Gas wellhead

Servel gas refrigerator

Gas heat pump

LESSON 5A: NATURAL GAS: SOLUTION OR PROBLEM?

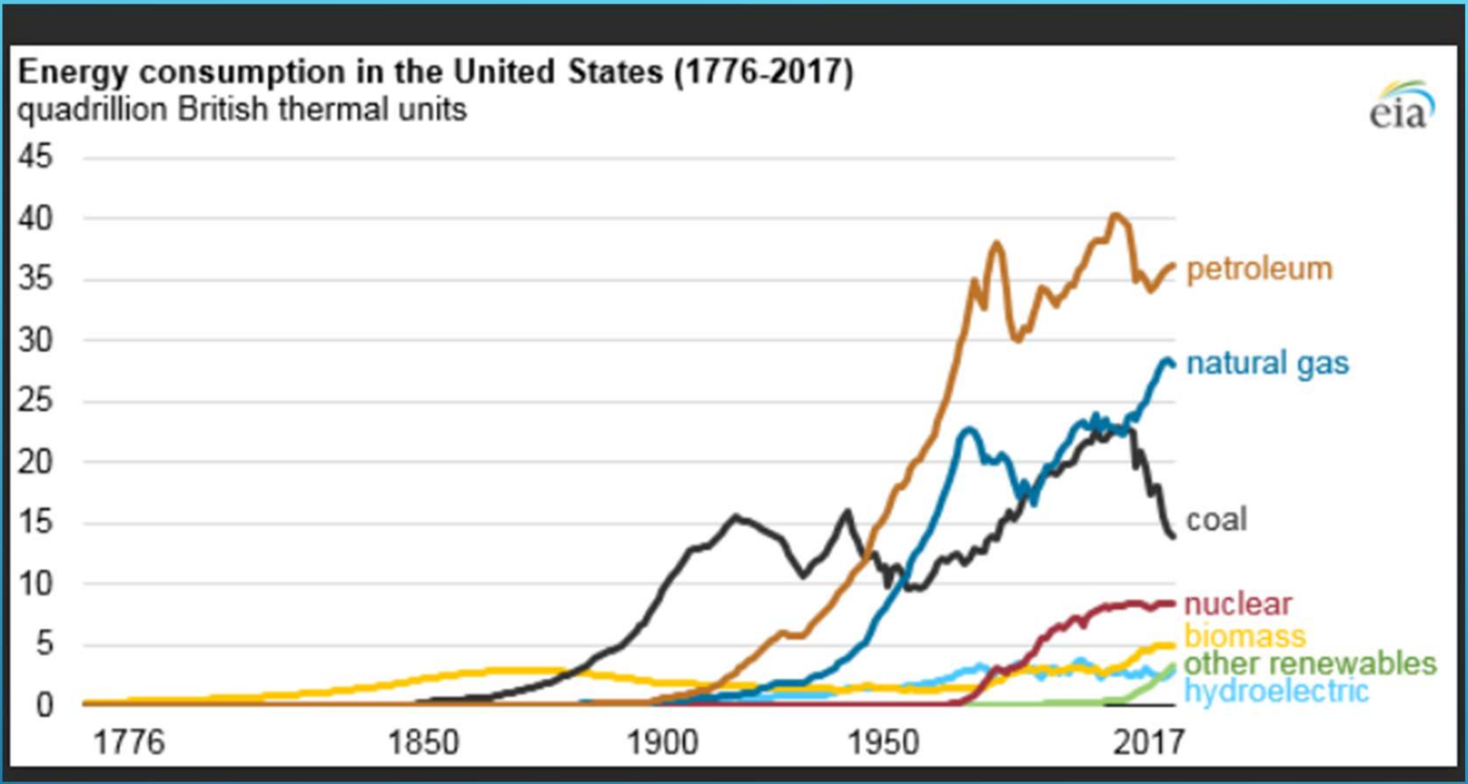
Ron Edelstein

OLLI - AU

CHP System

Proppant for a fracking operation

Drake well



Wood stove

Residential coal delivery

ENERGY SOURCES: THE LONG CYCLE

Ref: U.S. EIA

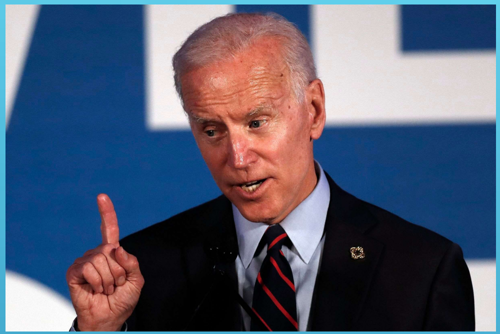
It could prove hard for Europe to wean itself from Russian gas, N.Y. Times, 3/25/22

- The Biden Administration wants to send more natural gas to Europe to help break its dependence on Russian energy
- But that lofty ambition will be largely symbolic because the U.S. doesn't have enough capacity to export more natural gas and Europe doesn't have the capacity to import significantly more
- Recently, the U.S. has already maximized the output of liquefied natural gas (LNG) terminals and diverted shipments originally bound for Asia to Europe
- But energy experts said that building enough terminals on *both* sides of the Atlantic to significantly expand U.S. exports of LNG could take 2-5 years
- And, perversely, any efforts to increase natural gas exports could undermine efforts by the Biden administration and Europe to combat climate change

U.S. LNG export terminal

RUSSIAN NATURAL GAS COULD PROVE HARD TO QUIT FOR EUROPE

- There's no rationale to end fracking while seeking rapid decarbonization
- "Fracking has to continue because we need a transition"
- "We're going to get to net-zero [CO2] emissions by 2050, and net-zero power emissions by 2030, but there's no rationale to eliminate, right now, fracking
- "We can also get people working right now capping wells that have been left uncapped right now [to reduce methane emissions from abandoned wells]."

