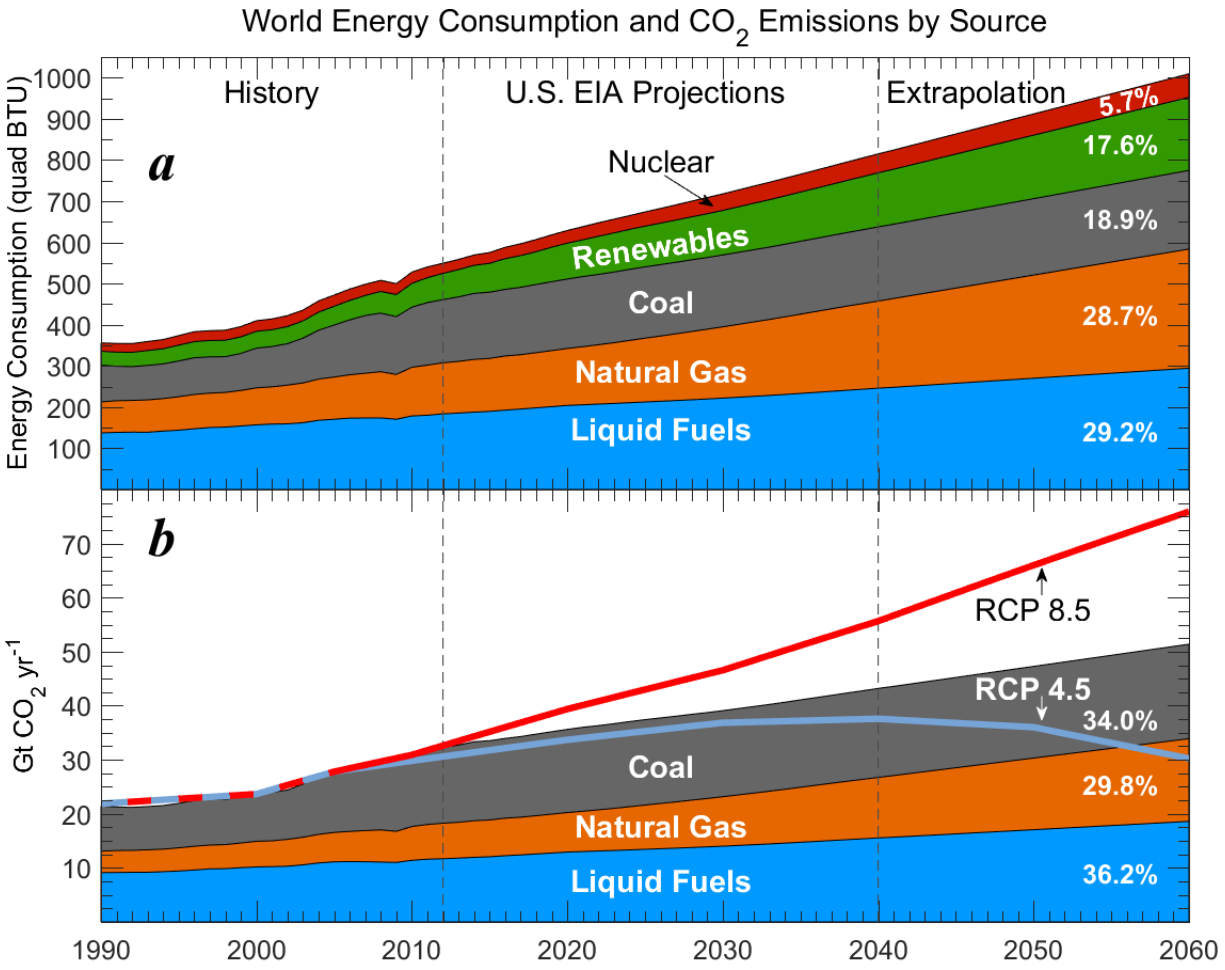
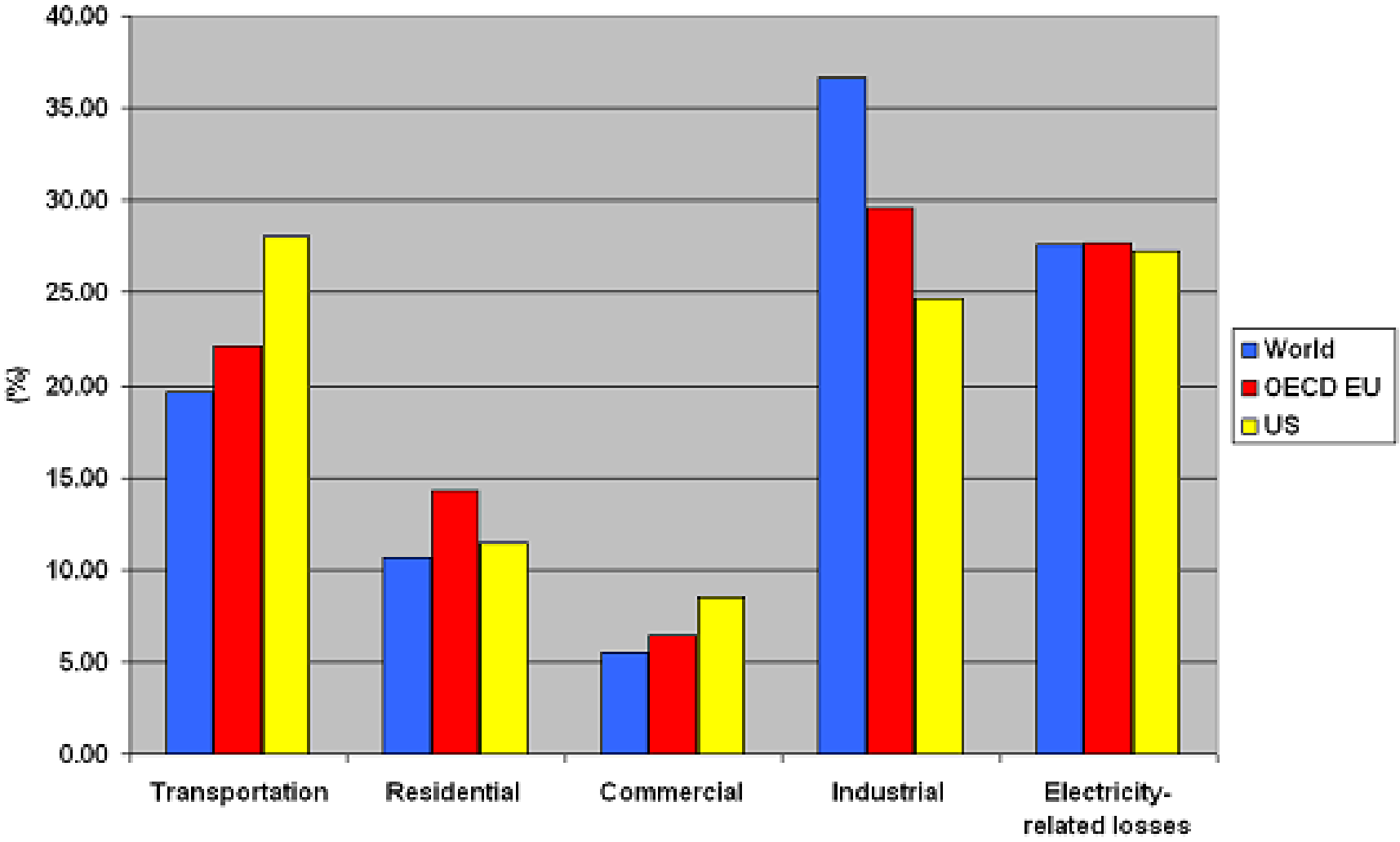


Figure 4.2 World energy consumption and CO_2 emissions

Paris Climate Agreement:
Beacon of Hope

BTU is a measure of heat, or energy.
1 BTU = 1055 joules

World Energy Consumption, By Sector



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)

