# World Energy Needs and Fossil Fuel Reserves

## AOSC / CHEM 433 & AOSC 633

Ross Salawitch & Walt Tribett

**Class Web Site: http://www.atmos.umd.edu/~rjs/class/spr2019**

**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 2019**





## Energy and Power

Simple equation connects energy and power:

Energy = Power × Time

**Size** of a **power** plant is commonly measured in units of power:

kW (kilo: $10^3$ Watts): Home solar

MW (mega: $10^6$ Watts) Industrial

GW (giga: $10^9$ Watts): Massive Hydroelectric

TW (terra: $10^{12}$ Watts): Large Nation and/or Global

**Output** of a **power** plant in units of energy:

kWh (kilo: $10^3$ W hour)

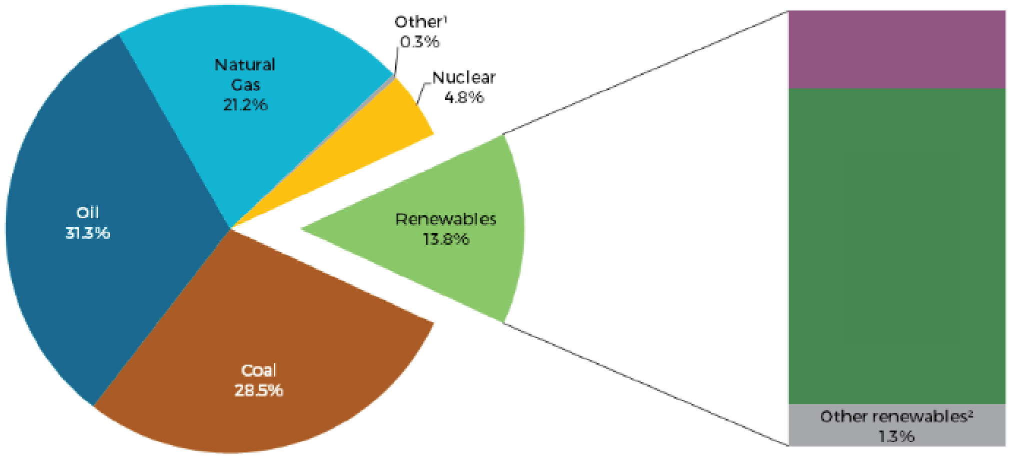
MWh (mega: $10^6$ W hour)

GWh (gig: $10^9$ W hour)

Capacity Factor: actual output of a power plant (energy) divided by maximum output if plant could run 24/7/365 at full capacity

# World Energy Supply: units of Energy

Figure 1: 2014 fuel shares in world total primary energy supply



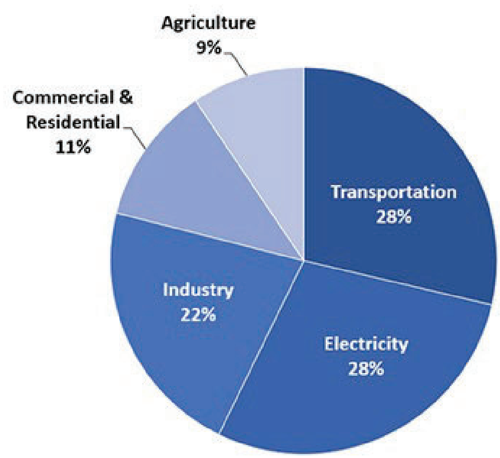

In 2014, world obtained
~80% of its **energy**
from combustion of fossil fuels

https://www.iea.org/newsroom/news/2016/july/renewable-energy-continuing-to-increase-market-share.html