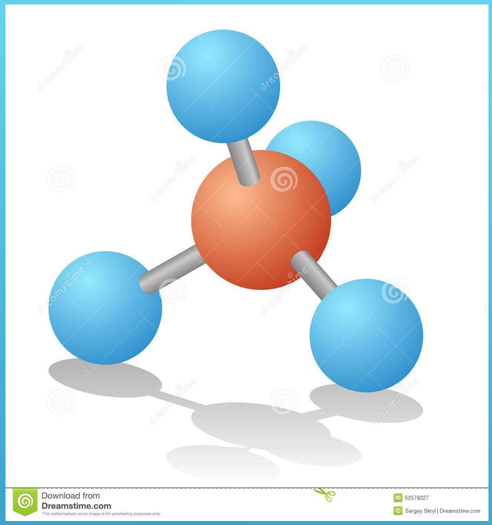


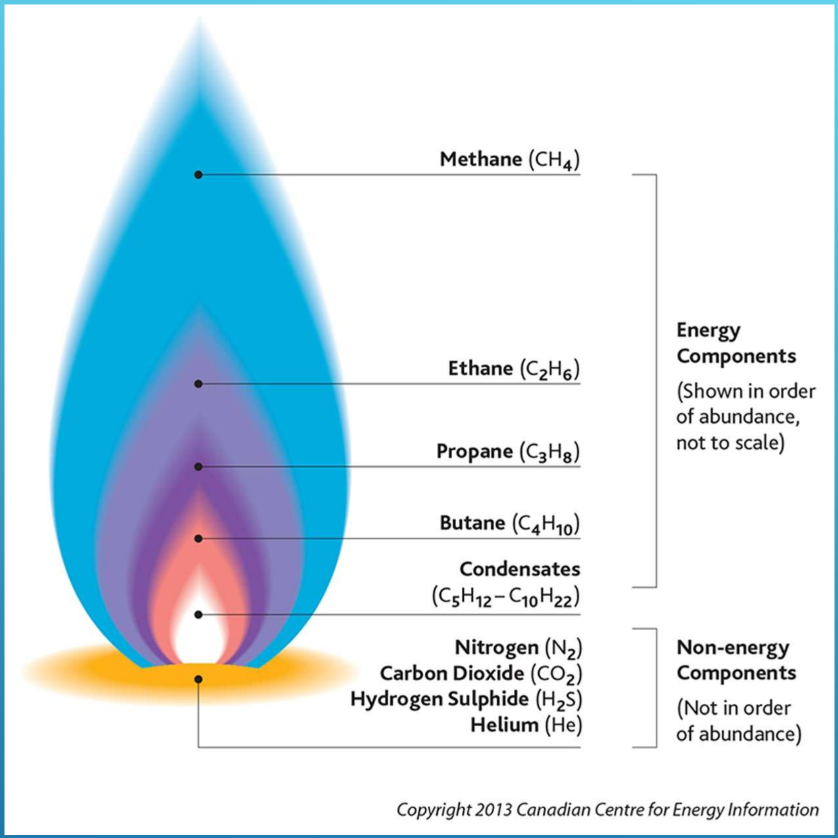
JOE BIDEN COMMENTS ON FRACKING

EandE News, 9/18/20

CONTENTS

- What is natural gas?
- How are oil and natural gas formed?
- History of Natural Gas
- CO_2 Facts
- The Shale Revolution
- Environmental considerations of hydraulic fracturing
- Renewable Natural Gas (RNG)
- Natural gas production and consumption and related CO_2 statistics
- Methane Emissions
- LNG Production and sales
- Fuel cells
- Environmental issues with natural gas
- Carbon capture and storage options
- Conclusions





Methane = 87-98%
Ethane = 1.5-9%
Propane = 0.1-1.5%
Butane = trace-0.6%
Pentane = trace-0.08%
CO2 = 0.5-1.0%
(mole percent)

WHAT IS NATURAL GAS? TYPICAL NATURAL GAS CONSTITUENTS

N.Y. governor backs statewide gas ban, E&E News, 1/6/22

- N.Y.'s governor announced her backing for what would be the nation's first *statewide natural gas ban for new buildings*
- A statewide natural gas ban would raise the national bar for climate action for buildings,, a top source of emissions and an area where state-level policy makers can exert an unusual degree of pressure
- A state blueprint called for the state to pass legislation requiring al new buildings to use zero-emission sources of heat by 2027, that would require most of them to use electricity rather than fossil fuels
- This would follow in the footsteps of NYC, which became the nation's largest U.S. city in December to ban the use of fossil fuels for building heat for new buildings
- Gov. Hochul also laid out a new target of electrifying 2 million homes by 2030, requiring a tenfold increase in the current rate of adoption of electric heat
- *What do you think of limiting home owners on their choice of heating fuels?*
- Ironically, in the near term, the source of additional electricity would probably mostly be natural gas power plants, until renewables, electric storage, and electric transmission lines caught up to the increased demand
- Natural gas bans first took place at the city level in CA in 2019, counteracted by a wave of state level preemption laws that prevent cities from restricting fossil fuel use in buildings. 20 states have passed such preemption laws

N.Y. Governor Hochul

NEW YORK AND NATURAL GAS

- A tiny proportion of organic matter — about 0.1% — escapes being eaten or oxidized on the surface. Transported by water, it sometimes sinks to the bottom of the sea or large continental lakes. It is partly preserved in these poorly oxygenated environments. It mixes with inorganic matter, such as clay particles and very fine sand, and with dead marine plankton. This mixture is transformed into dark, foul-smelling mud by anaerobic bacteria.
- Over time, this mud accumulates and hardens. Mud that contains at least 1 to 2% organic matter may be transformed into source rock, which eventually produces oil and gas deposits.
- The weight of accumulating sediment very slowly pushes the source rock further under the Earth's crust, by a few meters to a few hundred meters every million years or so. This gradual sinking is called subsidence and leads to the formation of sedimentary basins.
- At a depth of 2,000 meters, when the temperature reaches 100°C (212F), kerogen (solid, insoluble organic matter in sedimentary rocks) starts to release hydrocarbons.
- Between 2,000 and 3,800 meters, it turns into oil. This depth interval is known as the oil window.
- When the source rock sinks further, to between 3,800 and 5,000 meters, production of liquid hydrocarbons peaks. The liquids produced become increasingly lighter and gradually turn into methane (ch4) gas, the lightest hydrocarbon . This depth interval is known as the gas window.
- There are no hydrocarbons below a depth of 8,000 – 10,0000 meters (26,200-32,800 feet), because they are destroyed by the high temperatures found there.
- The proportion of liquids and gas generated in this way depends on the type of source rock. If the organic debris is composed mostly of animal origin, it will produce more oil than gas. If it is composed mainly of plant debris, the source rock will produce mostly gas.
- With an estimated average sedimentation of 50 meters every million years, it takes 60 million years for dead animals and plants to become hydrocarbons in sedimentary basins. Therefore, natural gas and oil are classified as non-renewable energy resources.

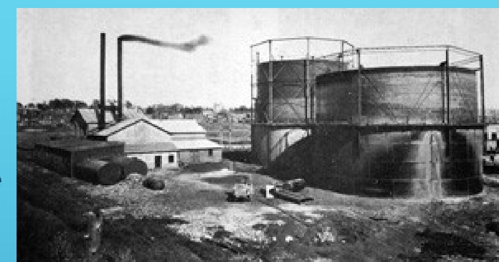
Figure 4: Photograph of the Utica Shale near the town of Donnacona, Quebec, Canada. Dark beds are shale, light beds are limestone. Part of the dark color in the Utica

HOW ARE OIL AND NATURAL GAS FORMED?

https://www.planete-energies.com/en/medias/close/how-oil-and-gas-deposits-are-formed

HISTORY OF NATURAL GAS

- 1785 - Britain was the first country to commercialize the use of natural gas. Natural gas produced from coal (manufactured gas plant - MGP) was used to light houses, as well as streetlights.*
- 1816 – First U.S. gas company (using MGP) founded in Baltimore (later became BG&E)
- 1821 – First natural gas from the wellhead used in Fredonia, NY for house lighting. Came from a shale gas well
- 1855 – The heating radiator was invented by Franz San Galliin St. Petersburg, between 1855 and 1857. In 1885, Dave Lennox helped advance home heating with the help of low-cost coal-burning cast iron radiators.
- 1859 –Drake dug the first oil well and hit oil and natural gas near Titusville, PA.
- 1872 - The first long-distance gas pipeline ran 25 miles from a gas field to Rochester, New York, in 1872. It used hollowed logs for pipes.
- 1872 - Iron pipe carried natural gas for the first time when a line 5.6 miles long and 2 inches in diameter was built from Newton Wells to Titusville, Pennsylvania
- Early 1900's: world's first CHP system by Thomas Edison in NY
- 1907 - The first gas well in TX was brought in from the Petrolia field. Brown began pumping gas to nearby cities and by 1913 was serving Dallas, Fort Worth, and 21 other towns.
- 1923 - The Regulo, the first commercial thermostat in domestic ovens, is fitted to the New World H16 Radiation Gas Cooker made by Davis Gas Stove, giving the user total control over the cooking process
- 1926 - Gas-fired refrigerators by Servel are added as a new domestic use for natural gas
- 1932 - The first domestic gas water heater to work efficiently is the instantaneous water heater. Bernard Friedman introduced the heater into Britain, under the name Ascot
- 1937 - Gas-fired air conditioning units by Servel are introduced in the U.S.
- 1947 - The first hydraulic fracturing treatment was pumped on a gas well operated by Pan American Petroleum Corporation in Grant County, KS.
- 1947: The purchase of the Big Inch and Little Big Inch oil pipelines by Texas Eastern was finalized; lines were converted to natural gas.



