LESSON 5B: OIL AND COAL: THE GOOD, THE BAD, AND THE UGLY

Energy and Climate Change

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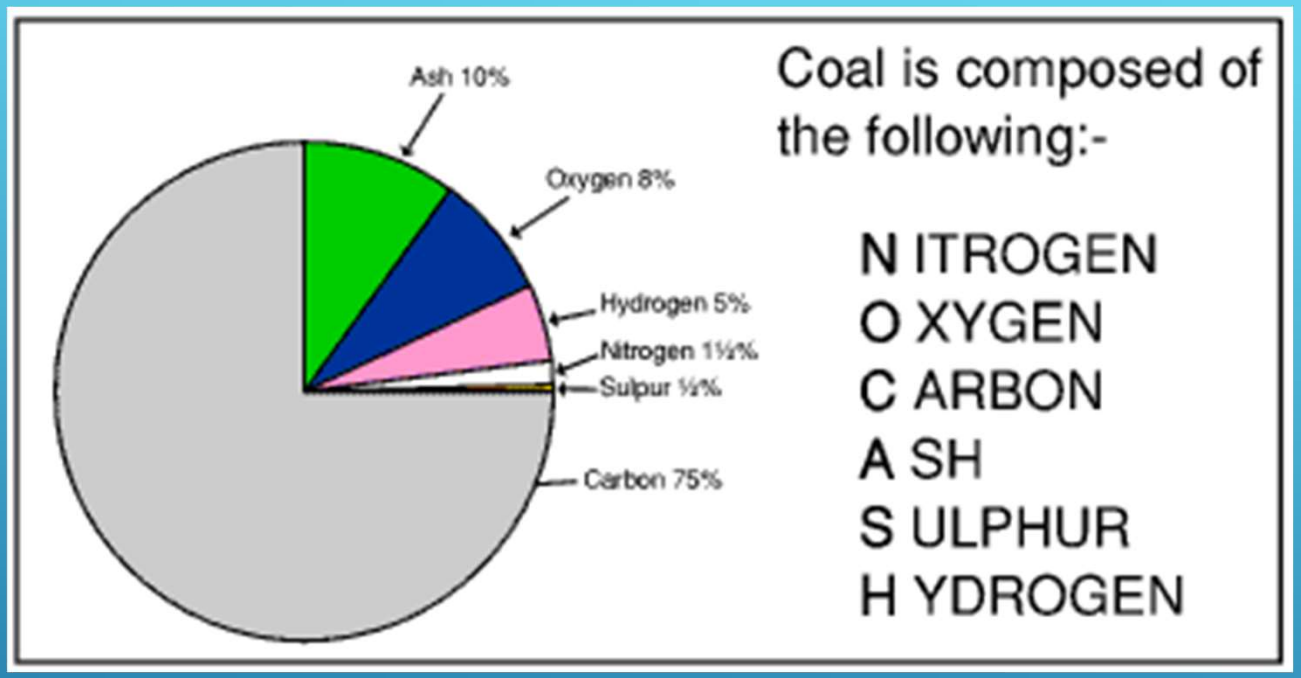
OLLI -AU

CONTENTS

- What are oil and coal?
- How is coal formed?
- History of Oil and Coal Use
- Coal and oil use and CO2 implications
- Coal exports
- Coal and Oil: Methane Emissions
- New power plants
- Jobs
- Coal vs. natural gas prices
- Coal plant retirements
- Carbon capture and storage (CCS)
- Environmental issues with oil and coal
- Conclusions

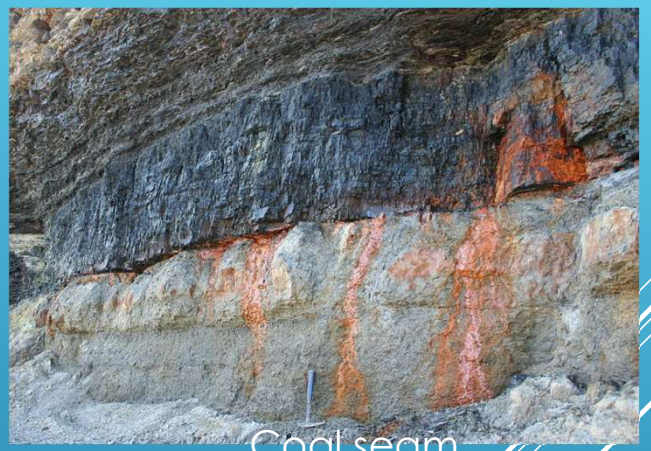


Typical sulfur content of fossil fuels:
coal -0.2-5%
Crude oil-1-4%
Natural gas-3-6 *ppb* <0.000001%

WHAT IS COAL? COAL CONSTITUENTS

HOW IS COAL FORMED?

- One theory states that about 360 million years ago, some plants evolved the ability to produce **lignin**, a complex polymer that made their **cellulose** stems much harder and more woody. Thus, the first **trees** evolved. But bacteria and fungus did not immediately evolve the ability to decompose lignin, so the wood did not fully decay but became buried under sediment, eventually turning into coal. About 300 million years ago, mushrooms and other fungi developed this ability, *ending the main coal-formation period of earth's history*.
- At various times in the geologic past, the Earth had dense forests in low-lying wetland areas. Due to natural processes such as flooding, these forests were buried underneath soil. As more and more soil deposited over them, they were compressed. The temperature also rose as they sank deeper and deeper. As the process continued the plant matter was protected from **biodegradation** and **oxidation**, usually by mud or acidic water.
- This trapped the carbon in immense **peat bogs** (000's of years) that were eventually covered and deeply buried by sediments. Under high pressure and high temperature, dead vegetation was slowly converted to coal. The conversion of dead vegetation into coal is called **coalification**. Coalification starts with dead **plant matter** decaying into **peat**. Then over millions of years the heat and pressure of deep burial causes the loss of water, methane and carbon dioxide and an increase in the proportion of carbon. Thus first **lignite** (also called "brown coal"), then **sub-bituminous coal**, **bituminous coal**, and lastly **anthracite** (also called "hard coal" or "black coal") may be formed.
- Coal is therefore classified as a nonrenewable energy resource.