# Major Contributors: Electricity Generation, Transportation, and Industrial Uses

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2016

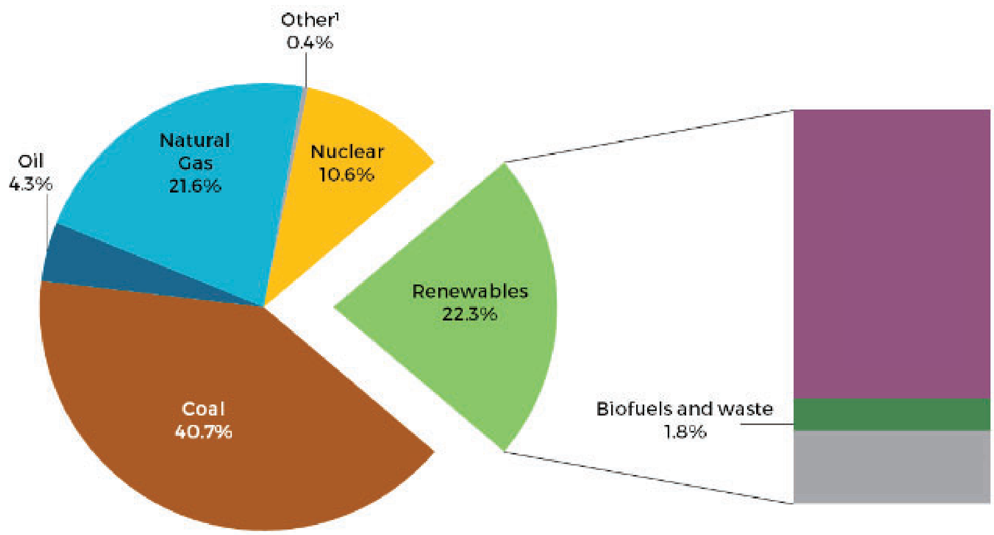



Total Emissions in 2016 = 6,511 Million Metric Tons of $CO_2$ equivalent

https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

# World Electricity Supply: units of Energy

Figure 4: Fuel shares in world electricity production in 2014




In 2014, world obtained
40.7% of its **electricity** from coal and 22.3% from renewables
Electricity constitutes ~38% of world energy

https://www.iea.org/newsroom/news/2016/july/renewable-energy-continuing-to-increase-market-share.html





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

Power (Energy/Time)

| Total Source | GW (year 2014) |
|---|---|
| Coal | 2,149.3 |
| Natural Gas | 1,515.8 |
| Hydro-electric | 1034.1 |
| Wind | 374.5 |
| Liquid Fossil Fuel | 389.3 |
| Nuclear | 376.6 |
| Solar | 175.2 |
| Other Renewable (Biomass) | 243.5 |
| Geothermal | 11.1 |
| Total | 6269.4 |

Source: https://www.eia.gov/outlooks/archive/ieo17/ieo_tables.php

In 2014, **35.3%** of global electricity generating capacity did not release prodigious GHGs to the atmosphere
(29.3% of this 35.3% involves hydro, wind, solar, biomass, and geothermal)

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

## Power (Energy/Time)

| Total Source | GW (year 2018) |
|---|---|
| Coal | 2,167.0 |
| Natural Gas | 1,768.8 |
| Hydro-electric | 1139.5 |
| Wind | 524.3 |
| Liquid Fossil Fuel | 380.7 |
| Nuclear | 373.9 |
| Solar | 352.4 |
| Other Renewable (Biomass) | 290.3 |
| Geothermal | 18.6 |
| Total | 7015.5 |

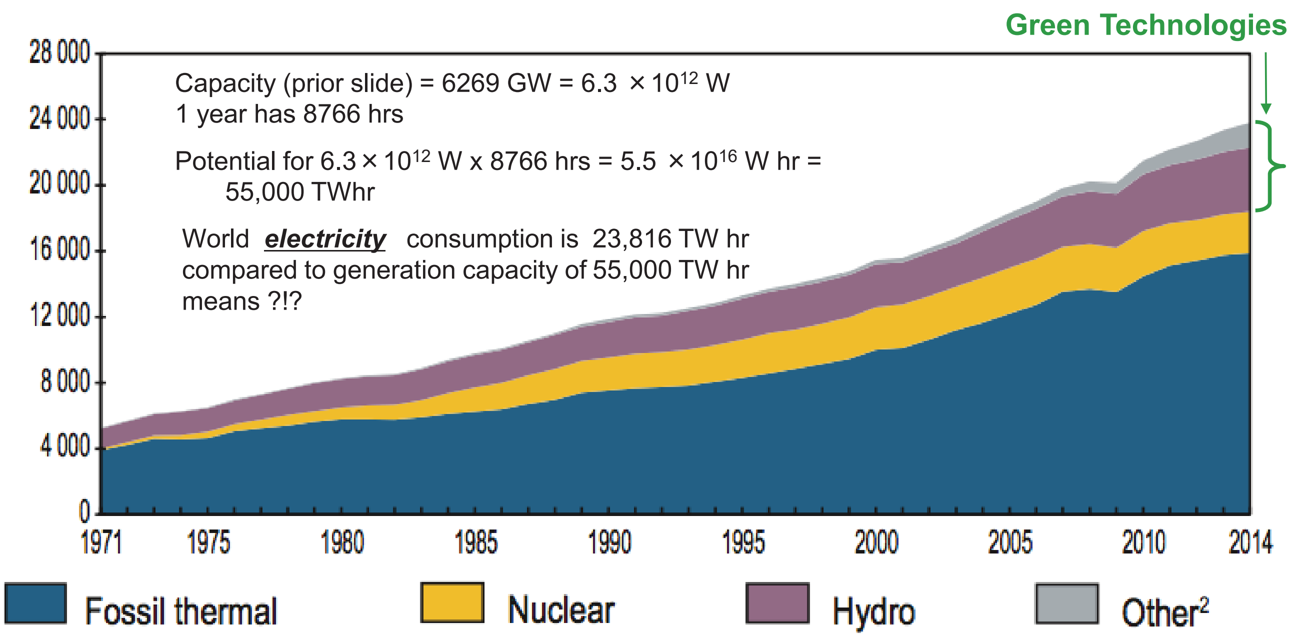
Source: https://www.eia.gov/outlooks/archive/ieo17/ieo_tables.php