* MGP – H_2 50%, CH_4 35%, CO, ethylene

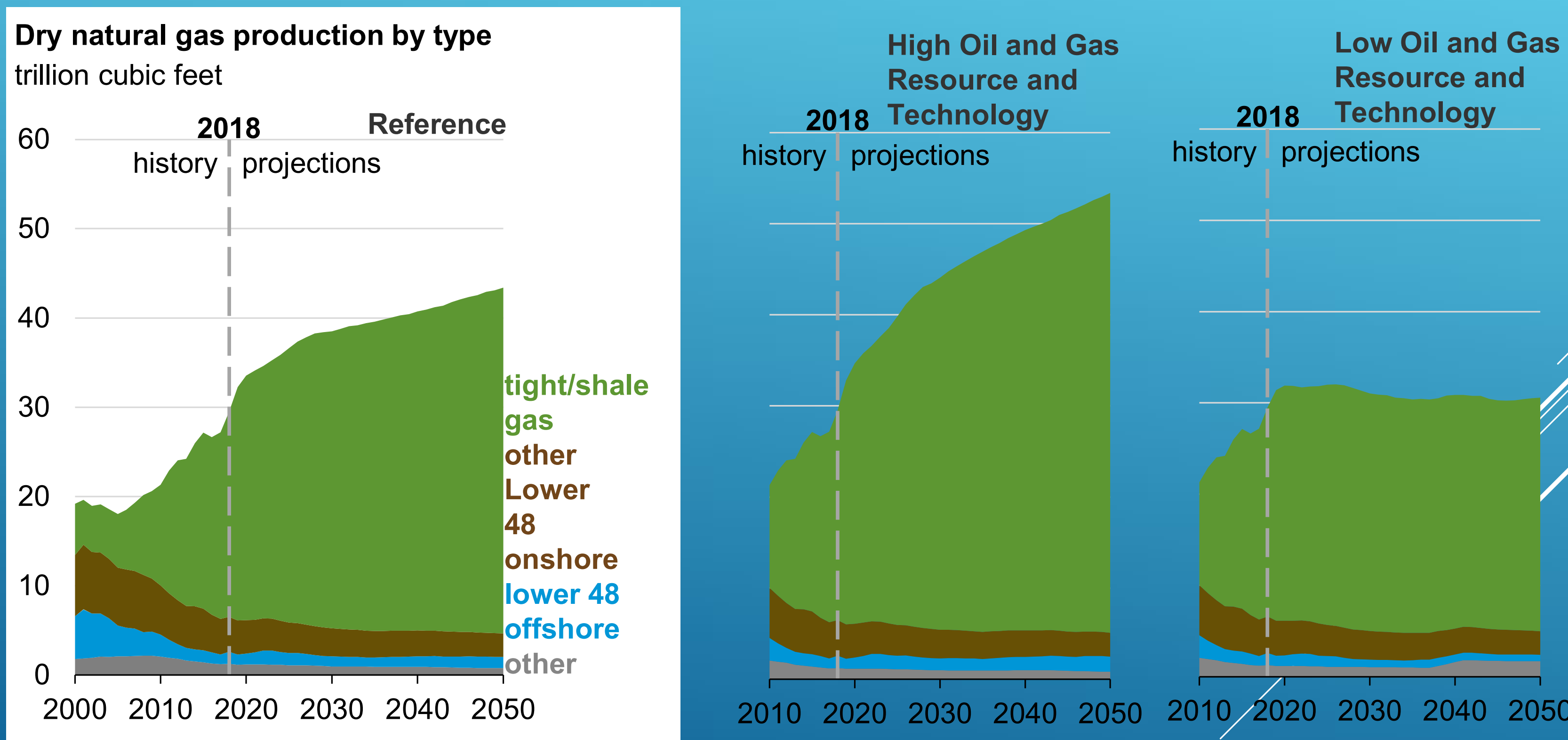
HISTORY OF NATURAL GAS (C0NTINUED)

- 1950 - Domestic natural gas customers exceed 18 million; gas now in 46 states
- 1951 - Trans-Continental Gas completed an 1,840-mile long gas pipeline from the vast reserves on the TX-LA Gulf Coast to the high-demand areas around Philadelphia, NJ, and NY
- Mid- 1960's - U.S. Army explored the potential for phosphoric acid fuel cells (PAFCs) that ran on "logistic fuels," fuels commonly available to units in the field.
- 1966 – Last MGP plant stops operating in U.S.
- 1977 - DOE successfully demonstrates massive hydraulic fracturing
- 1982 – World's first fully condensing furnace, the GRI-developed pulse combustion furnace, with 96% efficiency, produced in the U.S. by Lennox
- 1985 – Enron formed out of Northern Natural Gas and Houston Natural Gas
- 1988 -- Coalbed methane production reaches 50 Bcf/yr
- 1992 -- IFC PAFC150-kW fuel cell commercialized (GRI, EPRI, DOE R&D)
- 1991 – GRI R&D subsidizes Mitchell Energy's first successful Horizontal well in the Texas Barnett shale
- 1998 - Mitchell Energy engineers achieve commercial gas shale extraction
- 2001- Enron scandal
- 2003 -Coalbed methane production in the U.S. exceeds 1,600 Bcf/yr or 4.4 Bcf/d
- 2007 Shale gas production in U.S. reaches 1.29 Bcf/day
- 2007 – Enron ceased operations
- 2010 – SW Gas/DOE Aisin gas heat pump (9-ton) commercialized
- 2014 – Shale gas production reaches 50% of U.S. production
- 2021 – Tight European natural gas market threatened by Russia-Ukraine issue

Fuel cell

Gas heat pump

U.S. DRY NATURAL GAS PRODUCTION INCREASES AS A RESULT OF CONTINUED DEVELOPMENT OF TIGHT AND SHALE RESOURCES—



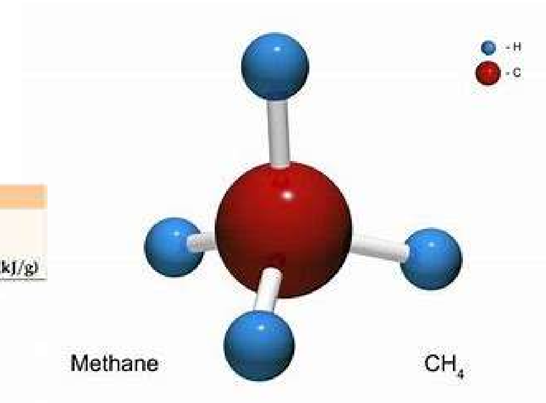
Ref: EIA AEO 2019

CO2 Facts: Natural gas is the lowest emitter of CO2 of all the fossil fuels

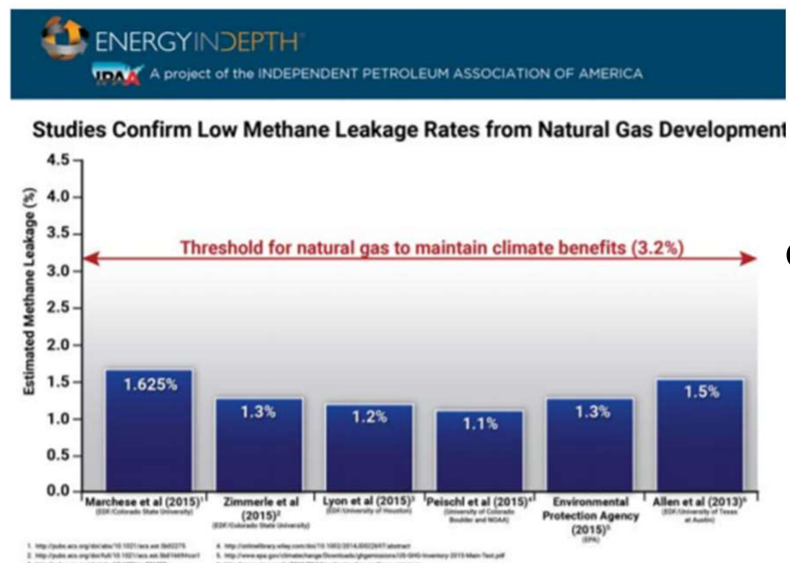
- **Coal – 207 pounds (lb) of CO2 are produced per MMBtu's of coal combusted**
- **Oil – 160 lb CO2/MMBtu's**
- **Natural Gas – 117 lb CO2/MMBtu's**
- **GWP (Global Warming Potential) of methane – 23-28 times CO2 long term (100 years) and 72-83 short term (10 years)**
- **Methane lifetime in atmosphere – 9.1 years**
- **Leakage of methane from U.S. natural gas system is only 1.5%**
- **"Breakeven" methane leakage with coal is 3.2-3.5% (GWP = 83) or 9.6% (GWP = 25)**
- **Breakeven with oil is 1.7% (GWP = 83) or 4.7% (GWP = 25)**