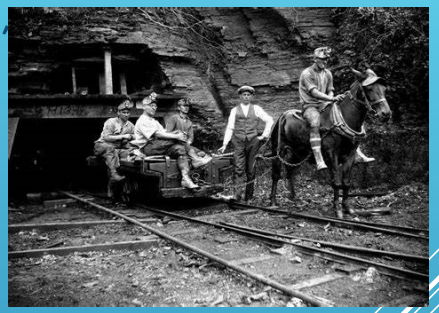


Coal seam

https://en.wikipedia.org/wiki/Coal

HISTORY OF COAL USE

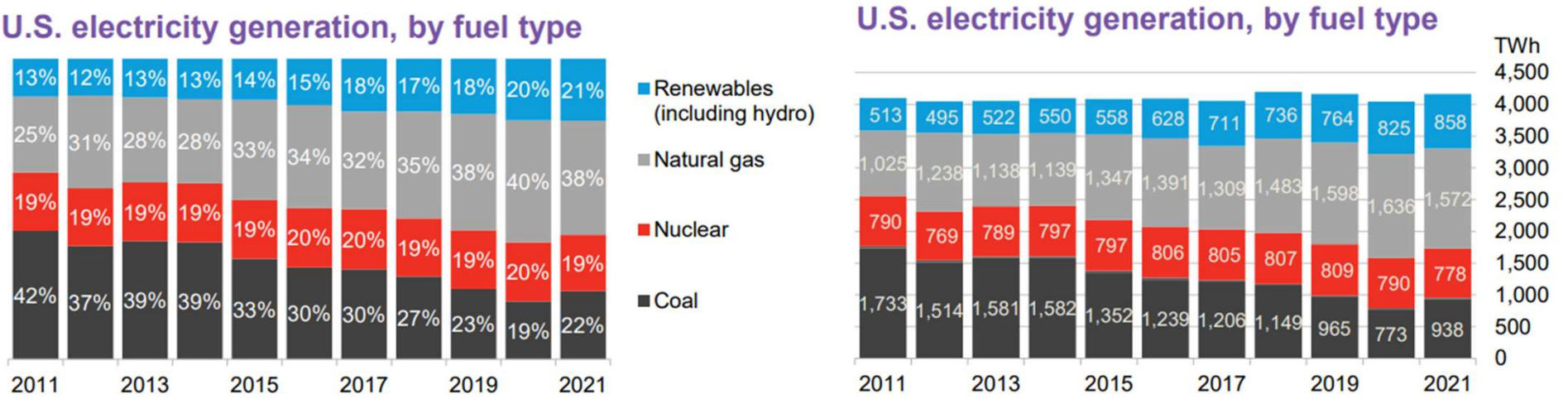
- In 1701, coal was found by Huguenot settlers on the James River in what is now Richmond, Virginia. By 1736, several "coal mines" were shown on a map of the upper Potomac River
- In 1748, the first commercial coal production began from mines around Richmond, Virginia. Coal was used to manufacture shot, shell, and other war material during the Revolutionary War.
- By the late 1700s, coal was being mined on "Coal Hill," now Mount Washington in Pittsburgh, Pennsylvania.
- In 1797, George Washington installed a coal-burning stove grate at Mt Vernon
- 1830: The first major boon for coal use occurred when the Tom Thumb, the first commercially practical American-built locomotive, was manufactured. The Tom Thumb burned coal, and in rapid fashion, virtually every American locomotive that burned wood was converted to use coal.
- The 1870s saw the next major surge in coal demand. In 1875, coke – a product of heating coal – replaced wood charcoal as the chief fuel for iron blast furnaces. Strip mining began in 1866 near Danville, Illinois, and by 1877, steam shovels were being used to reach a 3-foot thick coal bed in Kansas. With the rise of iron and steel, coal production increased by 300 percent during the 1870s and early 1880s.



HISTORY OF COAL USE (CONTINUED)

- In 1882 Edison built the first practical coal-fired electric generating station, supplying electricity to some residents of New York City. In 1901, General Electric Company built the first alternating current power plant at Ehrenfeld, Pennsylvania.
- By 1961, coal had become the major fuel used by electricity utilities to generate electricity, and a new era for coal began taking shape. U.S. coal production had more than doubled, increasing from 520 million tons to nearly 1.1 billion tons by 2000.
- 1978: The Powerplant and Industrial Fuel Use Act (PIFUA) inadvertently encouraged the building of new coal-fired power plants by disallowing the building of new natural gas power plants
- With the repeal of PIFUA (1987) and the lowering of natural gas and renewables prices, new powerplants by those energy sources have reduced coal use in power generation substantially, so that coal use in power generation has dropped down to less than 600 million tons per year, and coal as a share of the power generation market has gone from 53% in 1997 to 23% by 2019
- The Clean Power Plan, abrogated by the Trump Administration, would have brought further major reductions in coal use for power generation.
- Renewables provided more electricity than coal on 90 separate days in the first four months of 2020 (NYTimes 5/14/20)
- 8/31/20: EPA is relaxing regulations for wastewater coming from coal plants, EandE News
- 10/9/20: Trump Administration seeks to limit regulatory powers against coal, NY Times
- 2/1/22 Biden administration to reinstate air pollution rules weakened under Trump, NY Times -- covers mercury, fine particulates, co-benefits reinstated

U.S. energy overview: Electricity generation mix



COAL IS DOWN TO 22% OF ELECTRICITY GENERATION FROM 42% IN 2011 (BUT UP FROM 2020)!

(Max coal penetration was 53% in 1997)

Ref: BCSE 2022 Factbook

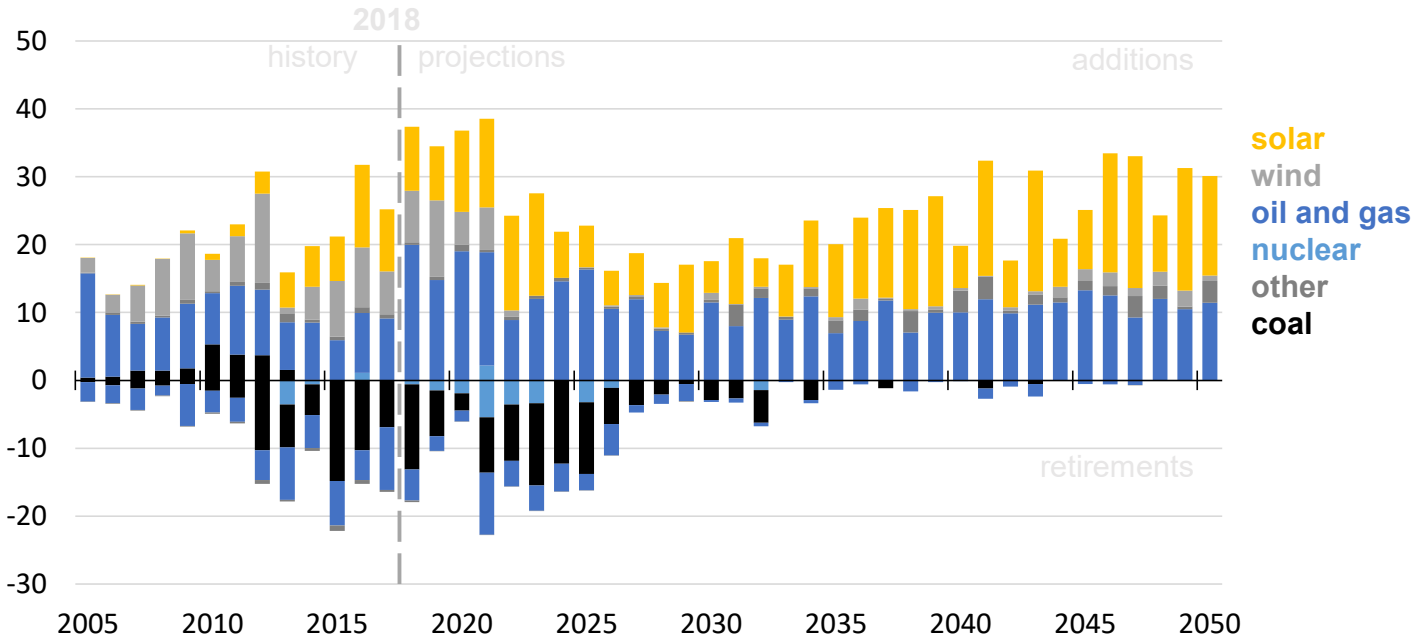
TOP-TEN COAL USING STATES

State	Coal Percentage of Generation	000's of GWhrs Coal Gen
Texas	33.9%	148
Indiana	84.5%	97.7
Ohio	67%	90.1
Illinois	43.2%	87.4
Kentucky	92%	83.4
Pennsylvania	36.1%	80.1
West Virginia	95.5%	77.6
Missouri	82.6%	77.7
Michigan	50.2%	53.1
Florida	22.5%	52