In 2018, **38.4%** of global electricity generating capacity does not release prodigious GHGs to the atmosphere
(33.1% of this 38.4% involves hydro, wind, solar, biomass, and geothermal)



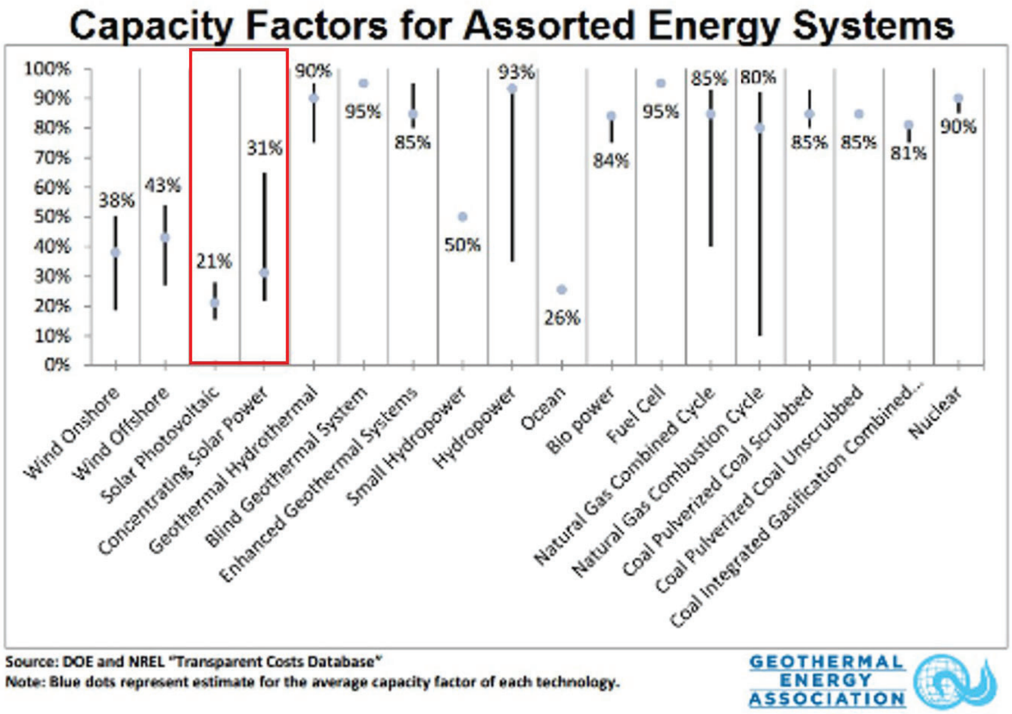

# World ***Electricity Consumption***:

## Energy (units: TW hr)




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

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



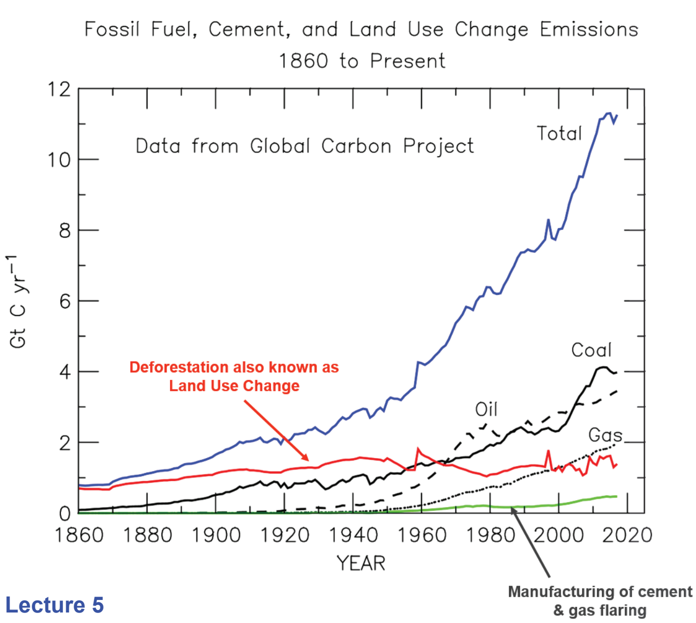

http://www.lightevolution.co.uk/blog/geothermal-visual-capacity-factors-for-assorted-energy-systems/