TABLE 5.5 Fuel Values and Compositions of Some Common Fuels

	Approximate Elemental Composition (%)			
	C	H	O	Fuel Value (kJ/g)
Wood (pine)	50	6	44	18
Anthracite coal (Pennsylvania)	82	1	2	31
Bituminous coal (Pennsylvania)	77	5	7	32
Charcoal	100	0	0	34
Crude oil (Texas)	85	12	0	45
Gasoline	85	15	0	48
Natural gas	70	23	0	49
Hydrogen	0	100	0	142

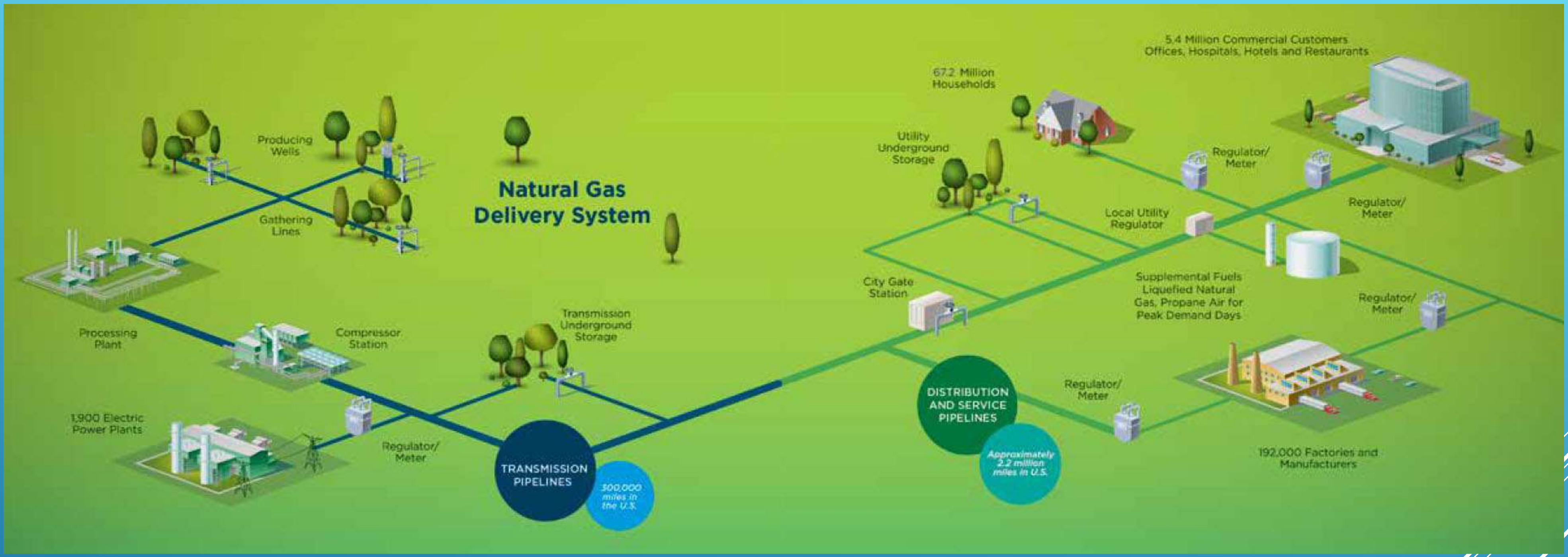


$CH_4 + 2O_2 = CO_2 + 2H_2O$



GWP = 83

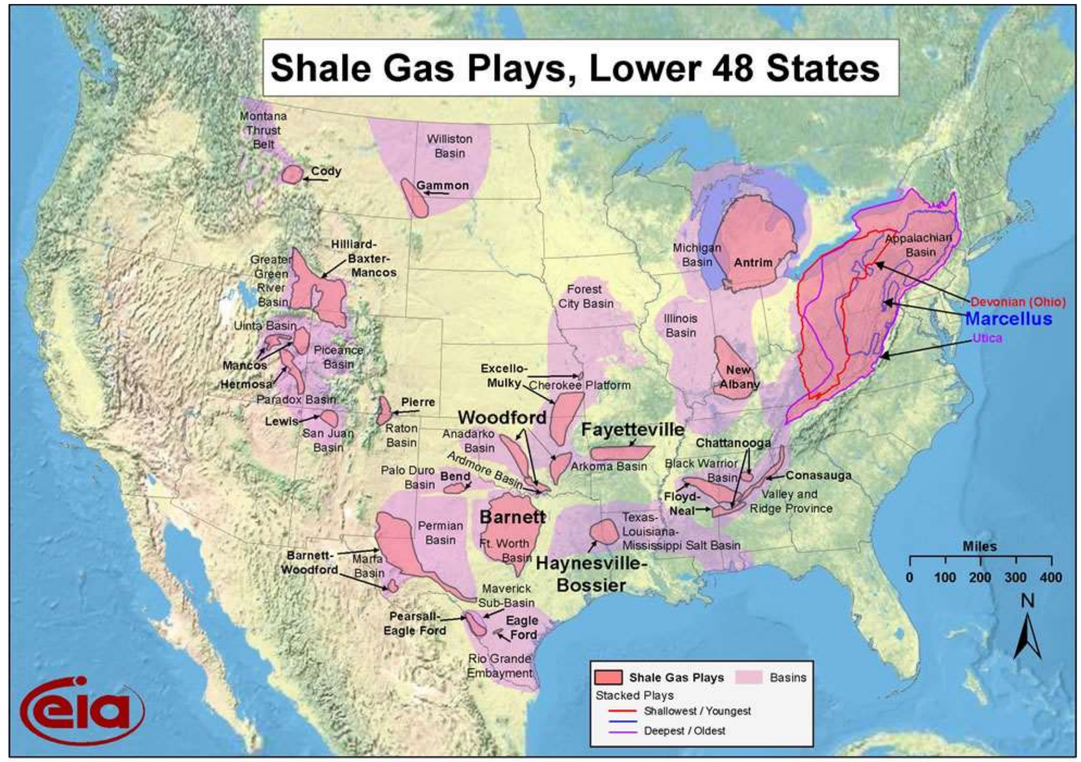
Ref: IPAA



NATURAL GAS SYSTEM

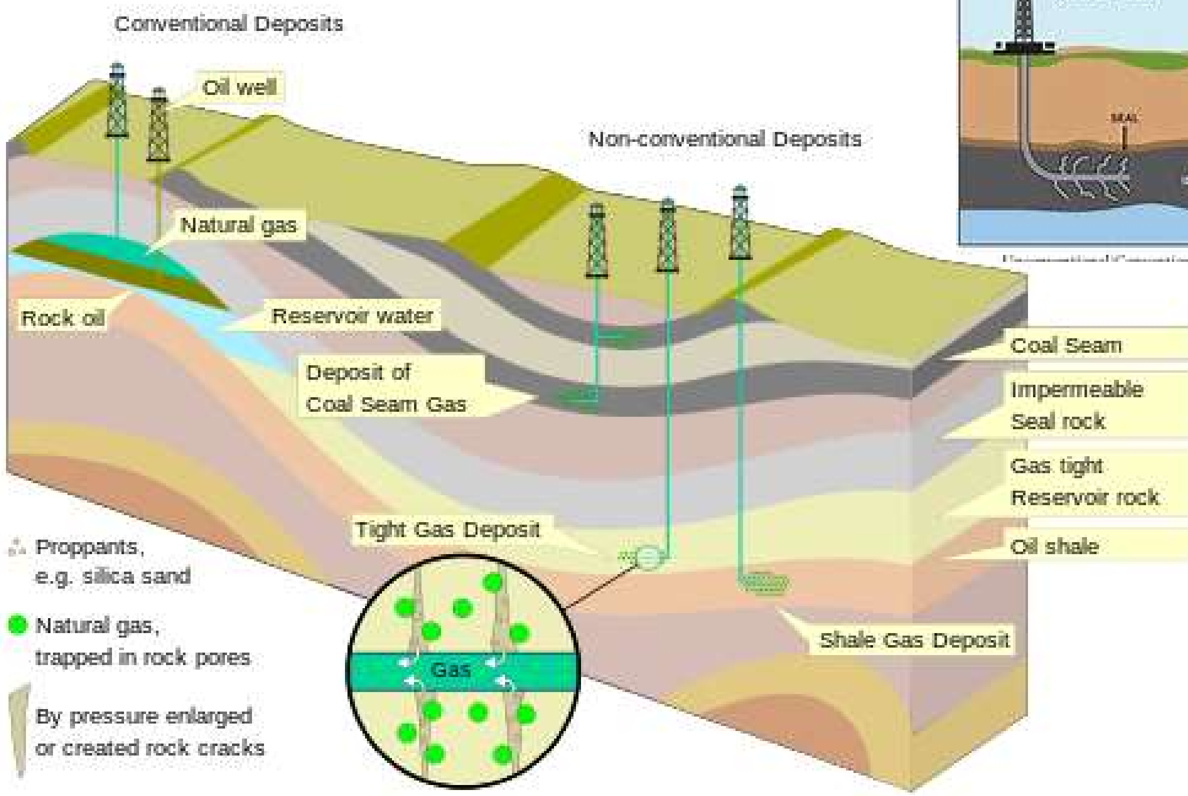
The Shale Revolution: What is it and what are its implications?