Huff Post, 9/28/15, 2014 data

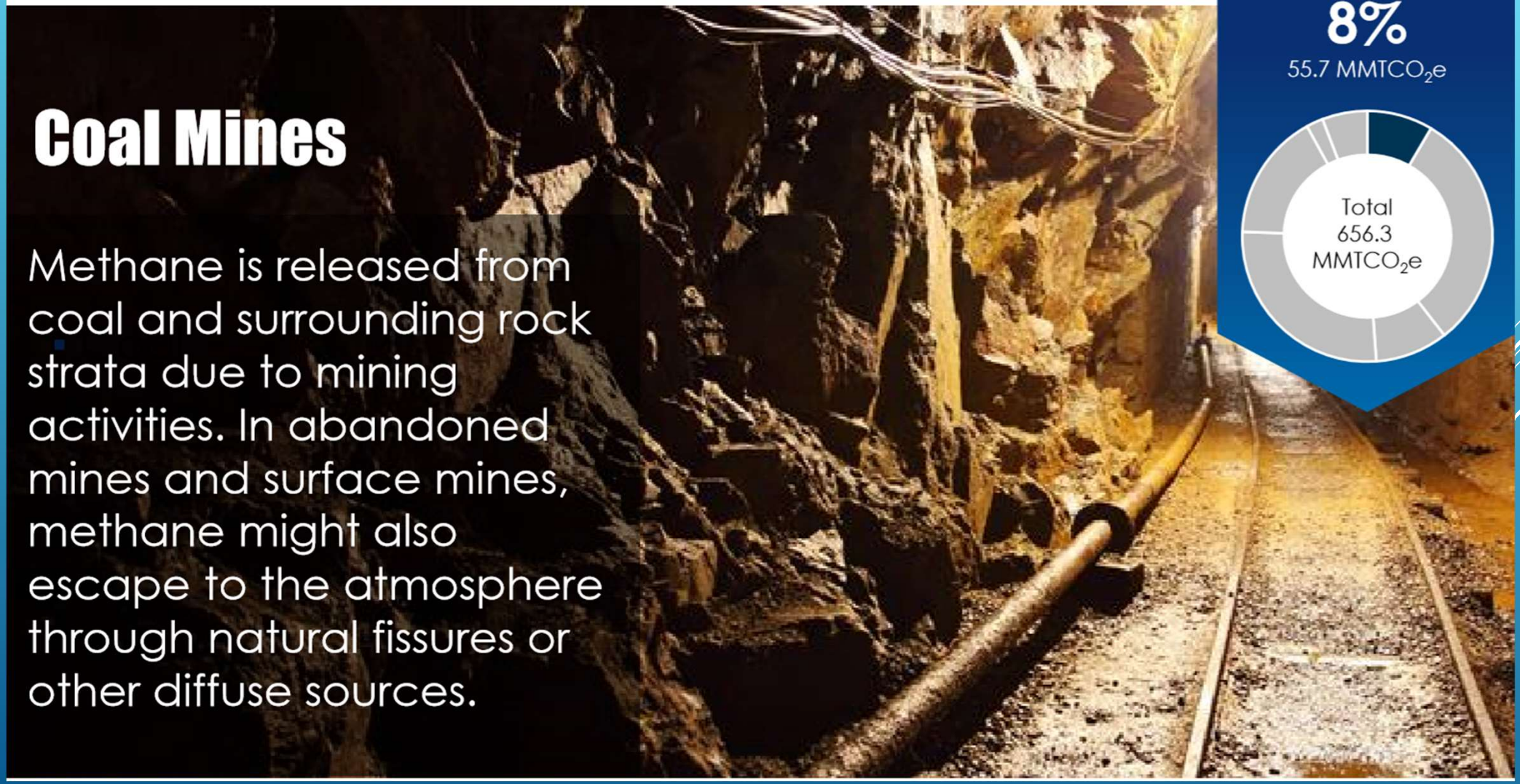
Expected requirements for new generating capacity will be met by renewables and natural gas—

Annual electricity generating capacity additions and retirements (Reference case)
gigawatts



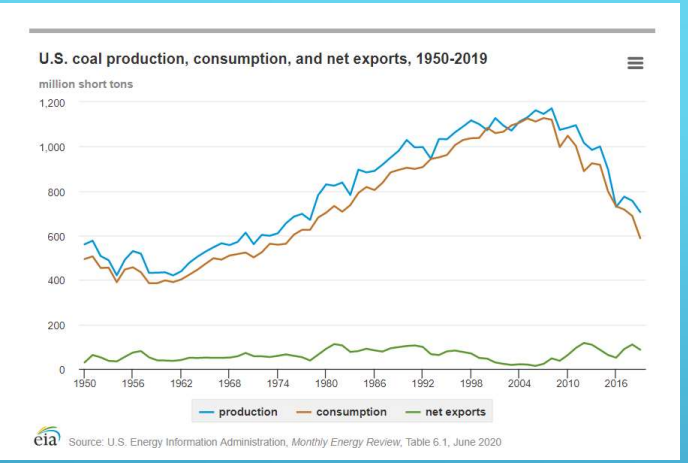
Coal Mines

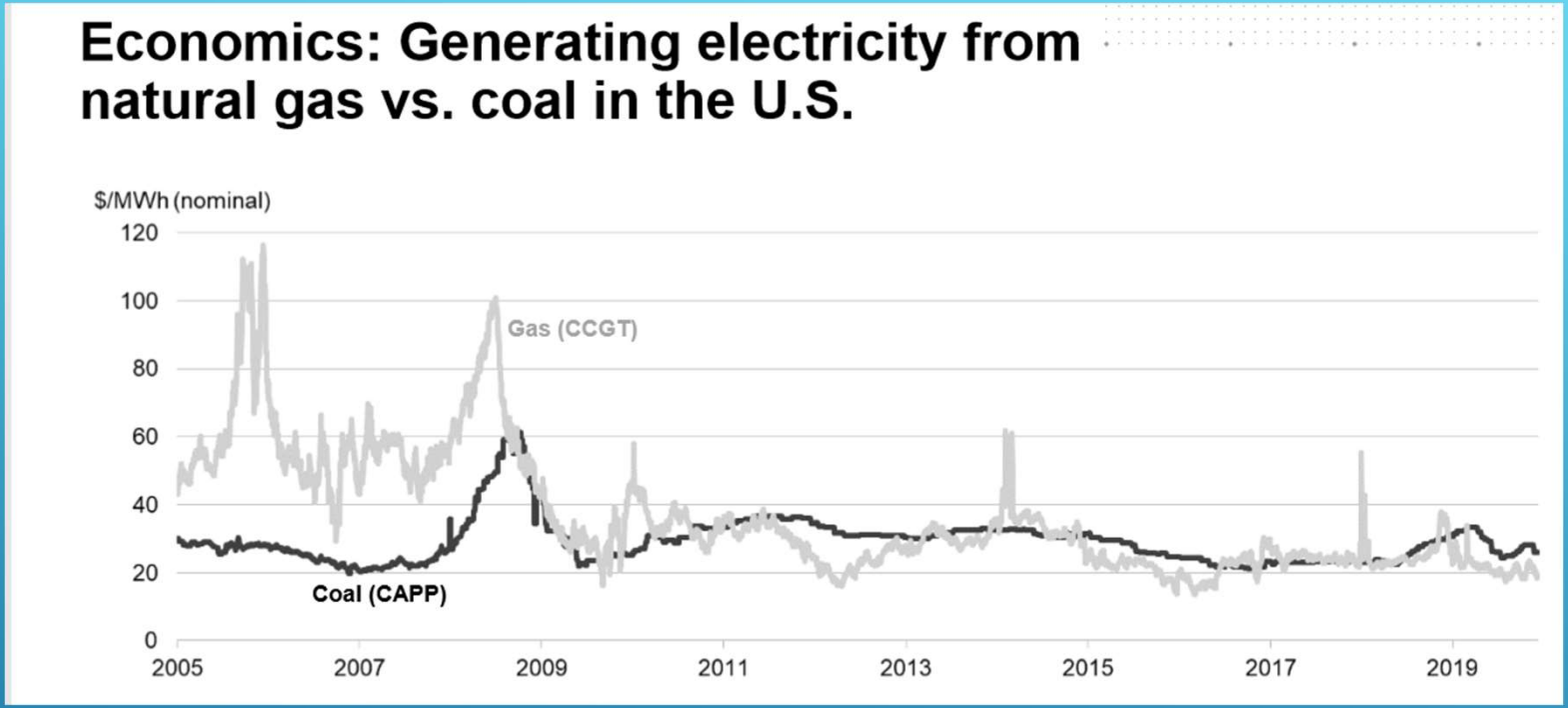
Methane is released from coal and surrounding rock strata due to mining activities. In abandoned mines and surface mines, methane might also escape to the atmosphere through natural fissures or other diffuse sources.