**Capacity Factor: actual output of a power plant (energy) divided by maximum output if plant could run 24/7/365 at full capacity**





# Fossil Fuel Emissions and Reserves




**Lecture 5**

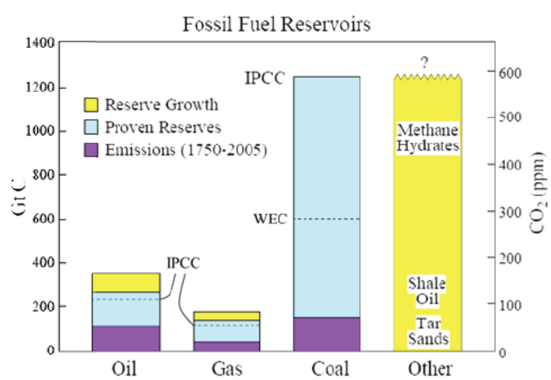
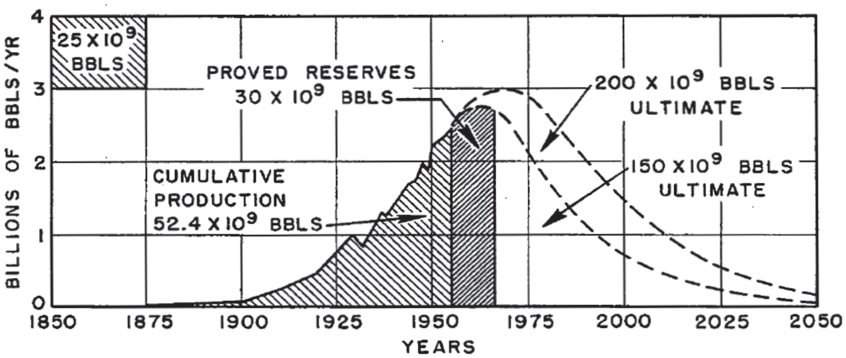


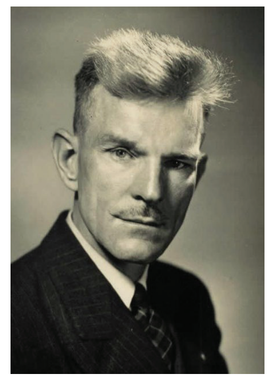

**Figure 1.** Fossil fuel-related estimates used in this study. Historical fossil fuel $CO_2$ emissions from the Carbon Dioxide Information Analysis Center [CDIAC; *Marland et al.*, 2006] and British Petroleum [*BP*, 2006]. Lower limits for current proven conventional reserve estimates for oil and gas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

# 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: *this prediction was remarkably accurate* !**

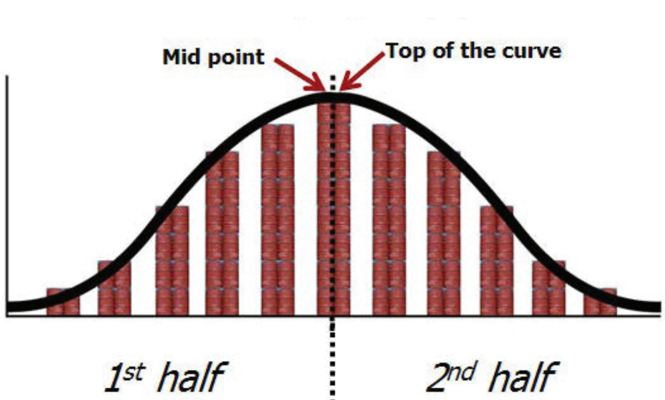






# Mathematics of Resource Use

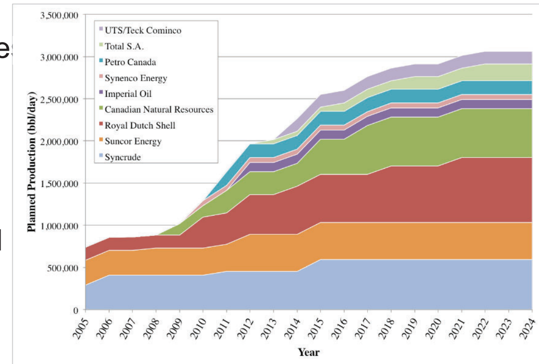
It is unlikely that an industry will go from full production of a resource to zero production the next year. It is reasonable to assume that production will follow an exponential growth while a resource is easy to find and relatively cheap to produce. As the resource becomes harder to find, prices rise,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




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

# 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 $\mathbf{C_{135}H_{96}O_9NS}$. 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?