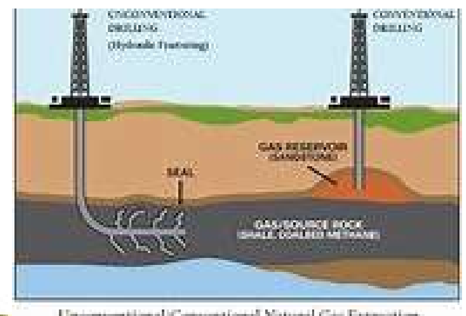
- Shale revolution was the results of 30 years of R&D on three technologies and innovative producers:
  - 3-D seismic
  - Horizontal drilling
  - Hydraulic fracturing



Source: Energy Information Administration based on data from various published studies.
Updated: March 10, 2010

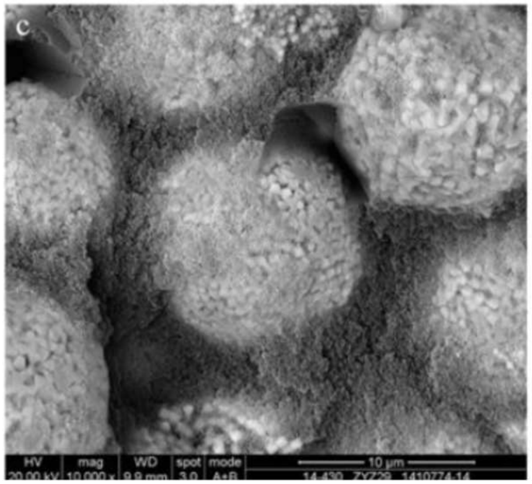
Illustration of Shale Gas Play



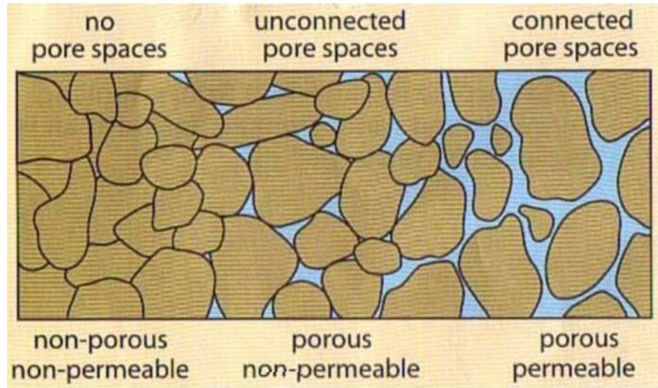


Shale rock

Shale: microscopically and permeability and porosity



Pore spaces in shale



Shale

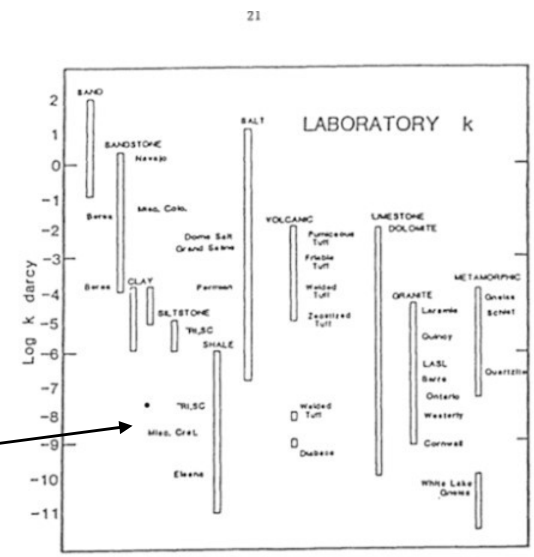


Figure 5-1. Laboratory Measurement of Permeability of Intact Specimens. [Boxes show range of measured values. Pressure was hydrostatic and less than 10 MPa and temperature about 25 C. Data from Brace (1980), Gloyna and Reynolds (1961), and Keller (1960).]

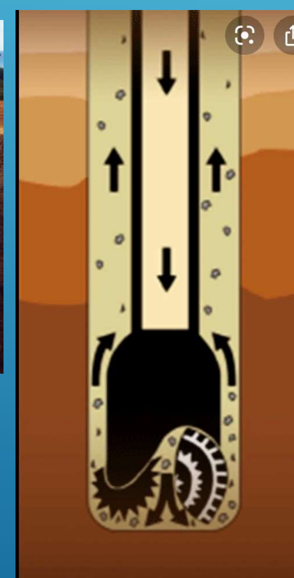
- Permeability: A measure of the ease of flow of a gas or fluid *through* a porous solid
- Porosity: A measure of a rock's ability to hold a fluid; ratio of pore space divided by total rock volume