DIRTY SECRET: COAL EXPORTS

- U.S. coal exports are holding steady
- Baltimore is the Number 2 coal exporting port in the country!
- China, committed to reducing domestic coal power plants, is building or planning to build 300 coal power plants around the world
- Since climate change is a global problem, you can't export CO2 emissions as a solution to climate change





COAL IS LOSING ECONOMICALLY TO NATURAL GAS

COAL COMEBACK?

Coal's on a comeback in energy-desperate Europe, E&E News, 3/11/22

- **Russia's invasion of Ukraine has offered coal a European lifeline**
- **Such a prospect would have seemed unthinkable a few weeks ago as European nations were rolling out increasingly ambitious plans to phase out carbon-intensive fuels**
- **But Russia's brutal attacks on Ukraine has upended Europe's energy markets, exposing Europe's dependency on Russian fossil fuels and prompting a scramble for alternatives**
- **Two coal plants, in Germany and the U.K., have already delayed retirement plans, and more are expected to follow**
- **"Really we see the upside to coal generation relative to pre-Ukraine invasion expectations coming from this summer onwards, as [natural] gas now looks out of the money for the next couple of years," said the head of European power analysis at S&P Global**
- **He predicted European coal generation will average 15 GW in 2022, up from 11 GW in 2021 and 8 GW in 2020**
- **Coal's revival may be short-lived, as Europe keeps some coal plants online to address the continent's energy crunch**
- **E.U. nations are still legally bound by a climate law targeting a 55% reduction in GHG emissions by 2030 compared to 1990 levels**

German coal power plant

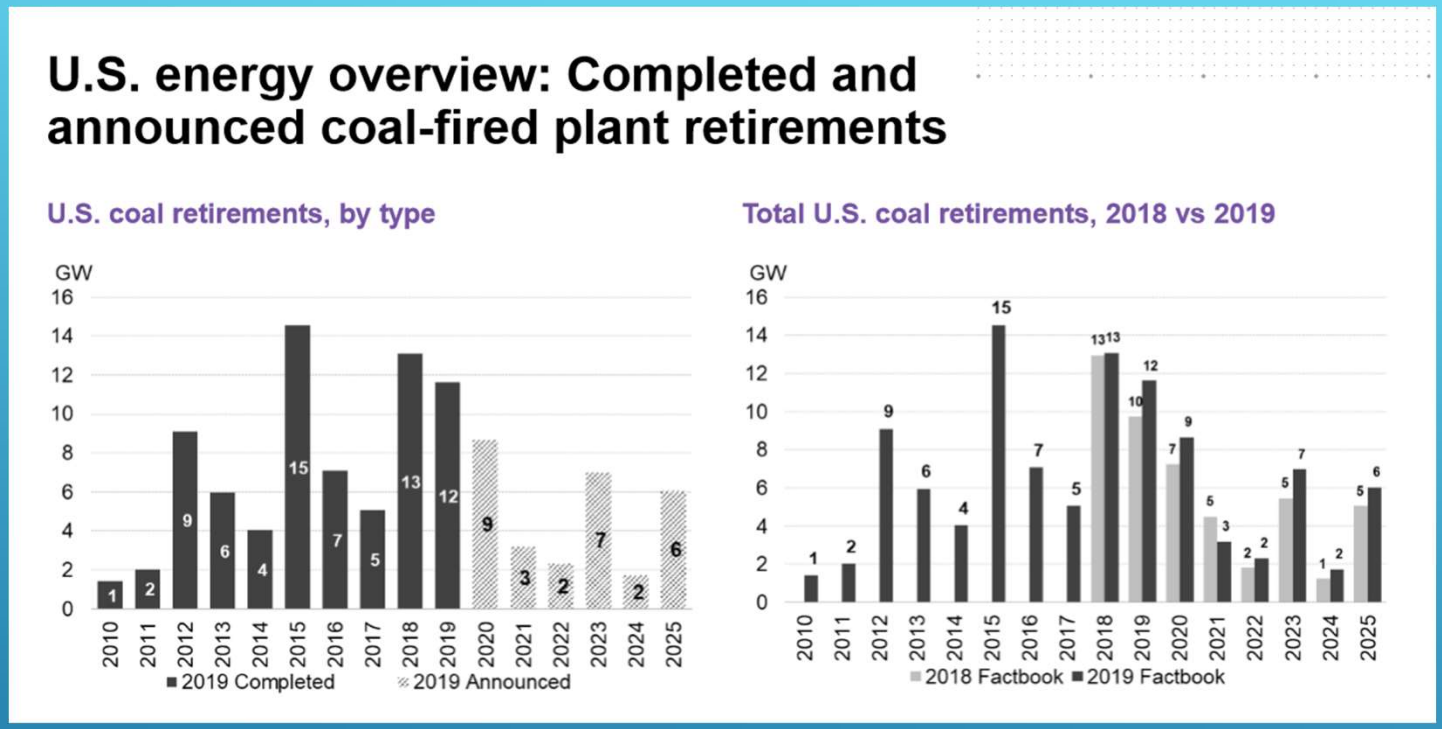
DESPITE VOW TO PUT 'MINERS BACK TO WORK,' COAL KEEPS COLLAPSING

- For decades, electricity poured from the Navajo 2,250 MWe power plant in NW Arizona, where it burned 240 rail cars of coal a day, generating 15 MM tonnes of CO_2 per year
- Similar scene at nearby Kayenta coal mine
- Despite the Administration's best efforts, coal's decline has only accelerated in recent years
- By late last year, both the Kayenta coal mine and the Navajo generating station went offline
- Since Trump was inaugurated, 145 coal-burning units at 75 power plants have been idled and coal production dropped from 775 MM tons in 2017 to 511 MM tons projected for 2020
- Air pollution has also declined rapidly as a result, despite rollback of environmental rules