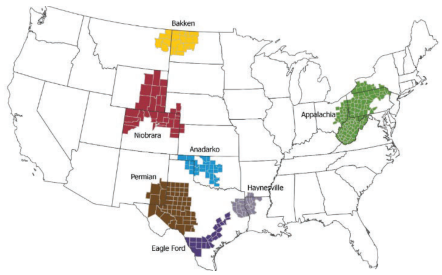
## Fossil Fuel Economics for $1000

**The "U.S. vehicle fleet pumped 1.3 billion tons of $CO_2$ into the atmosphere in 2008, and $820 million in capital was exported *every day* for the oil needed to do so" (Krupp and Horn, 2009)**

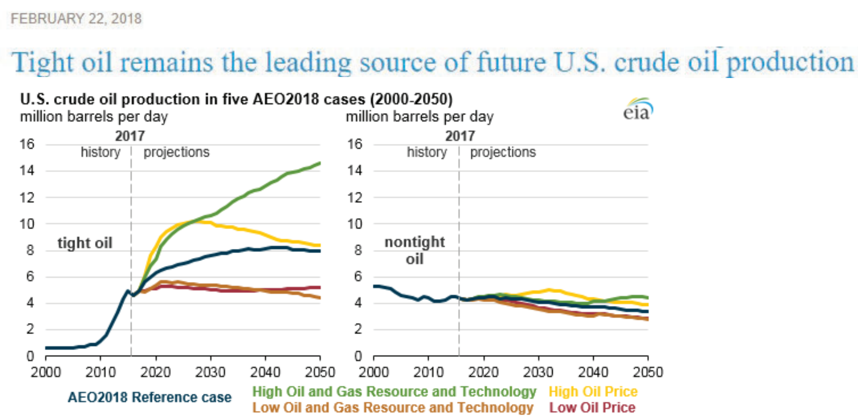
**In 2018, how much did the U.S. export in capital each day for the oil (i.e., gasoline) needed for our vehicle fleet?**

# Fossil Fuel Economics for $1000

**U.S. has greatly expanded production of so-called tight oil https://en.wikipedia.org/wiki/Tight_oil from the Permian, Bakken, and Eagle Ford deposits since 2008:**




https://www.cnbc.com/2018/06/13/permian-will-soon-pump-enough-oil-to-be-opecs-2nd-biggest-producer.html