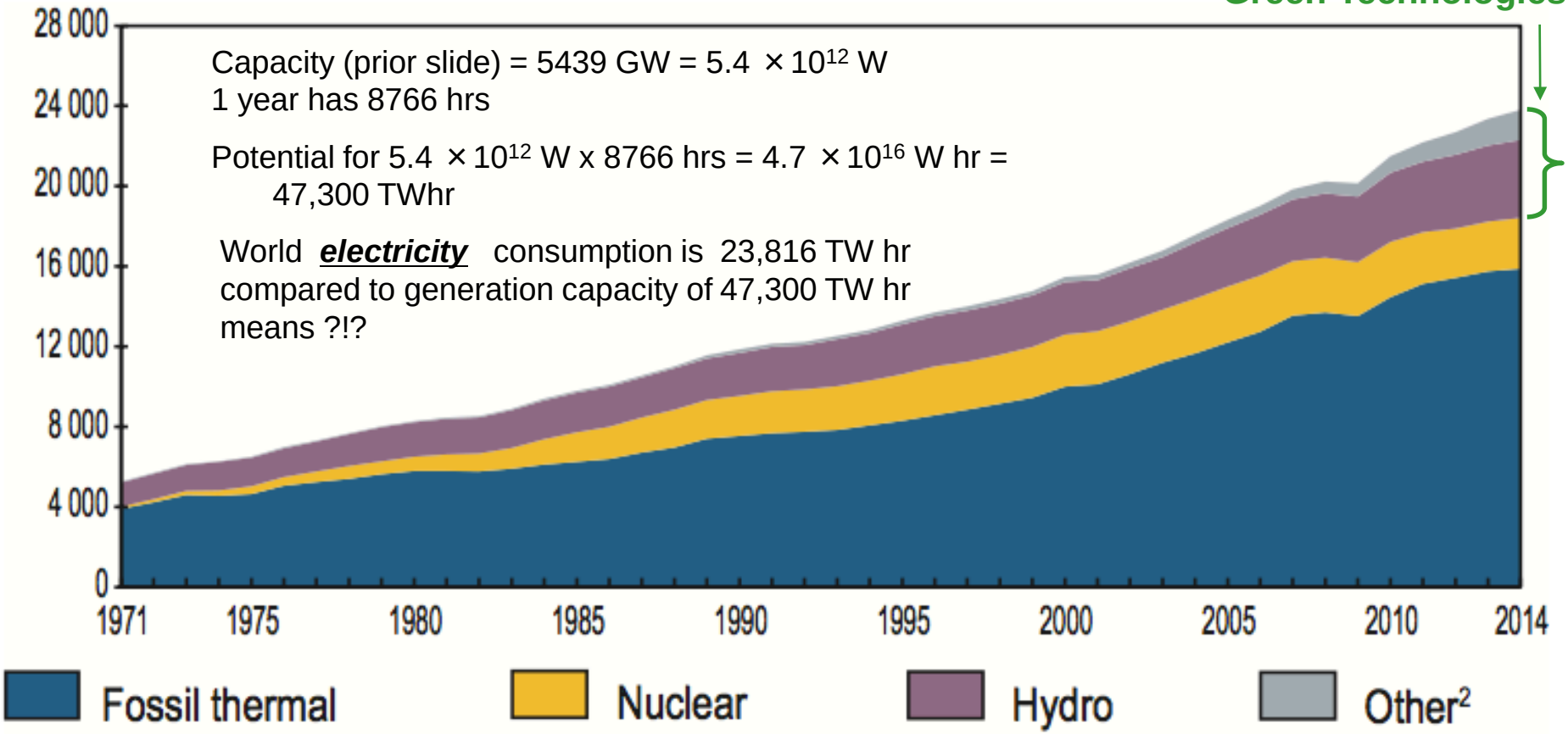
Total Source	GW (year 2012)
Coal	1,782
Natural Gas	1,423
Hydro-electric	979
Liquid Fossil Fuel	395
Nuclear	373
Wind	269
Biomass	113
Solar, Tidal	95
Geothermal	10
Total	5439

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

World ***Electricity Consumption***:

Energy (units: TW hr)

Green Technologies



Capacity (prior slide) = 5439 GW = 5.4 $\times 10^{12}$ W
1 year has 8766 hrs

Potential for 5.4 $\times 10^{12}$ W x 8766 hrs = 4.7 $\times 10^{16}$ W hr =
47,300 TWhr

World ***electricity*** consumption is 23,816 TW hr
compared to generation capacity of 47,300 TW hr
means ?!?

2. Includes geothermal, solar, wind, heat, etc.

Source: http://www.iea.org/publications/freepublications/publication/keyworld2016.pdf

Capacity

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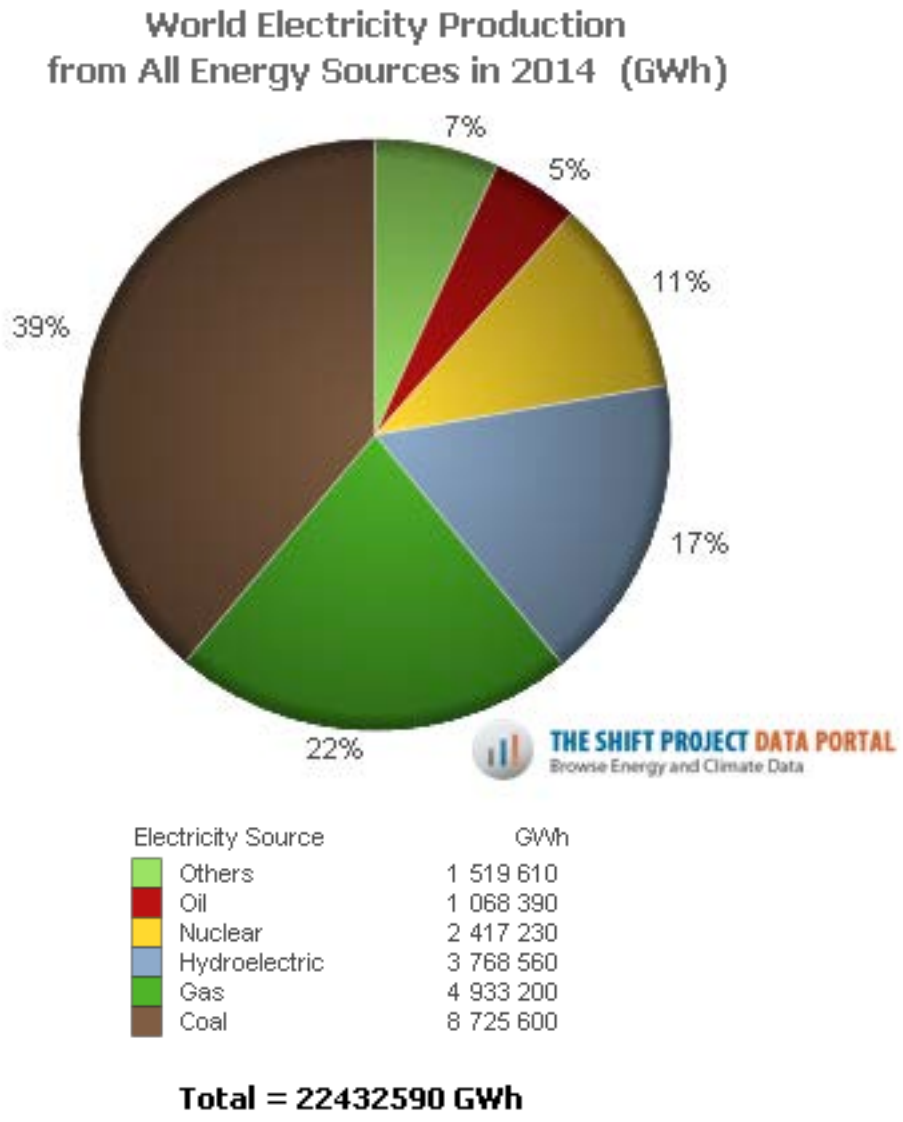
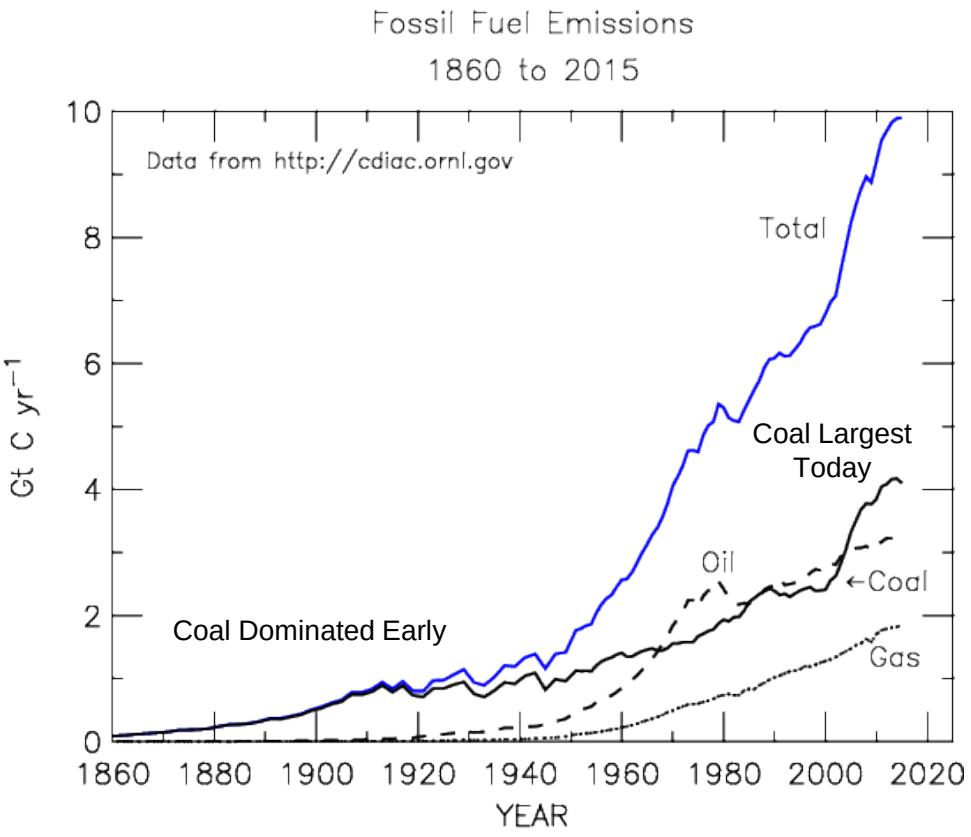


http://www.tsp-data-portal.org/Breakdown-of-Electricity-Generation-by-Energy-Source#tspQvChart