Navajo generating station

Kayenta coal mine

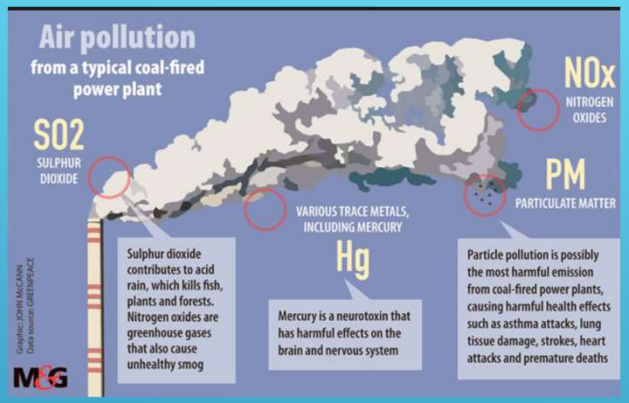
NY Times, 10/6/20



COAL POWER PLANT RETIREMENTS ARE CONTINUING FOR ECONOMIC REASONS

ENVIRONMENTAL ISSUES WITH COAL

- GHG emissions:
  - CO2 from coal combustion: 207 lb CO2/MMBtu
  - Methane release from coal mines and open pit mining
- Land use issues, especially with open pit strip mining (including mountain top removal and valley filling)
- Miner safety and health problems
- Emissions from coal combustion: SO2, NOx, particulates, acid rain, mercury and other heavy metals, fly ash and bottom ash
- Groundwater pollution in leaching from ash storage and landfill sites
- Coal ash hazardous constituents: arsenic, cadmium, chromium, lead, selenium, and mercury
- Water use in coal power plants

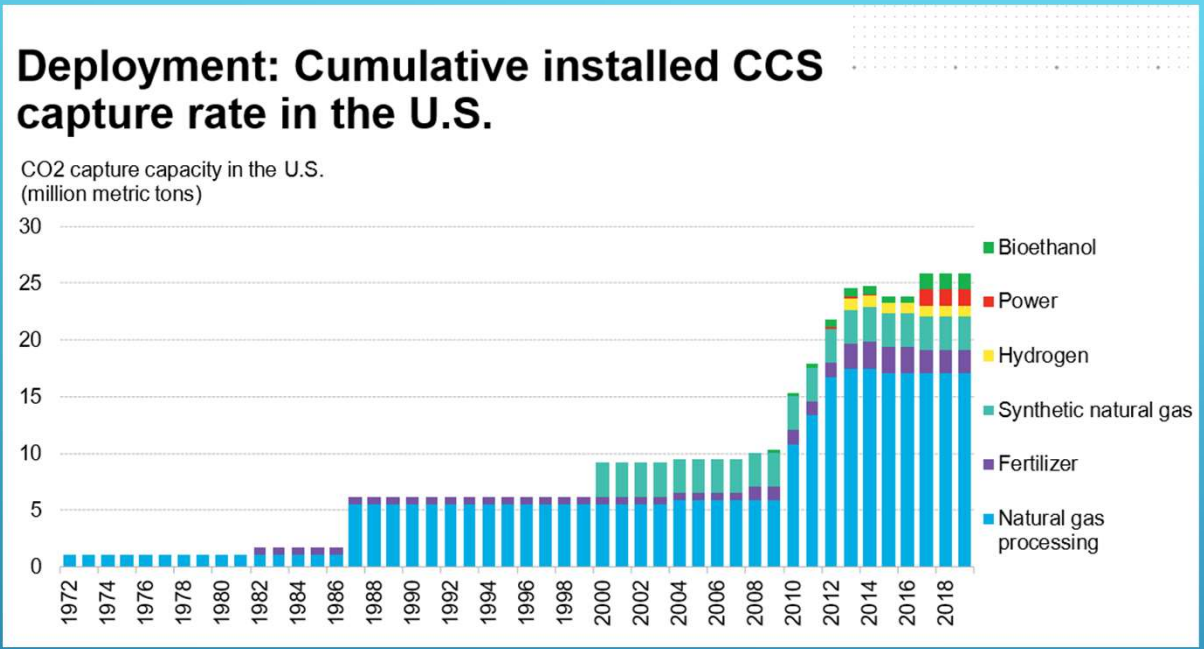


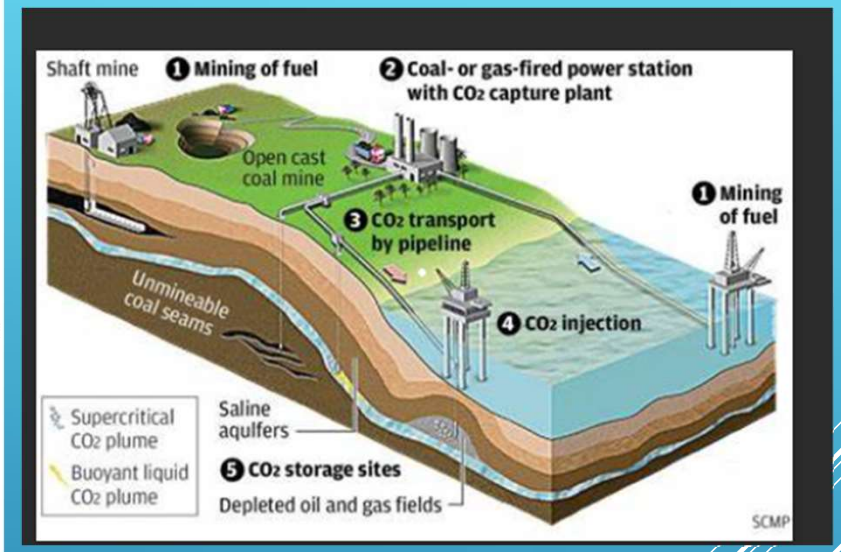
Ref: Greenpeace (figure)

CARBON CAPTURE AND STORAGE (CCS) CHALLENGES

- CO2 emissions from a coal power plant are 13-15% of stack emissions. From a NGCCS, CO2 percent is only 7% of emissions. These low percentages, especially from NGCCT plants, make it challenging to remove the CO2 from the exhaust.
- CCS *lowers* the total societal cost of addressing climate change by approximately 30%.-This does not mean that CCS lowers electricity prices. It means without CCS, more costly methods are needed to meet carbon dioxide reduction targets, which could add trillions of dollars
- CCS will not be widely used until CO2 is regulated. That's because CCS has only one purpose—compliance with environmental standards.
- Implementing CCS means a new industry must emerge on a large scale to capture, transport, store and inject CO2 deep underground. It's not as simple as adding a device to a plant.
- Capture is more expensive than sequestration. Capture accounts for about 3/4 of the total CCS costs.
- CCS raises the costs of electricity (compared to an uncontrolled plant) by between 30% and 80%. A key factor that drives this increase is the energy penalty associated with capture and compression of CO2 to make it ready for transport and injection.
- More large field demonstration projects are needed worldwide. Science and industry experience strongly indicate that sequestration is safe when practiced in an appropriate site. However, managing hundreds of sources injecting into a single sedimentary basin requires a high level of knowledge sharing and project coordination, as well as research and development support.
- Who will pay for the cost of building the CO2 pipelines that lead from the power plants to the sequestration sites? (RBE)
- Monitoring, permitting and long-term care programs must also be developed so that commercial and public sequestration sites can be developed and environmental protection assured.