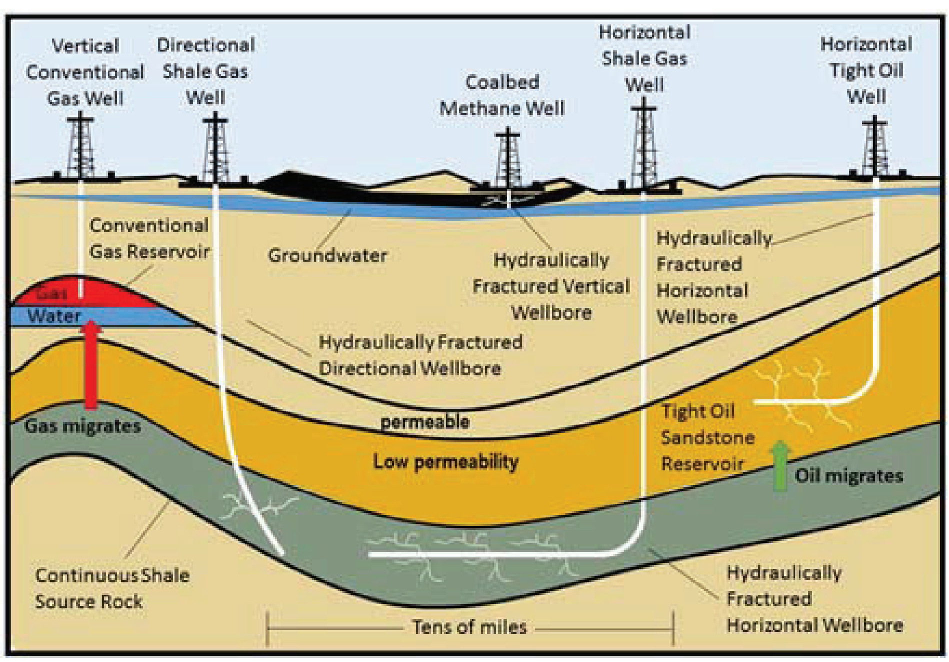

https://www.eia.gov/todayinenergy/detail.php?id=35052





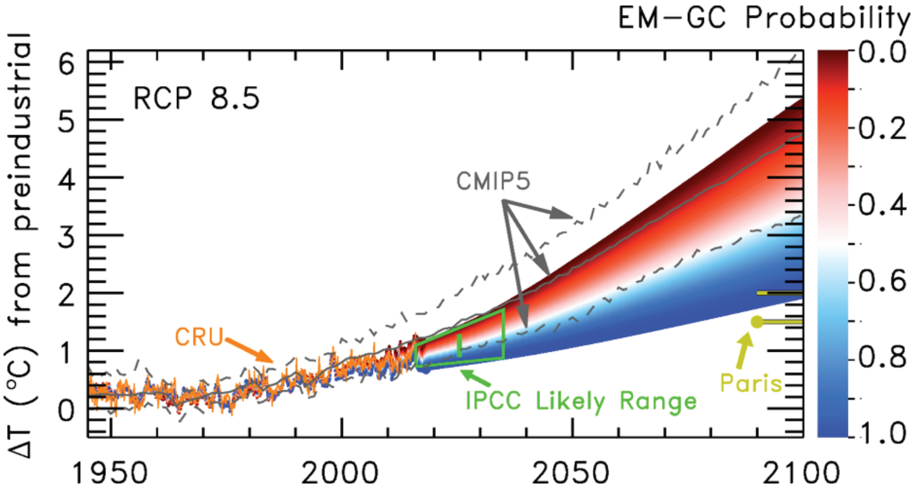
# Fossil Fuel Economics for $1000

**U.S. has greatly expanded production of so-called tight oil https://en.wikipedia.org/wiki/Tight_oil from the Permian, Bakken, and Eagle Ford deposits since 2008:**




https://www.accessscience.com/content/hydraulic-fracturing-fracking/326700

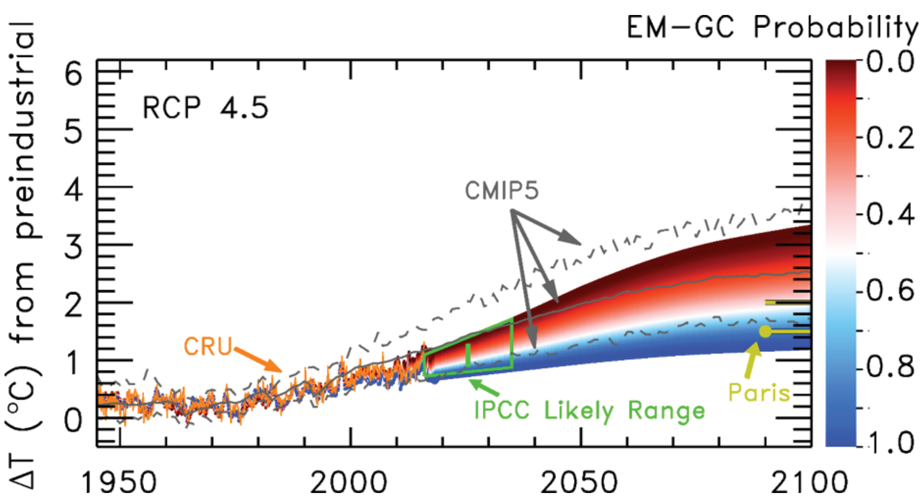
## EM-GC Forecast




**Projections of GMST from CMIP5 climate models used by IPCC lie on the "Warm Side" and in some cases well above our EM-GC projections**

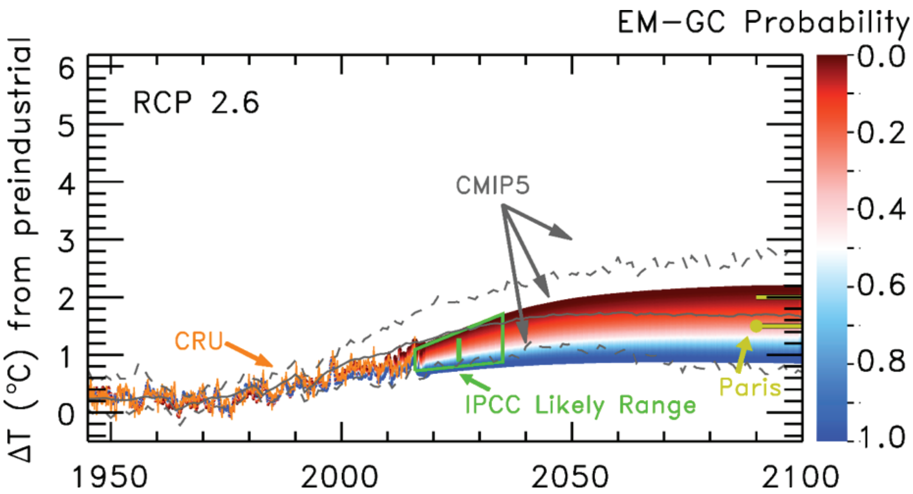



## EM-GC Forecast




**Projections of GMST from CMIP5 climate models used by IPCC lie on the "Warm Side" and in some cases well above our EM-GC projections**