Fossil Fuel Emissions and Reserves



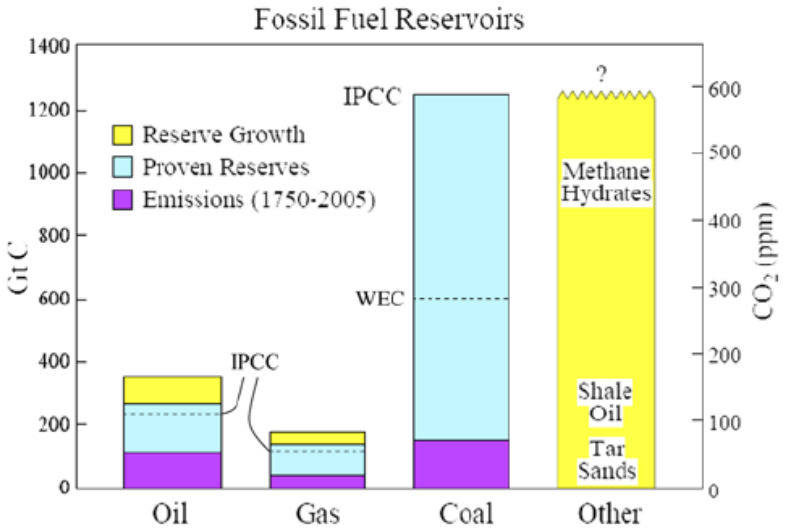


Figure 1. Fossil fuel-related estimates used in this study. Historical fossil fuel CO_2 emissions from the Carbon Dioxide Information Analysis Center [CDIAC; *Marland et al.*, 2006] and British Petroleum [*BP*, 2006]. Lower limits for current proven conventional reserve estimates for oil and gas from *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 !

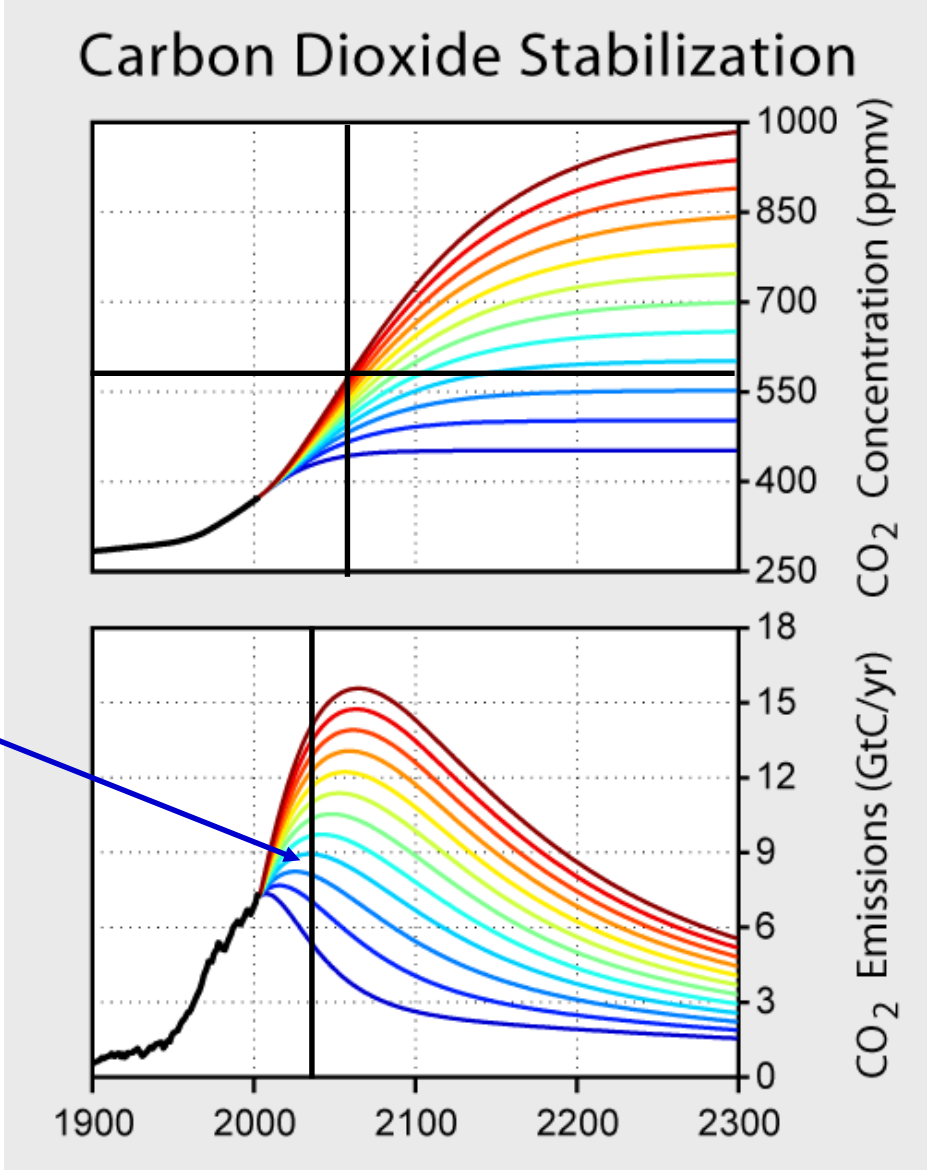
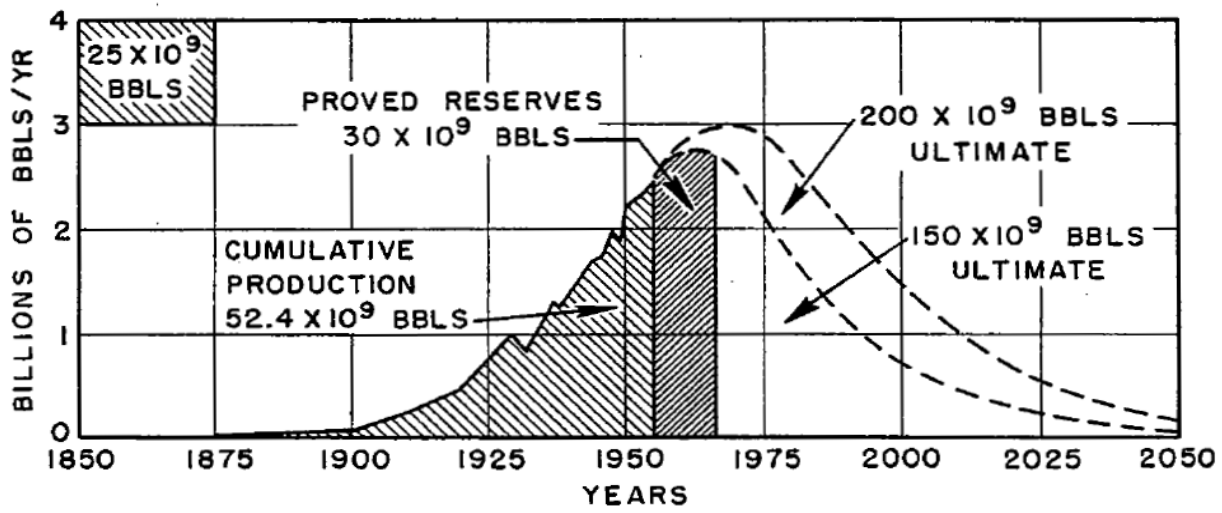
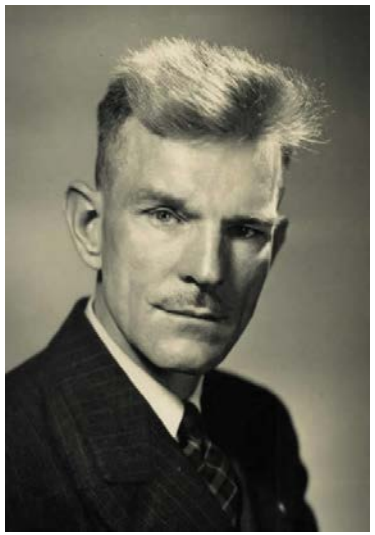


Image: "Global Warming Art" : http://www.globalwarmingart.com/wiki/Image:Carbon_Stabilization_Scenarios_png

Hubbert's Peak

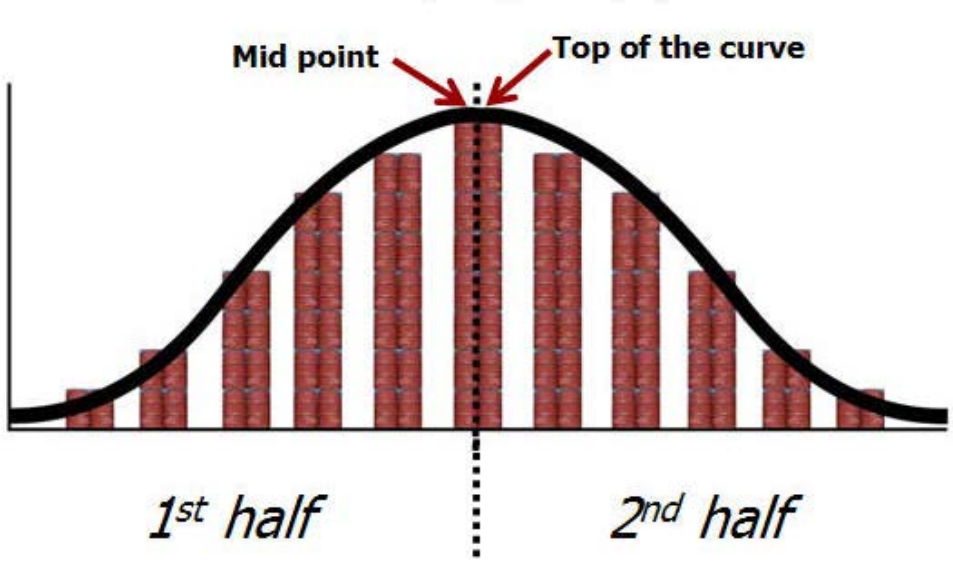


- **M. King Hubbert: Shell geophysicist**
- **1956 : presented a paper "Nuclear Energy and Fossil Fuels" that predicted US oil production would peak in 1970**
- **Paper was met with skepticism & ridicule**
- **But: *<u>this prediction was remarkably accurate</u>* !**