Ref: Clean Air Task Force

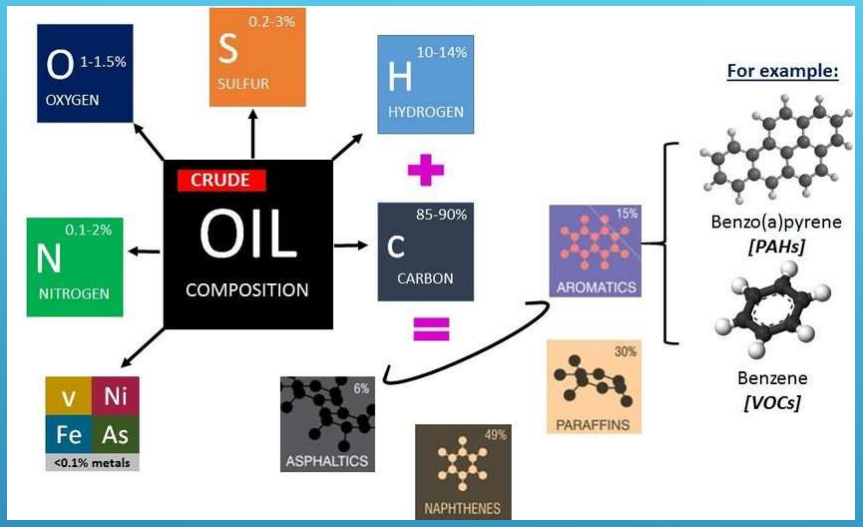




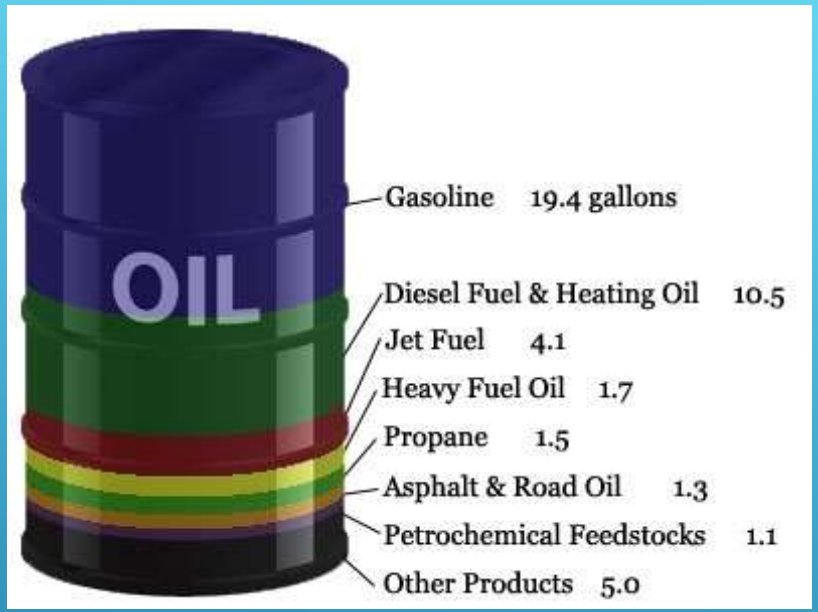
- Petra Nova is closed: what it means for carbon capture, EandE News 9/22/20
  - Pioneer CCS facility that demonstrated CCS on a commercial scale
- 32 announced CCS projects in U.S., half are with power sector

CARBON CAPTURE AND STORAGE (CCS): SMALL BUT GROWING

Re: BCSE 2020 Factbook



Crude oil

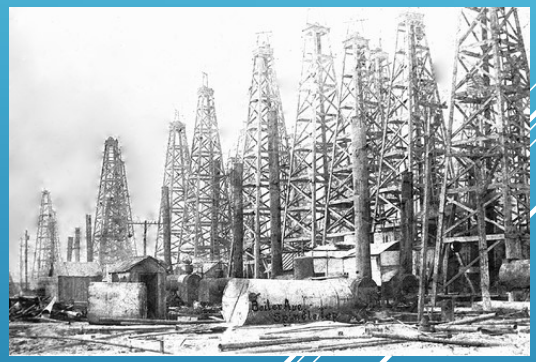


Refined oil

WHAT IS OIL? CRUDE AND REFINED OIL CONSTITUENTS

HISTORY OF OIL USE

- 1859: Drake well in Pennsylvania; first U.S. oil and gas well
- The principal product of the oil in the 19th century was kerosene, which quickly replaced whale oil for illuminating purposes in the U.S.
- The success of the Drake well quickly led to oil drilling in other locations in the western Appalachian mountains.
- 1874: Standard Oil formed by J.D. Rockefeller in Ohio
- 1880: Oil production in the Los Angeles Basin started with the discovery of the Brea-Olinda Oil Field in 1880, and continued with the development of the Los Angeles City Oil Field in 1893, the Beverly Hills Oil Field in 1900, the Salt Lake Oil Field in 1902
- 1892: The first commercially successful oil well drilled in Kansas was the Norman No. 1 near Neodesha, Kansas.
- 1894: Corsicana, Texas, 1894, Texas
- 1901: Capt. Anthony Francis Lucas, an experienced mining engineer and salt driller, drilled a well to find oil at Spindletop Hill, Oklahoma
- 1911: Supreme Court ordered the dissolution of Standard Oil as a violation of the Sherman Anti-Trust Act
- Early 1900's: oil emerged as the preferred energy source. The key drivers of that transformation were the electric light bulb and the automobile. Automobile ownership and demand for electricity grew exponentially and, with them, the demand for oil.
- By 1919, gasoline sales exceeded those of kerosene. Oil-powered ships, trucks and tanks, and military airplanes in World War I proved the role of oil as not only a strategic energy source, but also a critical military asset.

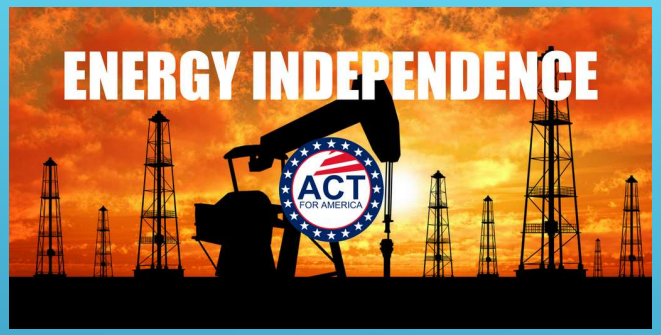


HISTORY OF OIL USE (CONTINUED)

- 1940's: Oil was a key strategic asset for both sides, possibly leading to Japan's efforts to attack the Allies. Germany resorts to synthetic oil production and attempts to capture the oil fields of the Soviet Union. UK begins to rely on Iran and Middle East oil
- 1960's: Formation of OPEC – shift of oil production away from the U.S. and European powers; 81% of the oil reserves in the world belong to their members
- 2005-2008: U.S. oil production declines to less than 6 MM BBL/day
- Oil production in the Bakken shale (ND) goes from 85,000 BBL/day (2004) to 419,000 BBL/day (2011) to 1.1 million BBL/day by 2014, The New Map, Dan Yergin, 2020
- 2005-2020: Technological breakthroughs in unconventional oil and gas production in the last 15 years have altered the North American energy landscape. U.S. Oil production climbs to over 13 MM BBL/day (2019). Oil use climbs to 20MM BBL/day.
- 2015/2016: Ban lifted on prohibition of crude oil exports. U.S. oil exports begin (to France and China)
- Post-2000: Negligible use of oil for electricity generation, except for some peaking plants and for resiliency purposes
- Today: With over 250 million vehicles in the U.S., plus airline use, oil has remained a mainstay of U.S. energy use, despite some penetration by EVs and NGVs
- 4/20/20: (WTI) Oil price futures contracts plunged into negative territory reflecting an unprecedented surplus of oil and lack of demand due to the Covid-19 pandemic
- 8/18/20: [ANWR] Arctic Protections End as U.S. Plans to Auction Oil Leases, NY Times
- 8/31/20: In Time, Big Oil Faded…, NY Times; Exxon Mobil "kicked out" of Dow Jones Industrial Average after a century of inclusion
  - ExxonMobil's exile from the Dow is the latest sign of Big Oil's fading fortunes, Washington Post, 9/6/20
- Trump signs offshore drilling bans for eastern Gulf, Atlantic (FL, GA, AL, SC, NC) through 2032, EandE News, 9/8/20
  - Plan to drill for oil off Atlantic coast appears dead as blasting permits [for seismic location of oil] wane, Washington Post, 10/2/20
- BP makes a $1.1B bet on offshore wind projects, EandE News, 9/11/20
  - Example of oil industry expanded interest in big electricity projects and a "green pivot"
- U.S., European oil giants go separate ways on climate, EandE News, 9/11/20
  - U.S. oil giants "doubling down on oil and gas investments.
  - BP, Shell, Total have lined up behind Paris Agreement and boosted investments in renewables
- BP says oil demand could be almost dead by 2050, EandE News, 9/14/20, 9/25/20
  - Predicts 50%-80% reduction in world oil use