Cement

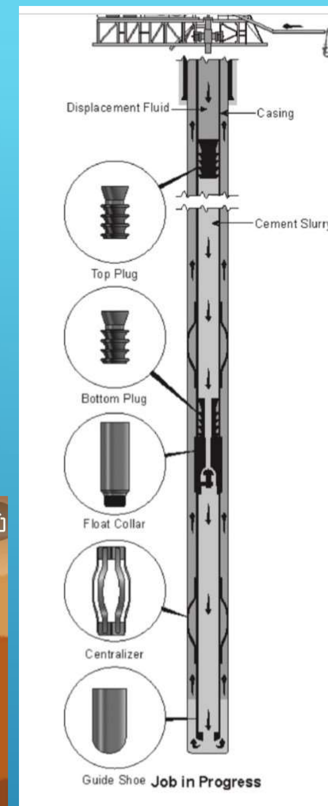
Steel Casing

Casing Design

Installing well casing



Drilling

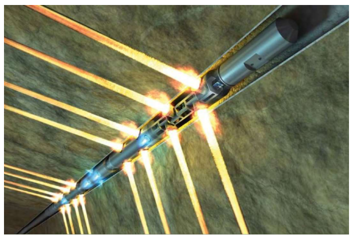


Cementing

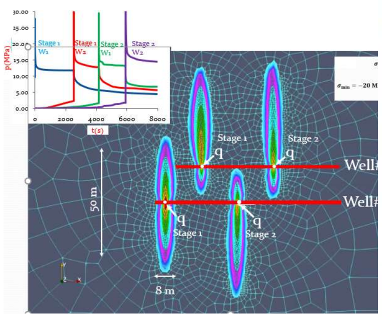
DRILLING, CASING AND CEMENTING

Illustration of Natural Gas Fracturing

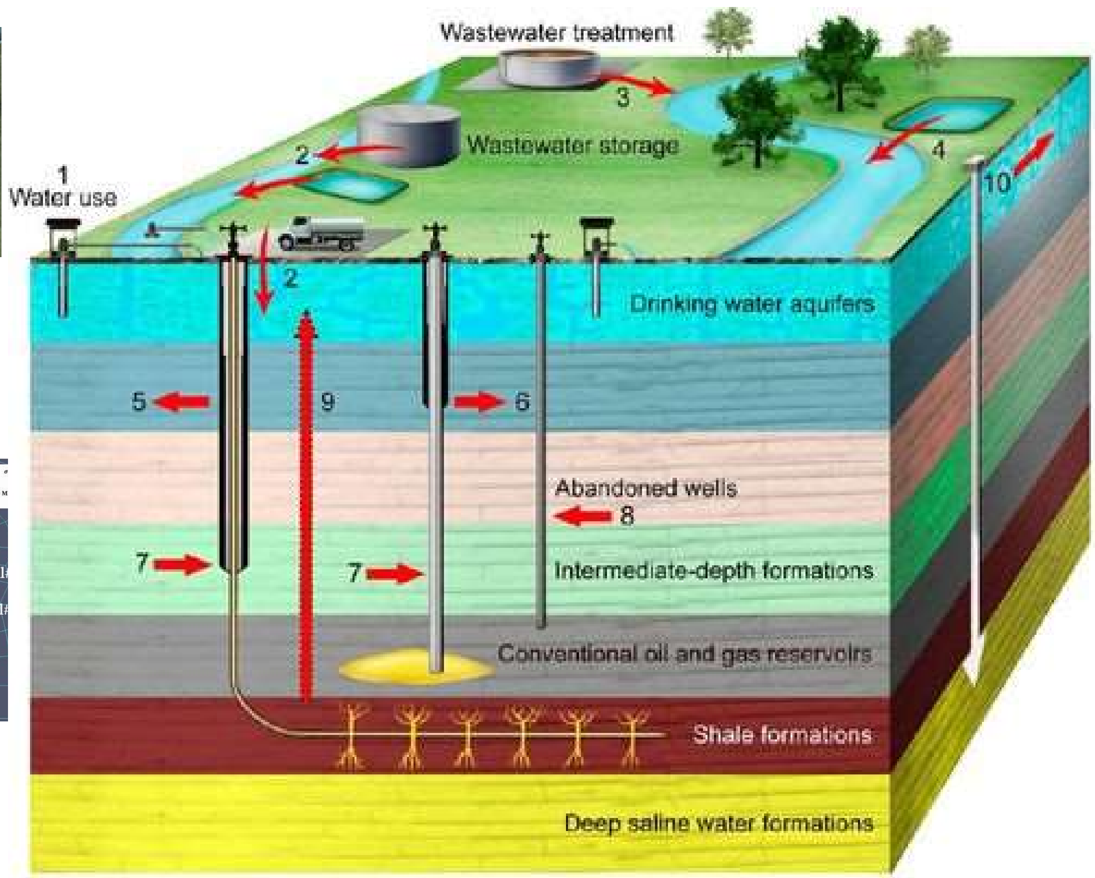
Proppant

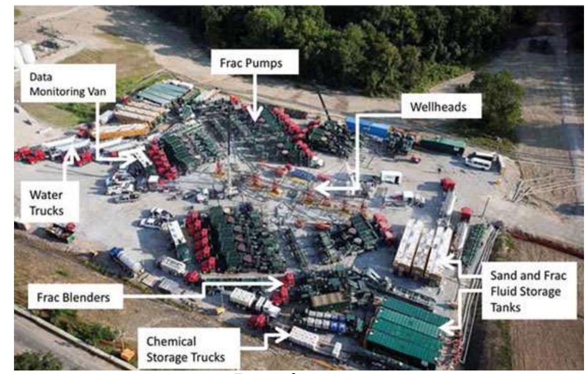


Perforating



Fracturing





During

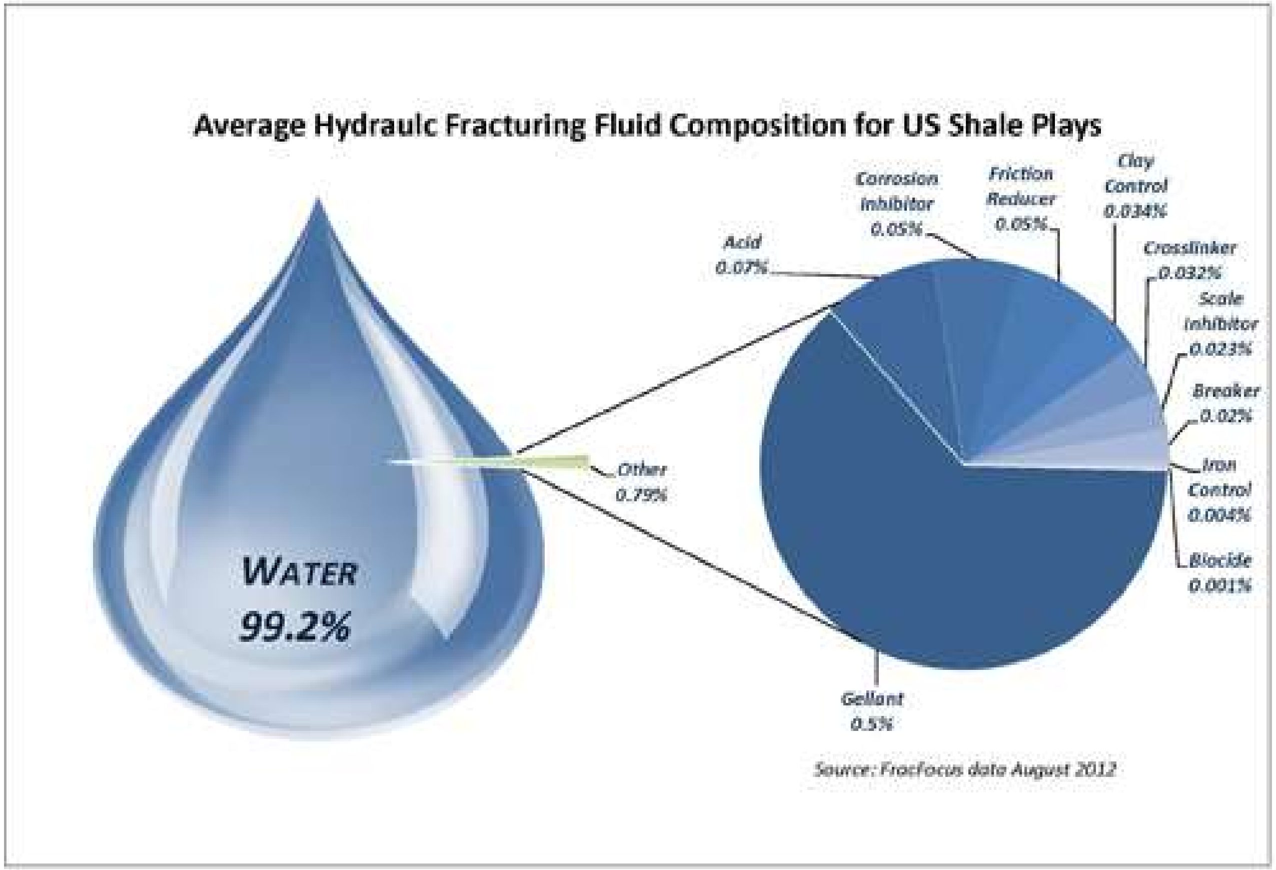
After

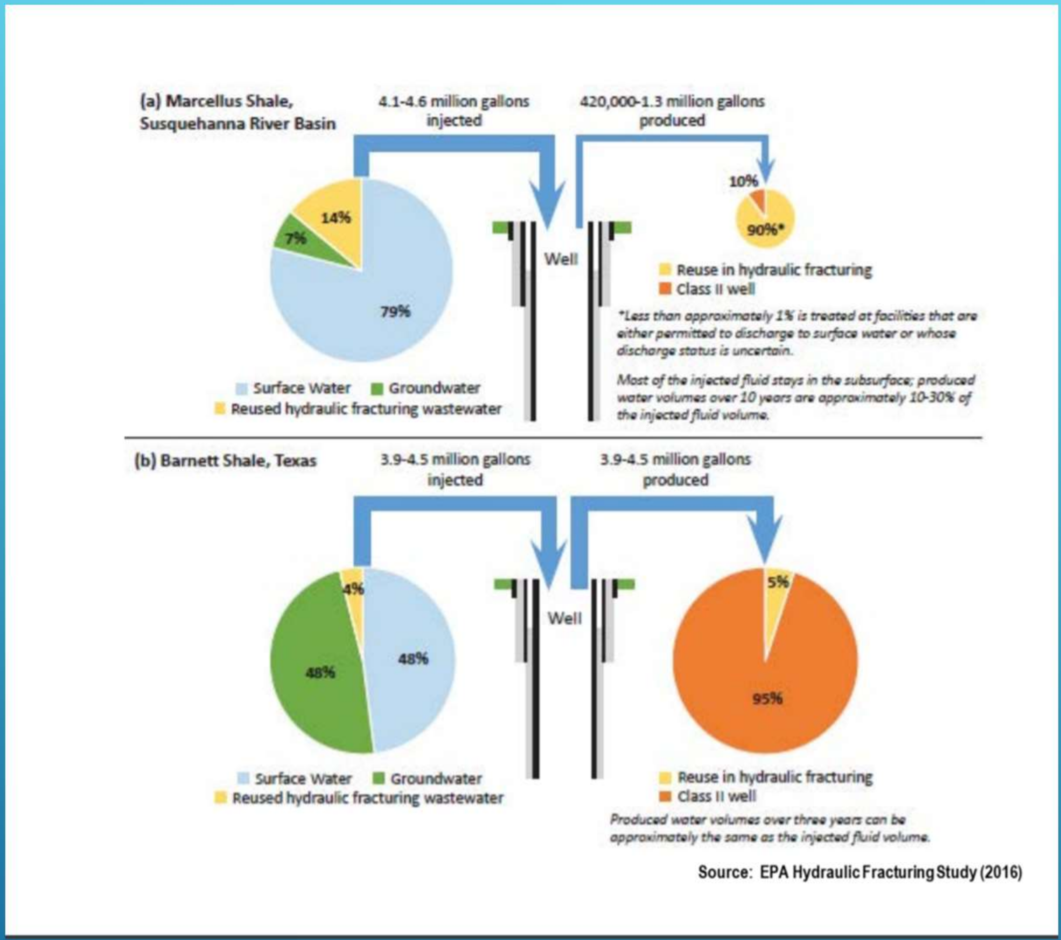
Environmental Considerations of Hydraulic Fracturing

- Water use – 4-5 million gallons of water per well (2 weeks worth of golf course watering)
- Chemicals used – proppants (sand), lubricants, detergents: 99% of ingredients are water and sand
- Ground (drinking) water issues – should not be a concern – 2 to 6 layers of steel and concrete pipe between ground water aquifers and the gas well.
  - Aquifers (down to 2,000 feet) are shallow, gas wells are deep (usually below 5,000 feet)
- Air pollution
- Seismic events (mini-earthquakes) with disposal of produced water (from ancient buried seas) – must be disposed of in proper zones
- Drilling muds and drill cuttings recycling or disposal
- Hydraulic fracturing fluid *and* produced water recycling or disposal

National Driller
Containing, Disposing of Drilling Mud and Drilling Cuttings | 2015 ...
Visit