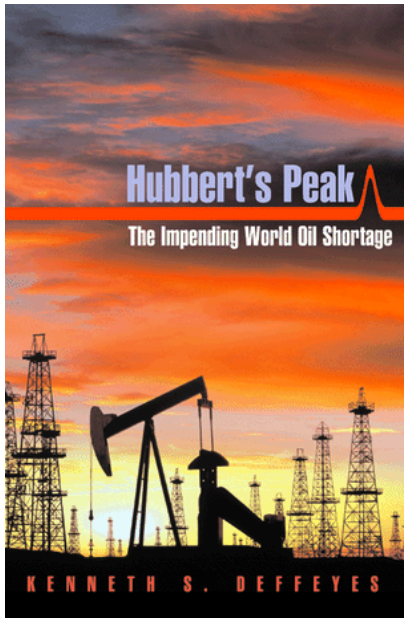
Mathematics of Resource Use

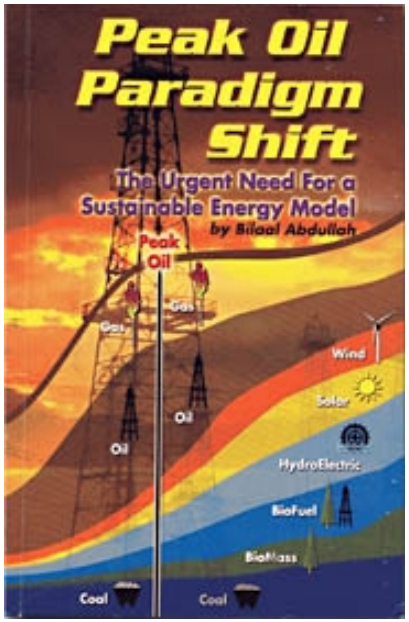
It is unlikely that an industry will go from full production of a resource to zero production the next year. It is reasonable to assume that production will follow an exponential growth while a resource is easy to find and relatively cheap to produce. As the resource becomes harder to find, prices rise,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

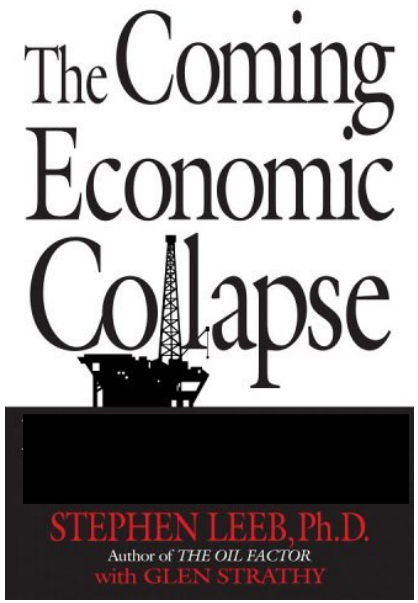


The area beneath this curve is the total amount of resource available.

Extensive Literature on This Subject

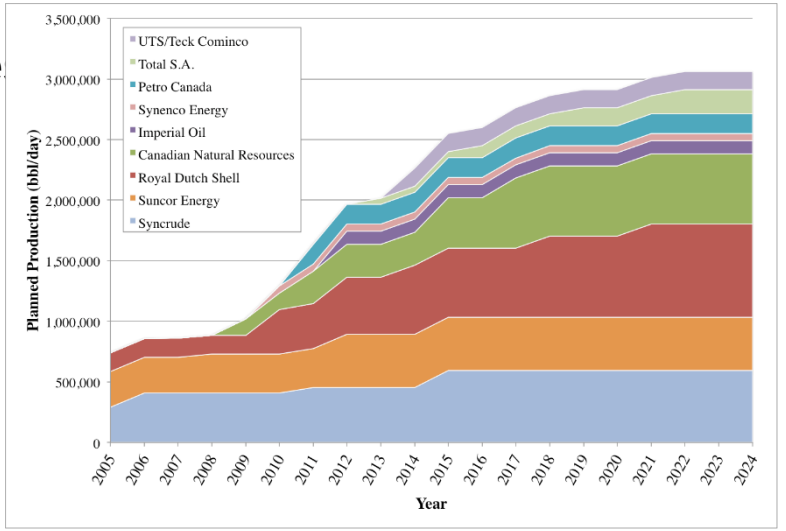






Canadian oil sands (tar sands)

- 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



See http://en.wikipedia.org/wiki/Tar_sands 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?

- Coal is a complex mixture of substances that can be approximated by the chemical formula . The elements come from prehistoric plant material.
- Coal may also contain, among other elements, copper, arsenic, lead, mercury, and uranium.
- Higher grades of coal, bituminous and anthracite, have been exposed to higher pressure and have less oxygen. Anthracite has less sulfur. **U.S. supply of anthracite is nearly exhausted.**
- The oxymoron “clean coal” means different things to different people

Future Use of Fossil Fuels

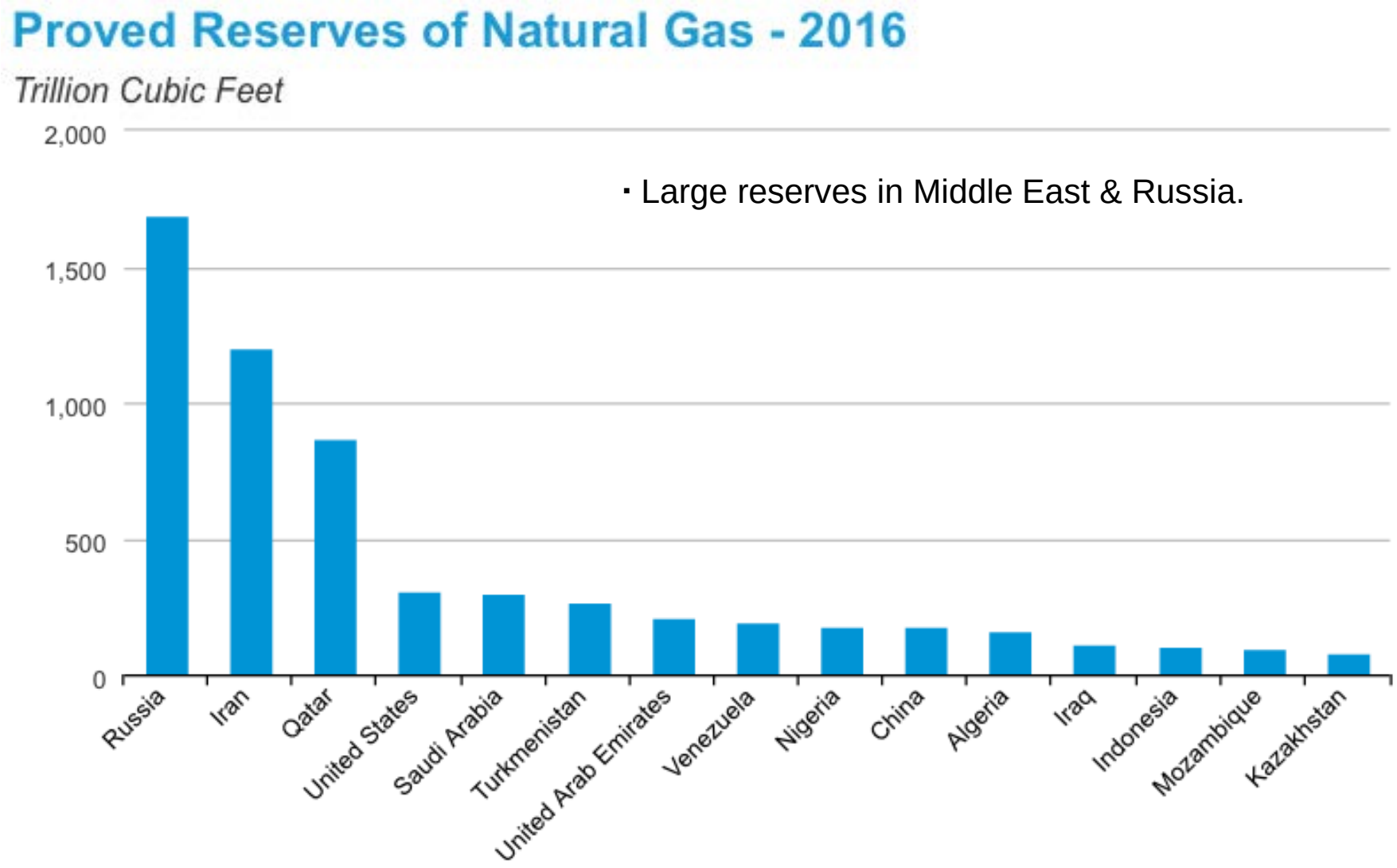
- If society decides to continue to reply on fossil fuels, we will become increasingly reliant on **coal** (in the short term) and **oil sands** (in the long term)