## EM-GC Forecast




**Projections of GMST from CMIP5 climate models used by IPCC lie on the "Warm Side" and in some cases well above our EM-GC projections**





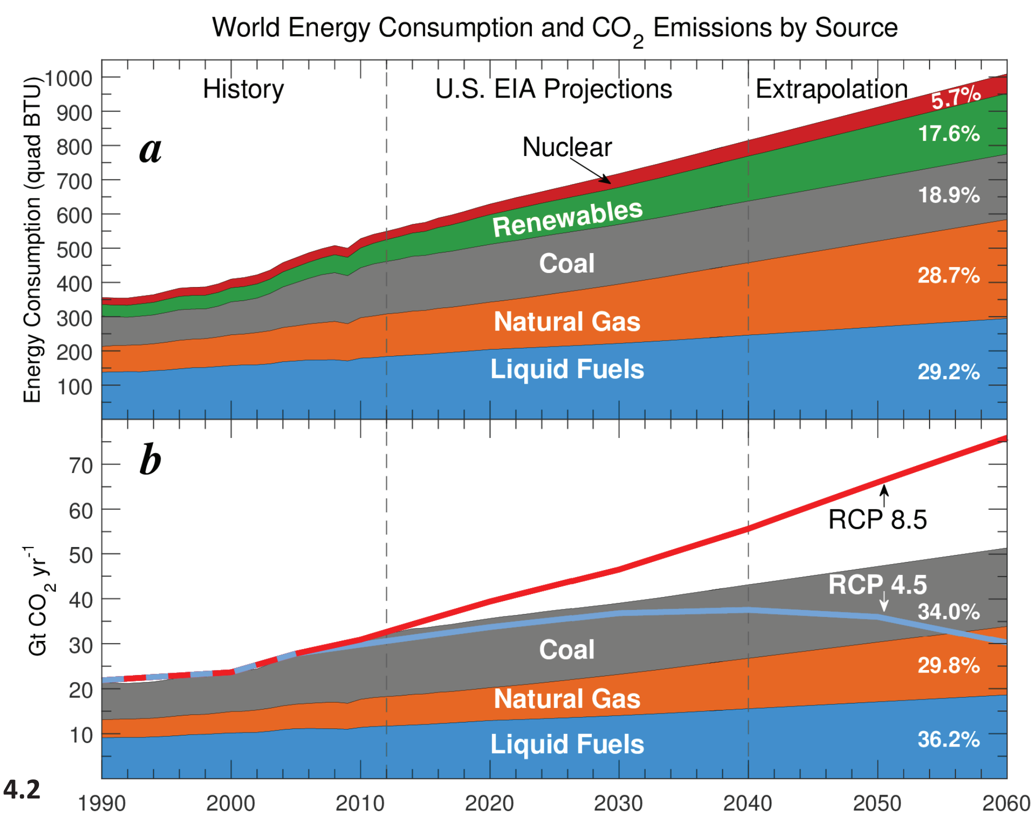



**Figure 4.2**

Paris Climate Agreement: Beacon of Hope

World Energy Consumption and $CO_2$ Emissions, Modified to Meet RCP 4.5 in 2030