PETROLEUM PRODUCTS CONSUMED AND PRODUCED IN U.S. IN 2019

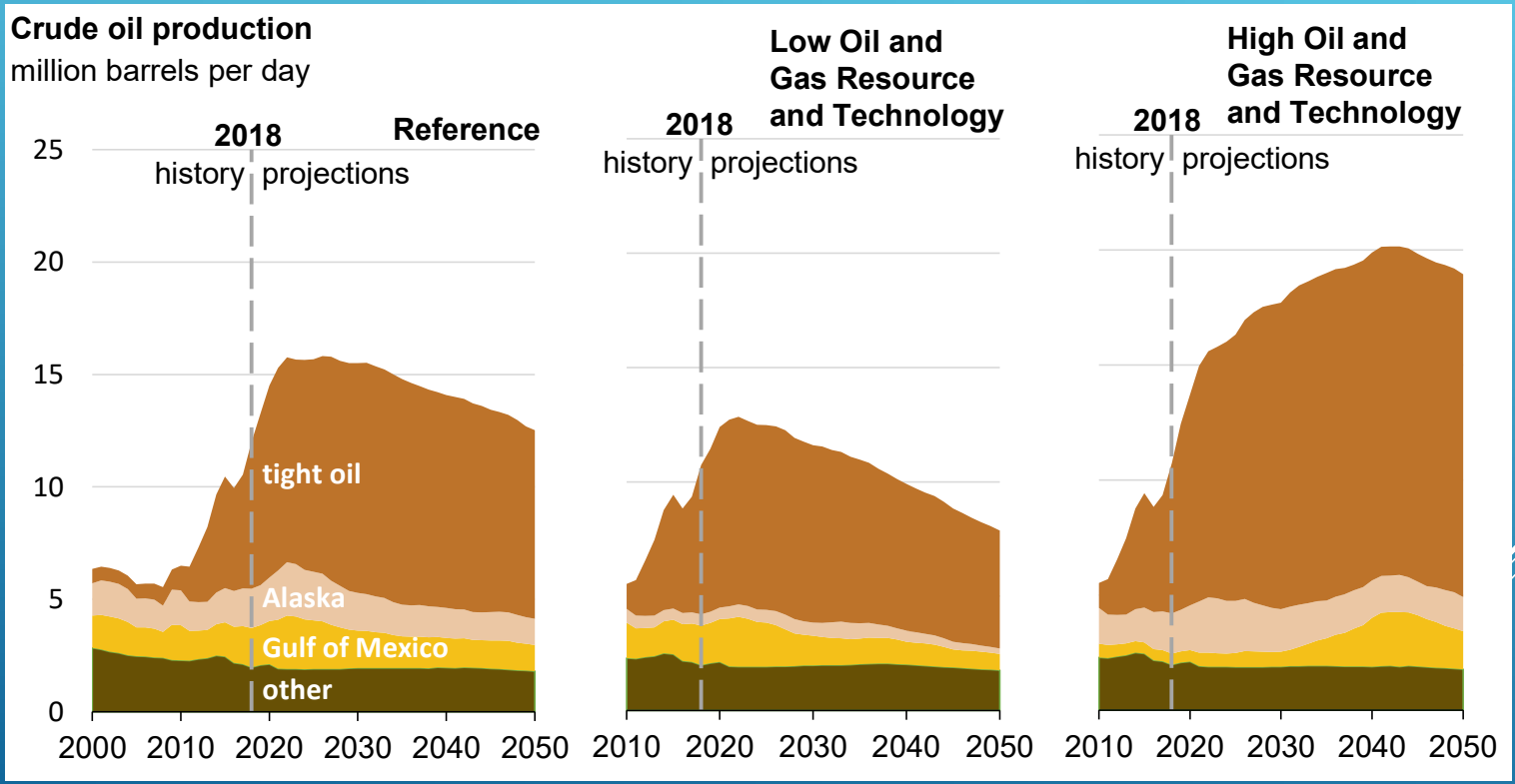
- Finished motor gasoline – 9.3 MM barrels/day (BBL/day)
- Distillate (diesel fuel and home heating oil – 4.1 MM BBL/day
- Natural gas liquids (NGLs) – 3.1 MM BBL/day
- Kerosene (jet fuel) – 1.7 MM BBL/day
- Asphalt, Petrochemical feedstocks, etc. – 2.3 MM BBL/day
- Total: 20.5 MM BBL/day
- Compare this to: 2019 U.S. domestic oil production: 12.2 MM BBL/day
- *With NGLs (3.1 MM BBL/day) and ethanol production (1.1 MM BBL/day), this brings total U.S. oil products production to 16.4 MM BBL/day, or 80% of the way to (oil) energy independence!*