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

Fossil Fuel	GHG Output (pounds CO_2 per kWh)
Oil Sands	5.6
Coal	2.1
Oil	1.9
Gas	

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

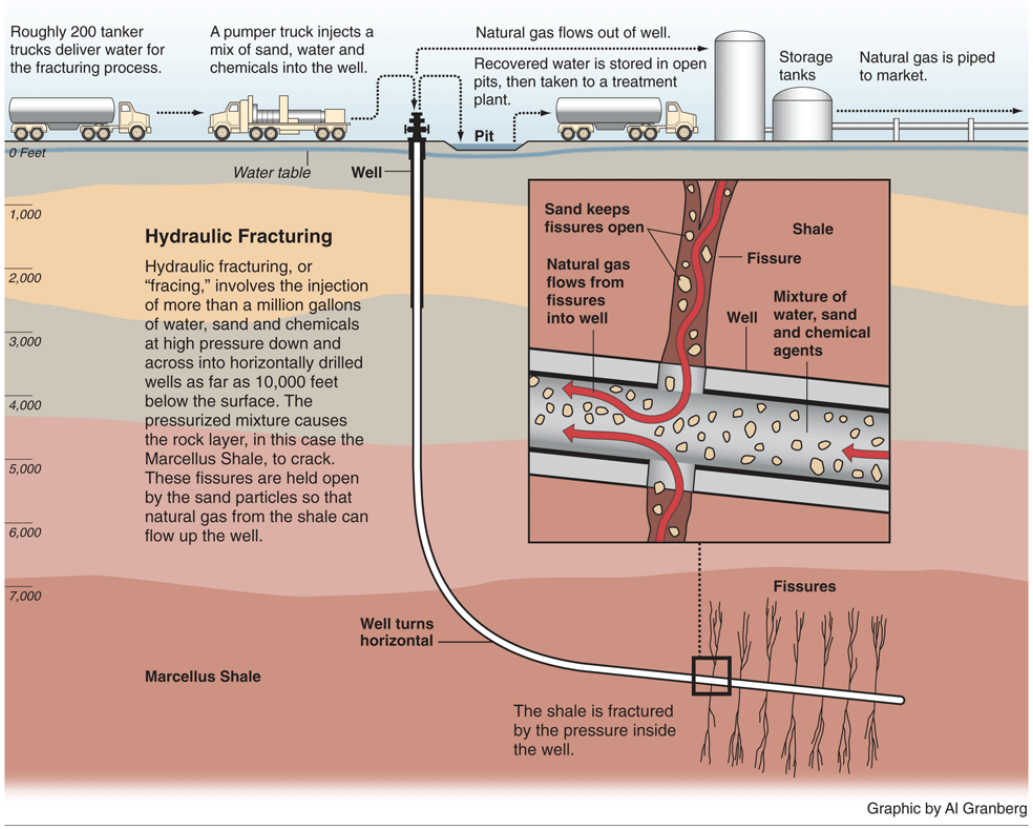
Natural Gas: Transition Fuel or Game Changer ?



- Large reserves in Middle East & Russia.

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

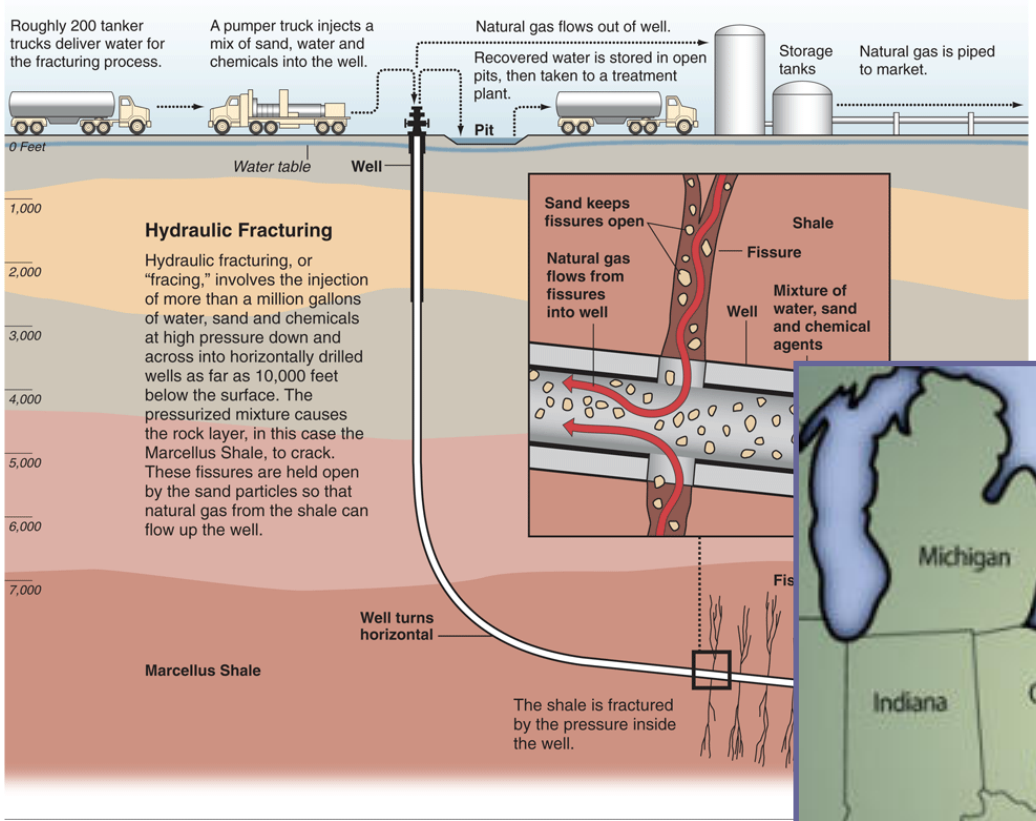
Natural Gas: Fracking



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

Image: http://www.propublica.org/images/articles/natural_gas/marcellus_hydraulic_graphic_090514.gif

Natural Gas: Fracking



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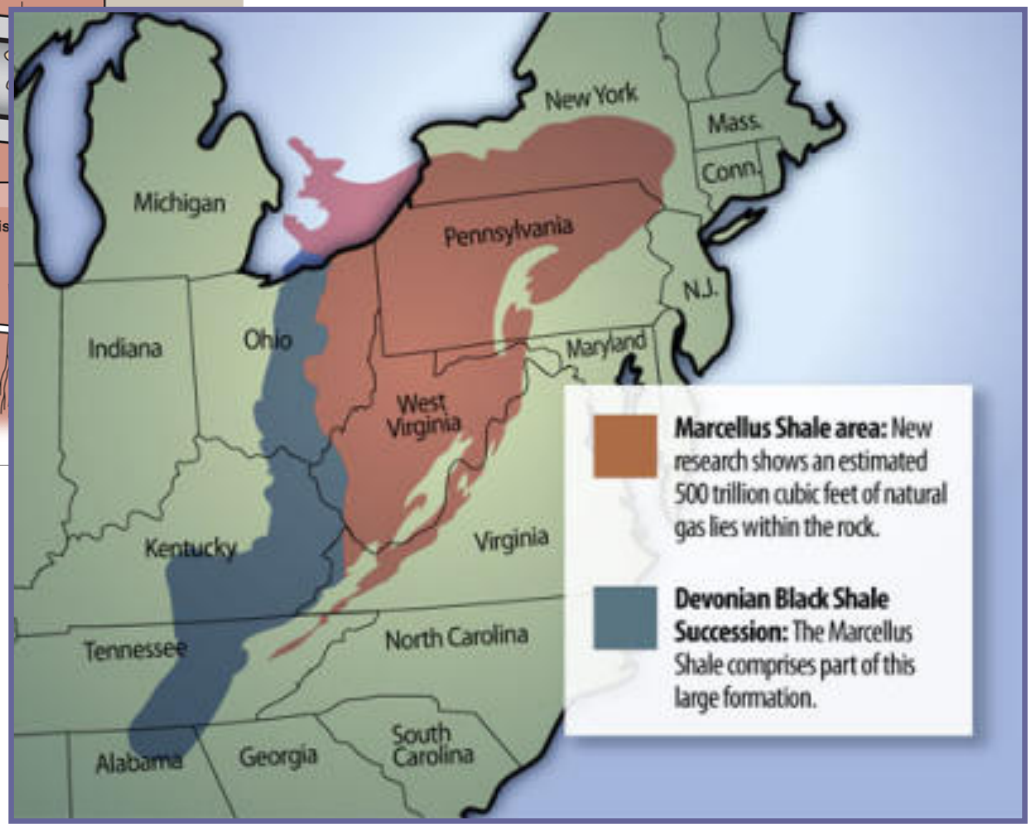