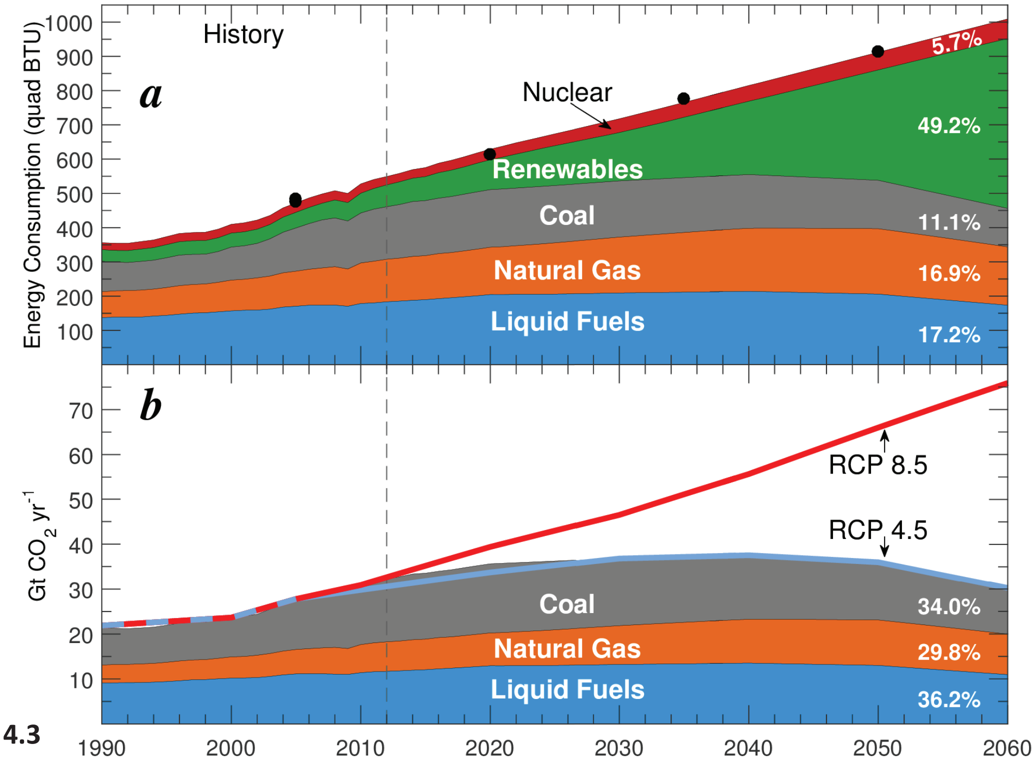



**Figure 4.3**

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





World Energy Consumption and $CO_2$ Emissions, Modified to Meet RCP 2.6 in 2030

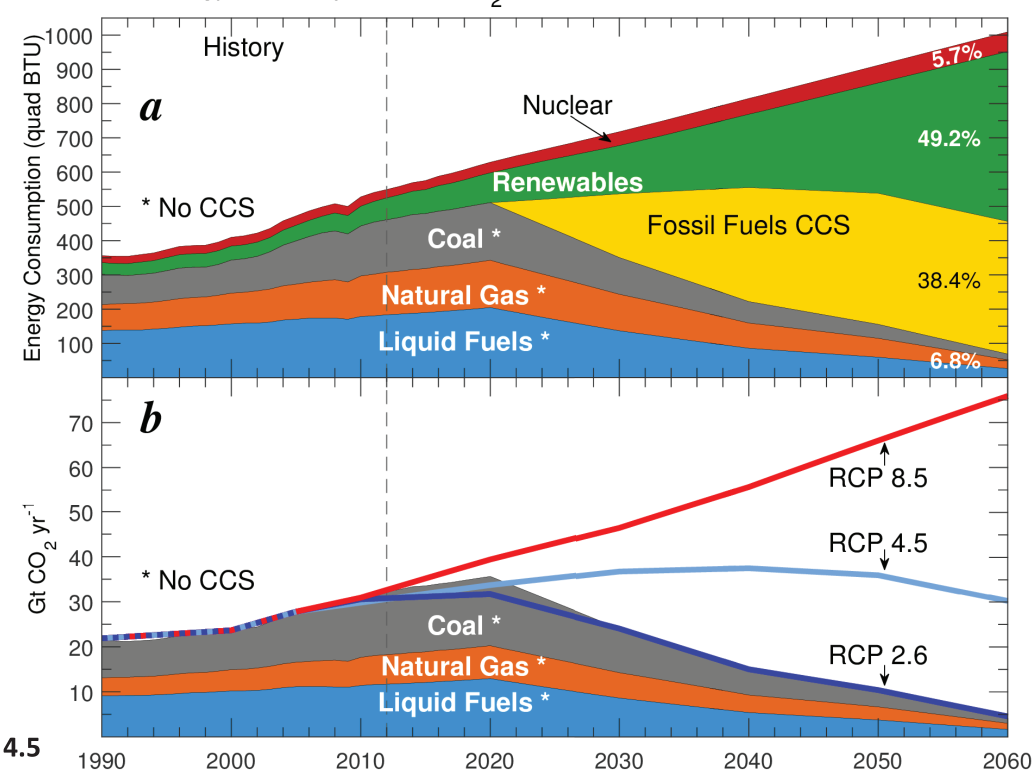



**Figure 4.5**

**Achieving RCP 2.6 requires 93% world energy to be supplied by sources that do not emit GHGs, by year 2060**