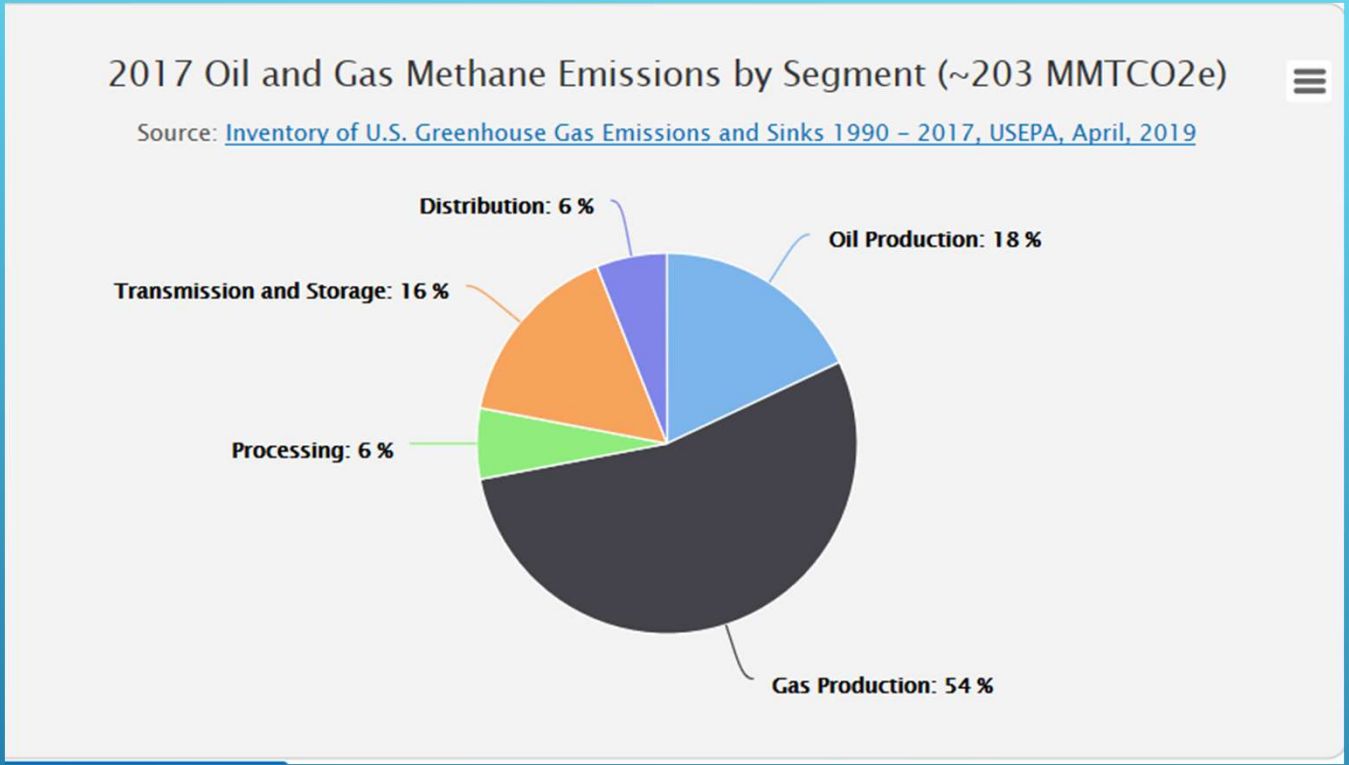
ENVIRONMENTAL ISSUES WITH OIL

- GHG emissions:
  - CO2 from oil combustion: 160 lb CO2/MMBtu
  - Methane release from oil production and processing
- Land and water use issues with oil spills, train accidents
- Oil combustion: NOx, SO2, particulates, acid rain
- Land use for oil wells
- Water use for hydraulic fracturing
- *All* the NRDC air pollution issues for well drilling and completion and hydraulic fracturing
- Microseismic with production water disposal
- Drilling mud, production water disposal
- Presence of BTEX, sulfur compounds
- Legacy issue – 2.57 million abandoned oil wells – methane and other emissions
  - Cost of plugging one driller's oil wells could be $1 billion, EandE news, 10/9/20

TIGHT OIL DEVELOPMENT DRIVES U.S. CRUDE OIL PRODUCTION FROM 2018 TO 2050—



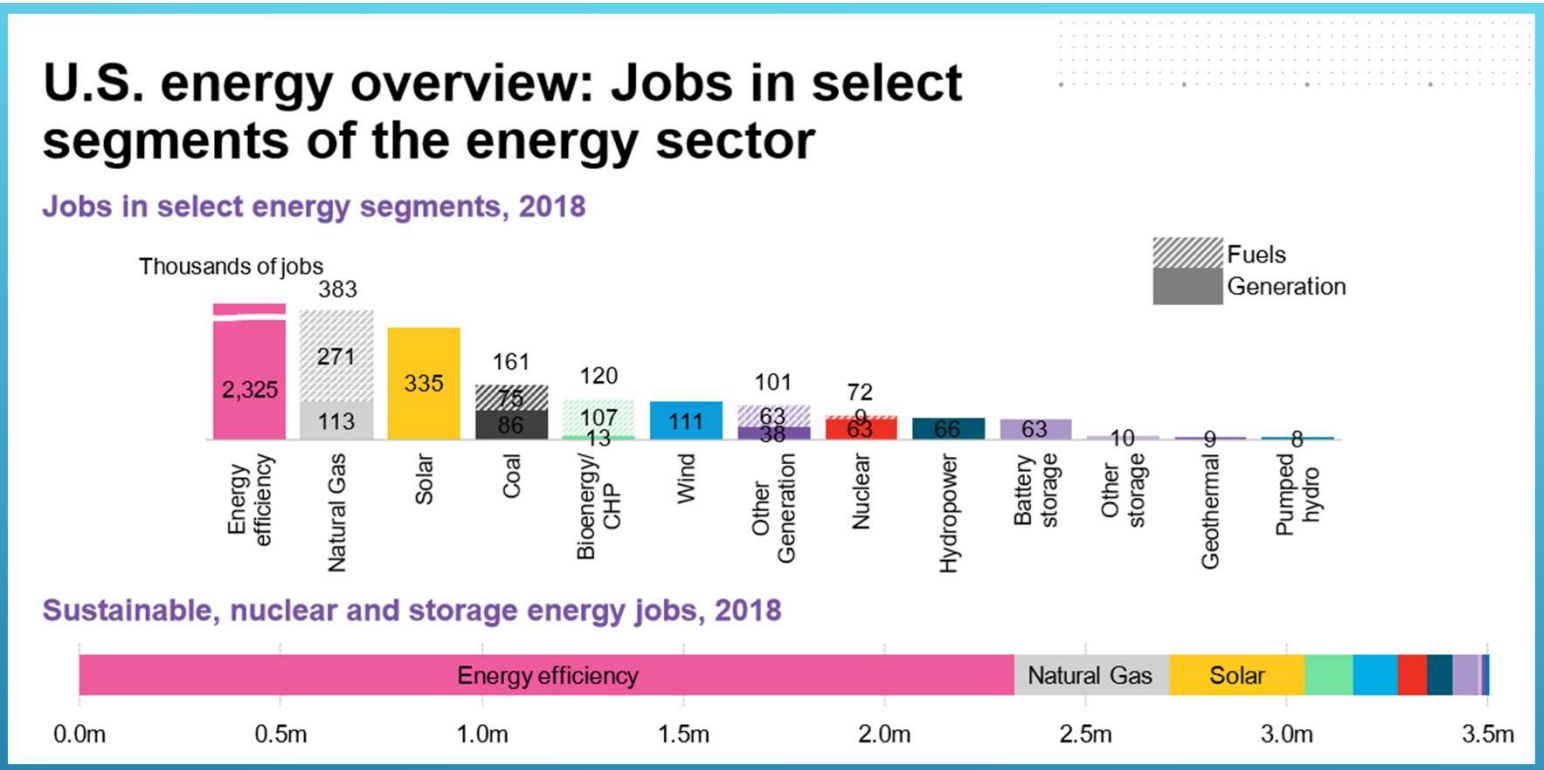
Ref: EIA AEO 2019



METHANE EMISSIONS FROM THE U.S. OIL PRODUCTION SYSTEM, 2017

Total: 36.5 MM tons of CO_2e for oil production systems

Ref: U.S. EPA



THE JOBS QUESTION

Ref: BCSE 2020 Factbook

CONCLUSIONS

- Coal use continues to decline in the power generation sector, currently for economic reasons
- CCS is in the demonstration R&D phase, not ready for prime time, but is the only answer the coal and utility industry has to CO2 reduction from coal plants, aside from closing down coal power generation plants
- Exporting coal to other countries simply transfers the CO2 emissions abroad, and since Climate Change is a worldwide problem, does not solve the CO2 problem
- Oil use in U.S. (mainland) power generation is negligible, except for resiliency purposes
- Oil use, while down from its peak, is projected to remain steady
- Oil is now the primary source of CO2 emissions from fossil fuels, primarily from the transportation sector
- Reducing oil use for transportation will be a difficult challenge. Possible answers: EVs and other alternative fueled vehicles, biofuels