http://akrondave.files.wordpress.com/2011/01/marcellus-shale.jpg

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

Paris Climate Agreement:
Beacon of Hope

EM-GC Forecast

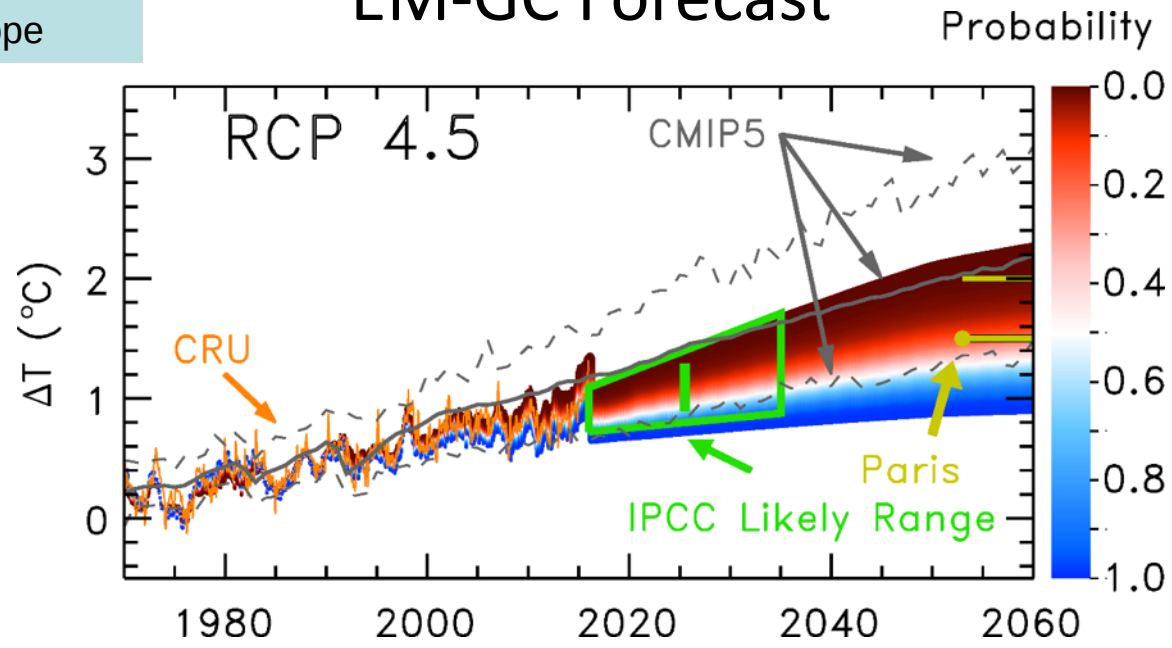


Figure 2.19

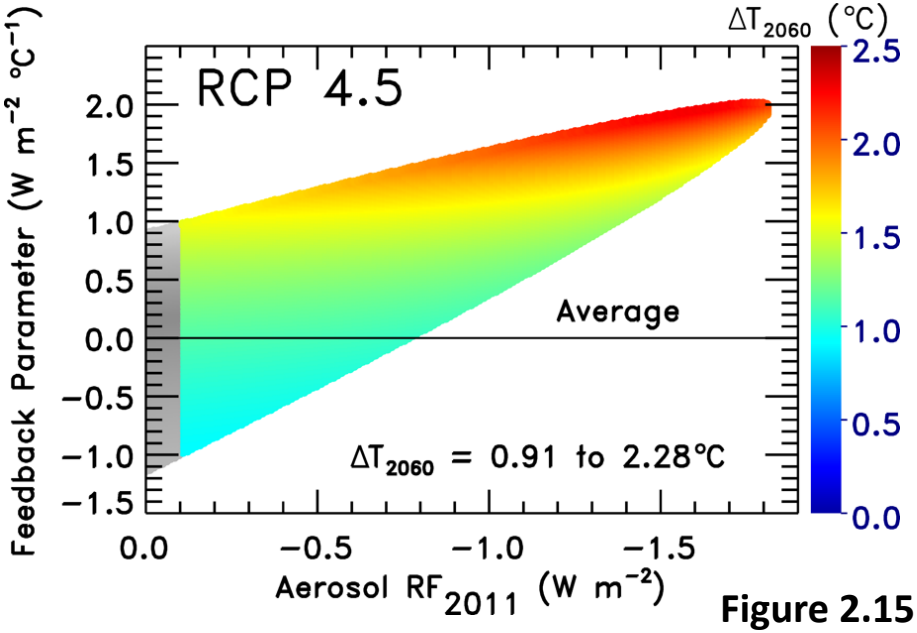


Figure 2.15

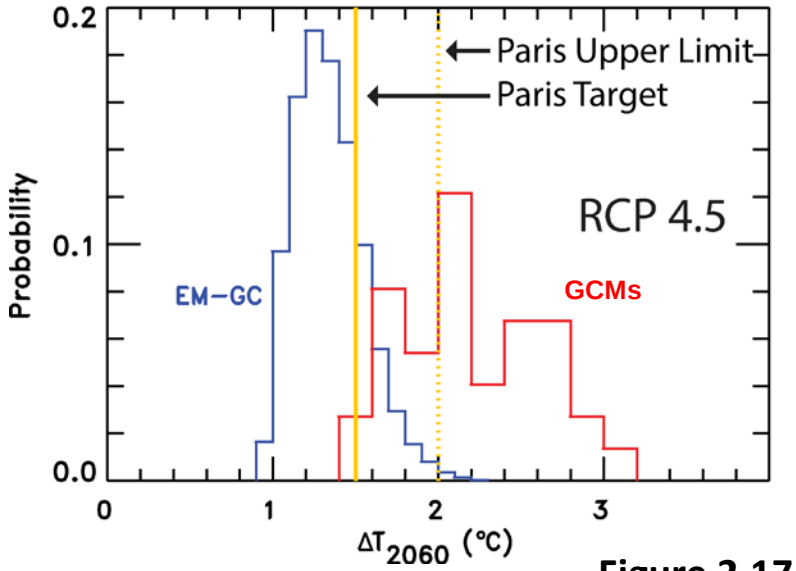
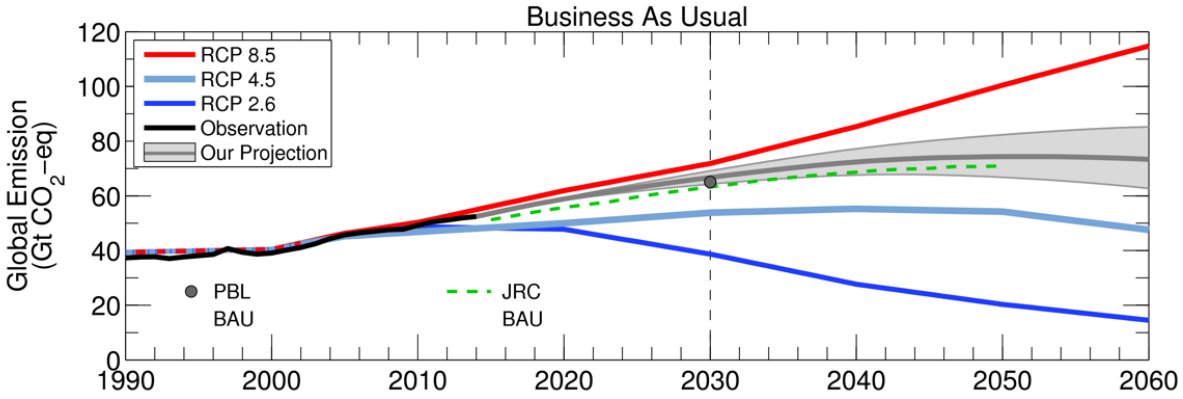
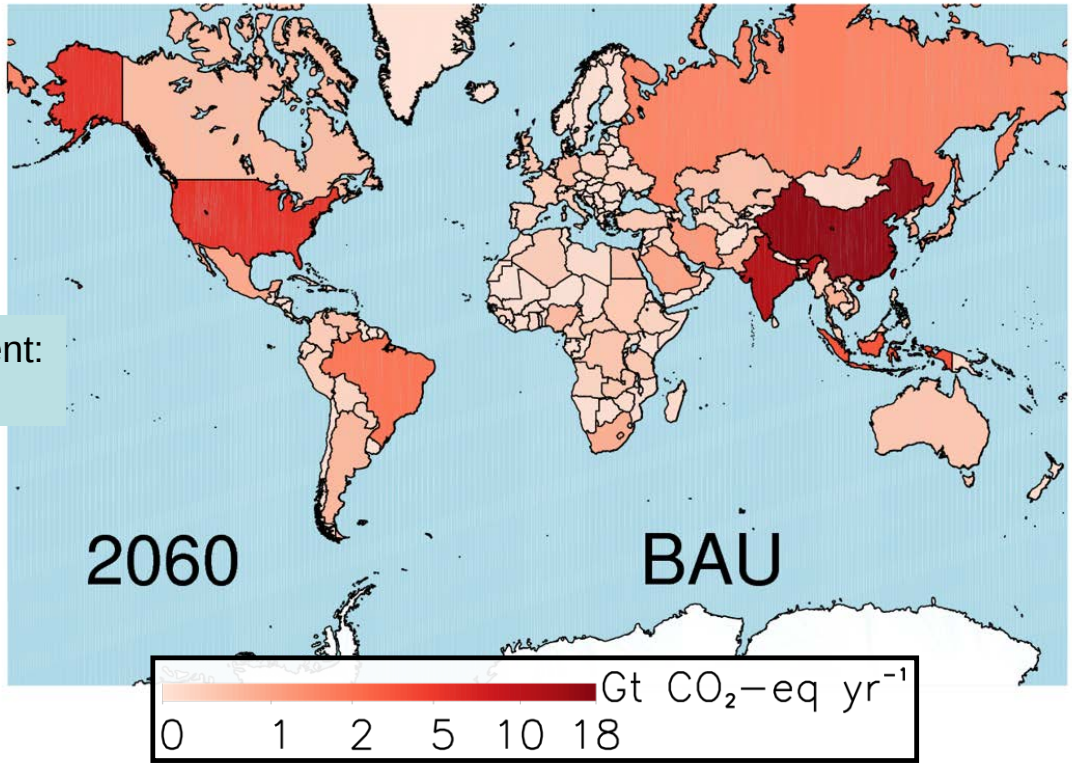


Figure 2.17



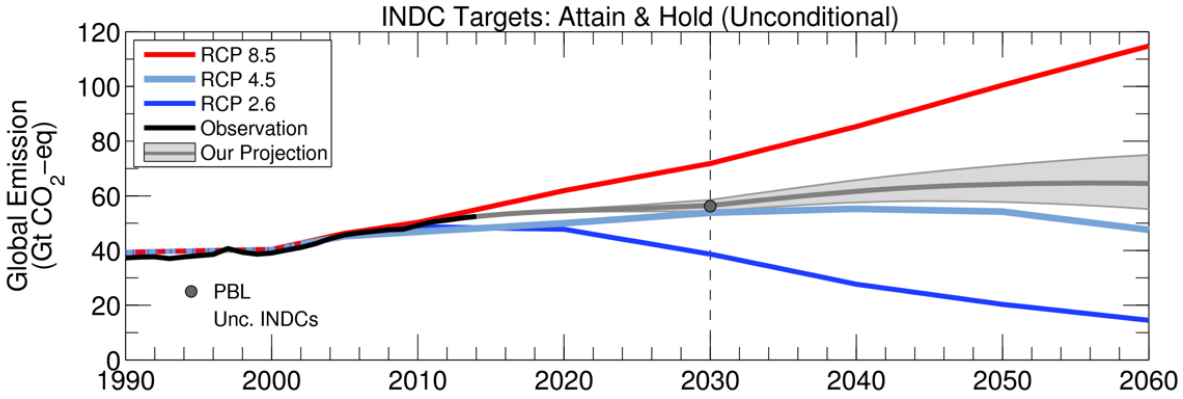


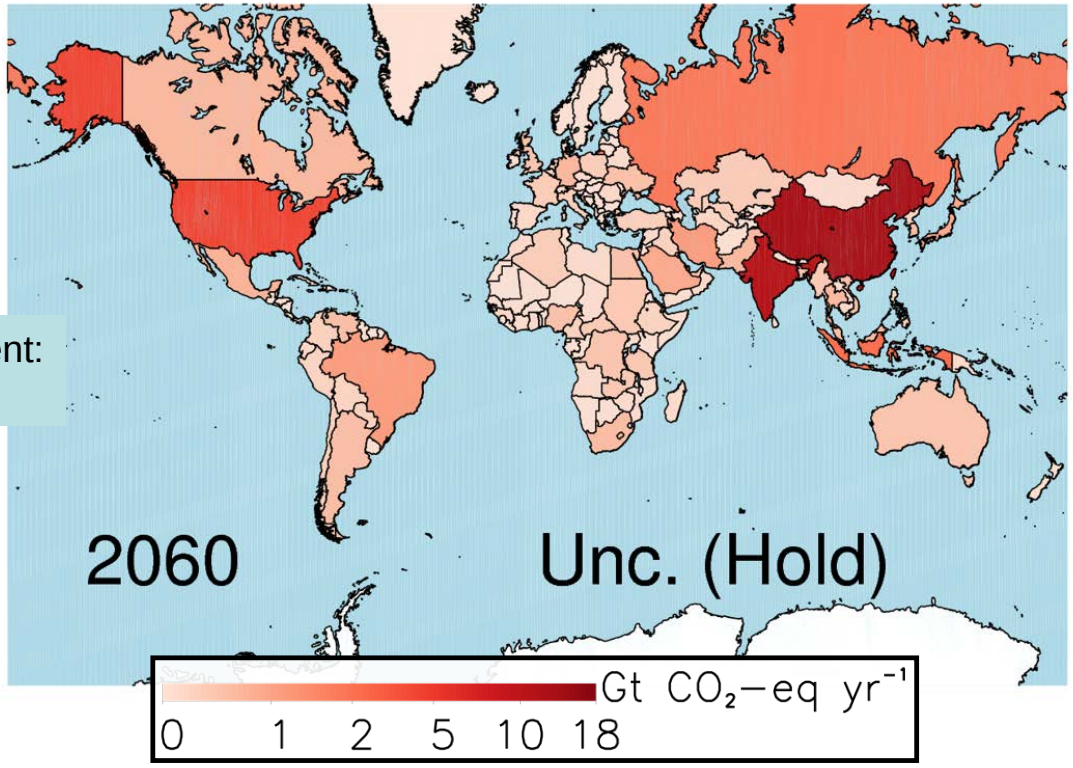
Paris Climate Agreement:
Beacon of Hope

Figure 3.8 & 3.13

BAU: Business as Usual
JRC: Joint Research Center of the European Commission
PBL: Planbureau voor de Leefomgeving, Netherlands

CO_2-eq: Considers emissions of CO_2, CH_4, & N_2O combined using IPCC (2013) GWPs on 100-yr horizon





Paris Climate Agreement:
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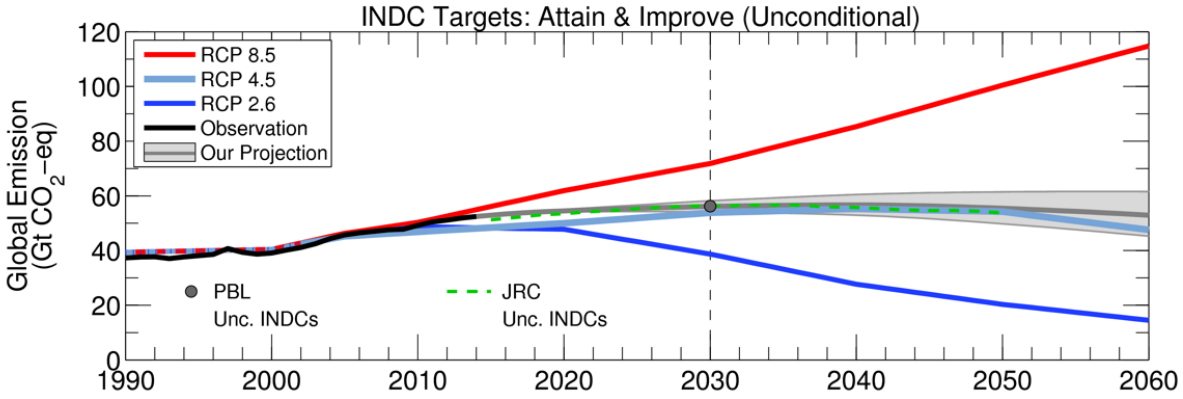

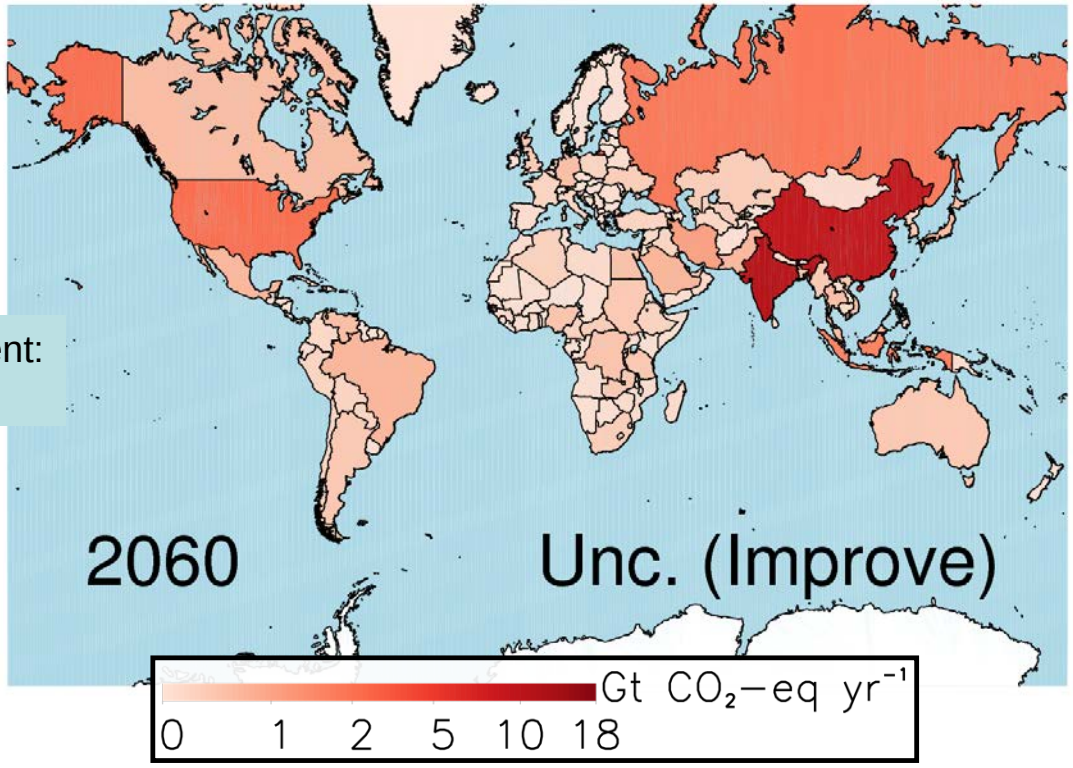

Paris Climate Agreement: Beacon of Hope

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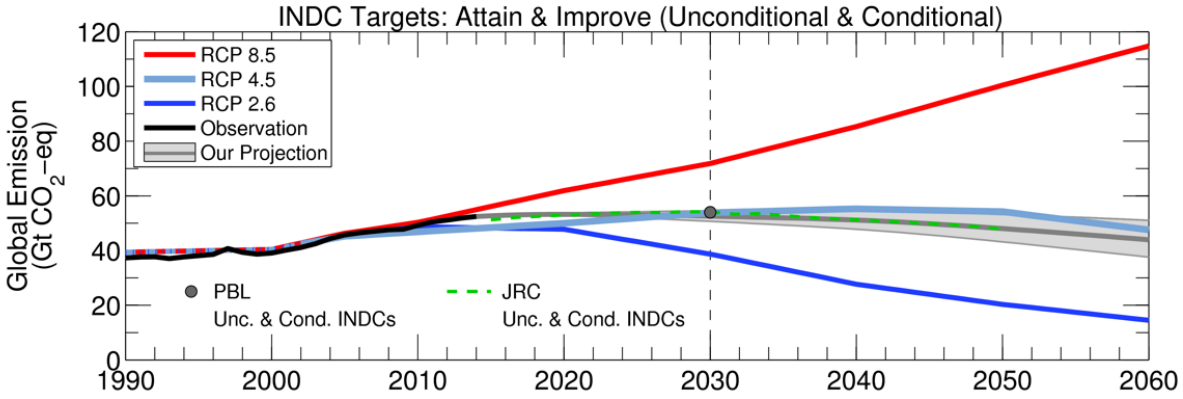

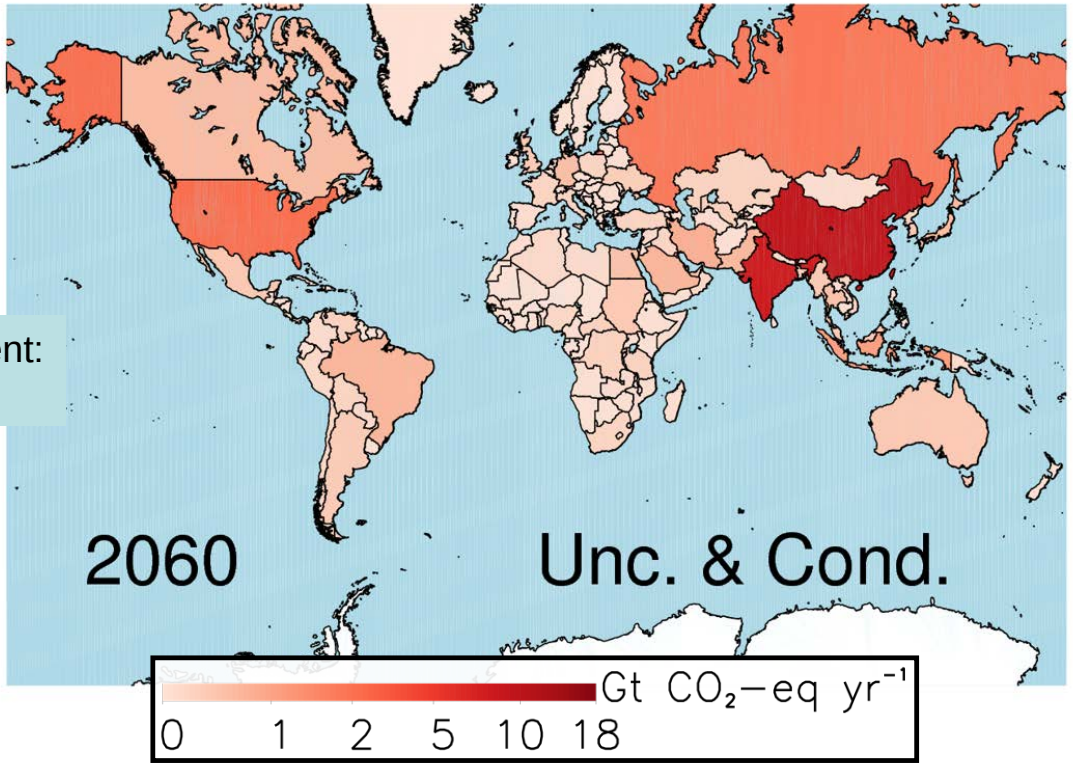

Paris Climate Agreement: Beacon of Hope

Figure 3.11 & 3.13

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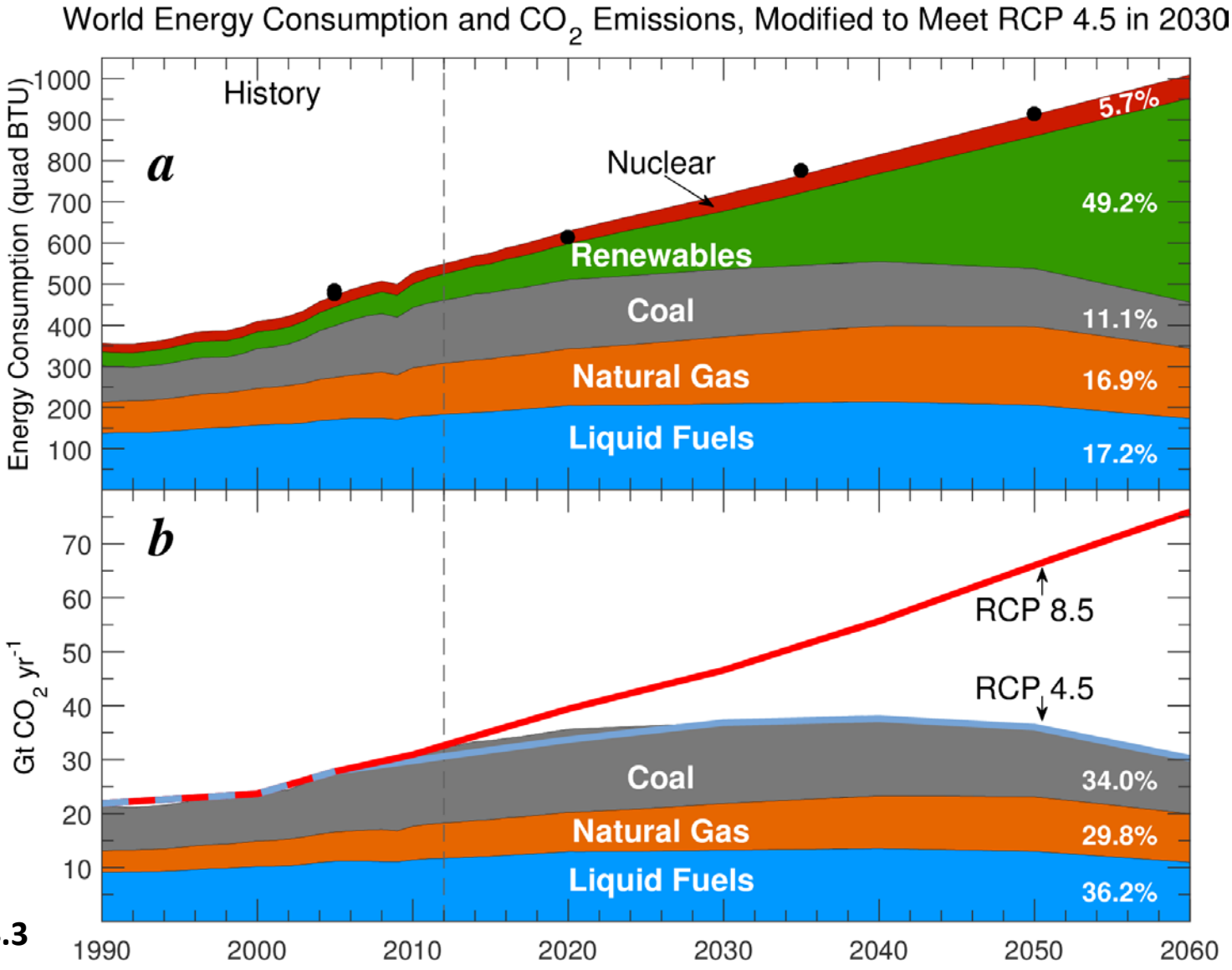

Figure 4.3

Achieving RCP 4.5 requires half of world energy to be supplied by sources that do not emit GHGs, by year 2060