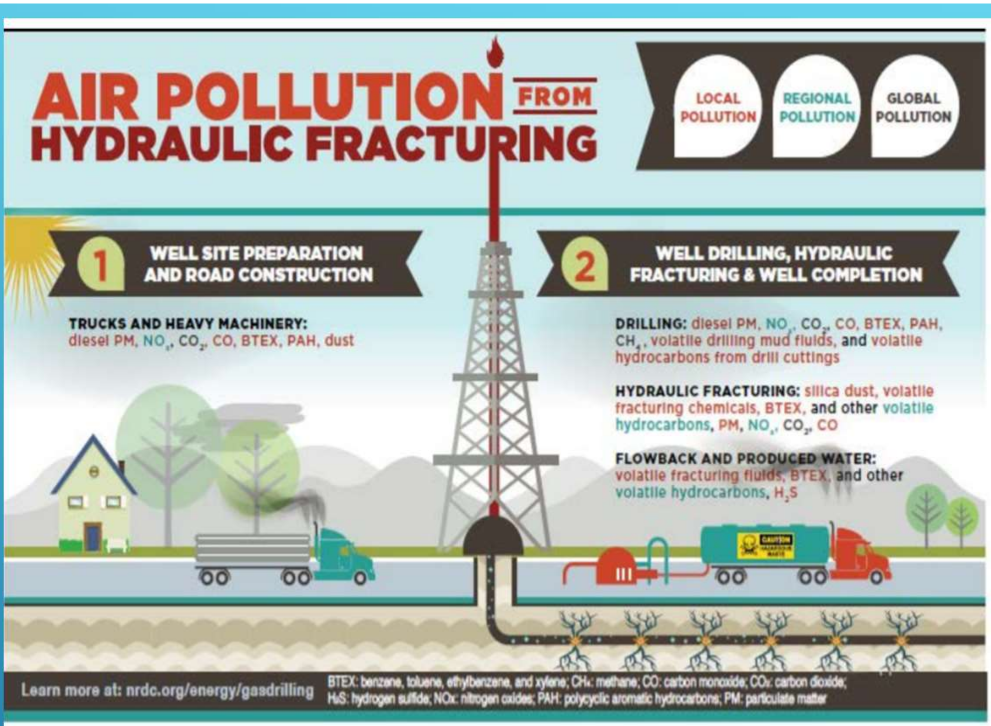
Fracture Fluids Composition



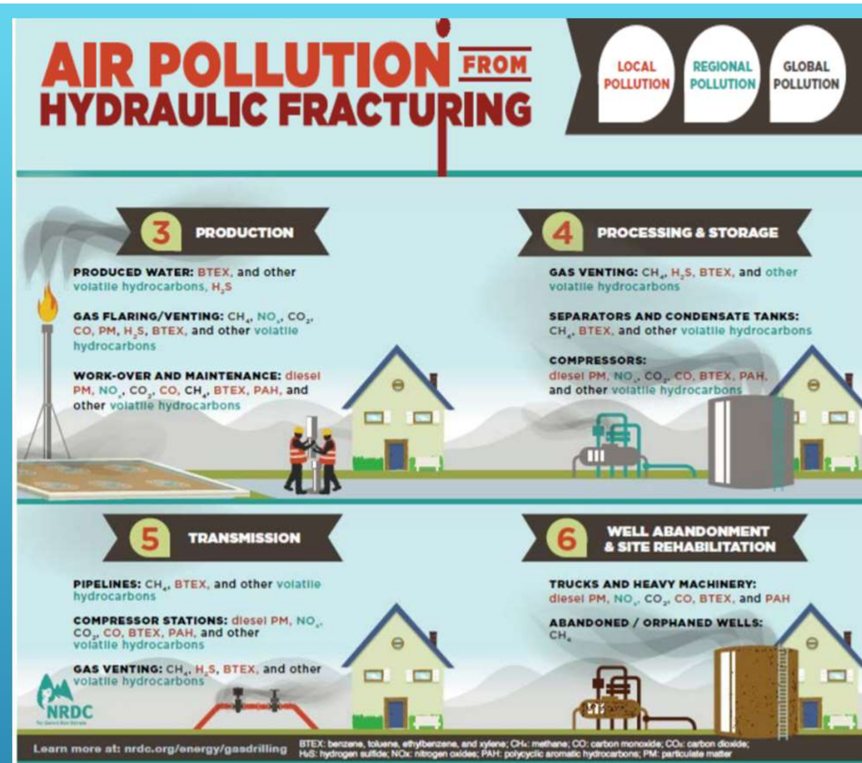


HYDRAULIC FRACTURING WATER USE AND DISPOSAL

Ref: EPA

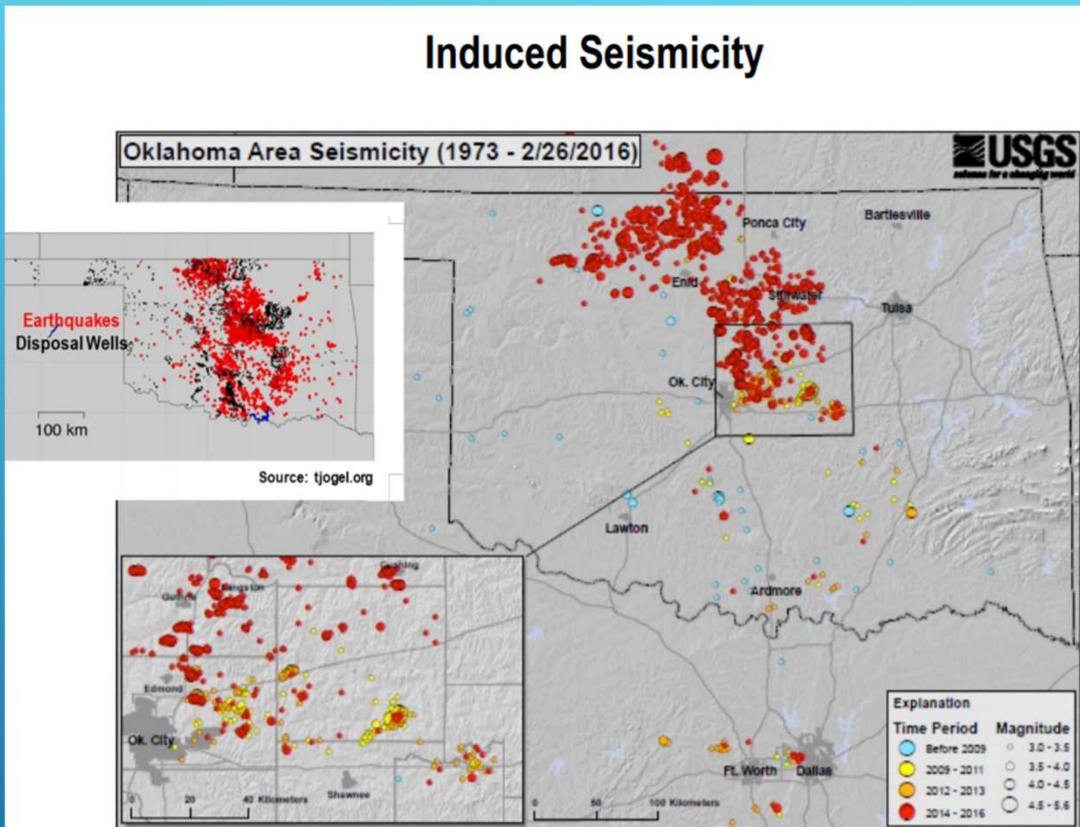


Source: Natural Resources Defense Council



POTENTIAL AIR POLLUTION FROM HYDRAULIC FRACTURING

Ref: NRDC



- To reduce induced seismicity, the state has identified 15,000 square miles of active fault zones, and restricted or eliminated produced water disposal in those area
- Oklahoma's 180-day moving average of 2.8 magnitude or greater earthquakes peaked at approximately 4.5 per day in summer 2015, declining to about 2.3 a day in fall 2016.

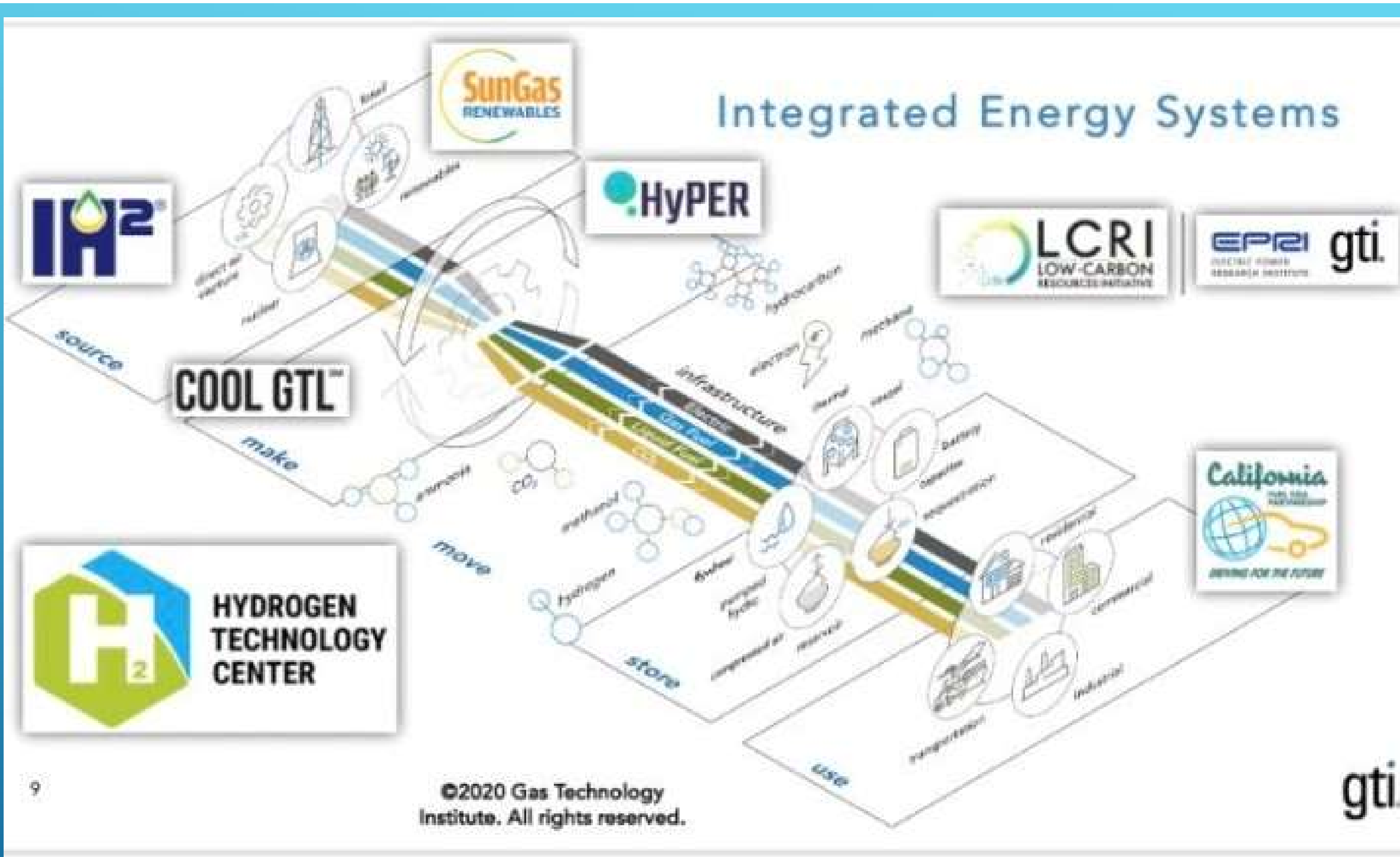
INDUCED SEISMICITY AND DISPOSAL WELLS FOR PRODUCED WATERS

Ref: USGS, TJOGEL

- The vast majority of U.S. RNG is produced through biological decomposition of waste in landfills. In 2017, RNG met 43% of natural gas demand from the transportation sector, according to the EPA and EIA.
- Key drivers of consumption have been the California Low Carbon Fuel Standard and the national Renewable Fuels Standard
- Traditionally, biogas (the feedstock for RNG) has been converted to electricity for use onsite or sold into the power market.
- Meanwhile, large investor-owned natural gas utilities either facing or concerned about potential regulations on $CO2$ emissions plan to “green” their gas systems by replacing geologic natural gas with RNG.
- In 2019, for instance, SoCal Gas and VGS (Vermont Gas) committed to displacing 20% of their gas supply with RNG by 2030, Summit Utilities committed to 5% RNG by 2020 and Dominion Energy committed to 4% by 2040. FortisBC committed to 15% of its supply from RNG by 2030. WGL is considering RNG sources of supply.

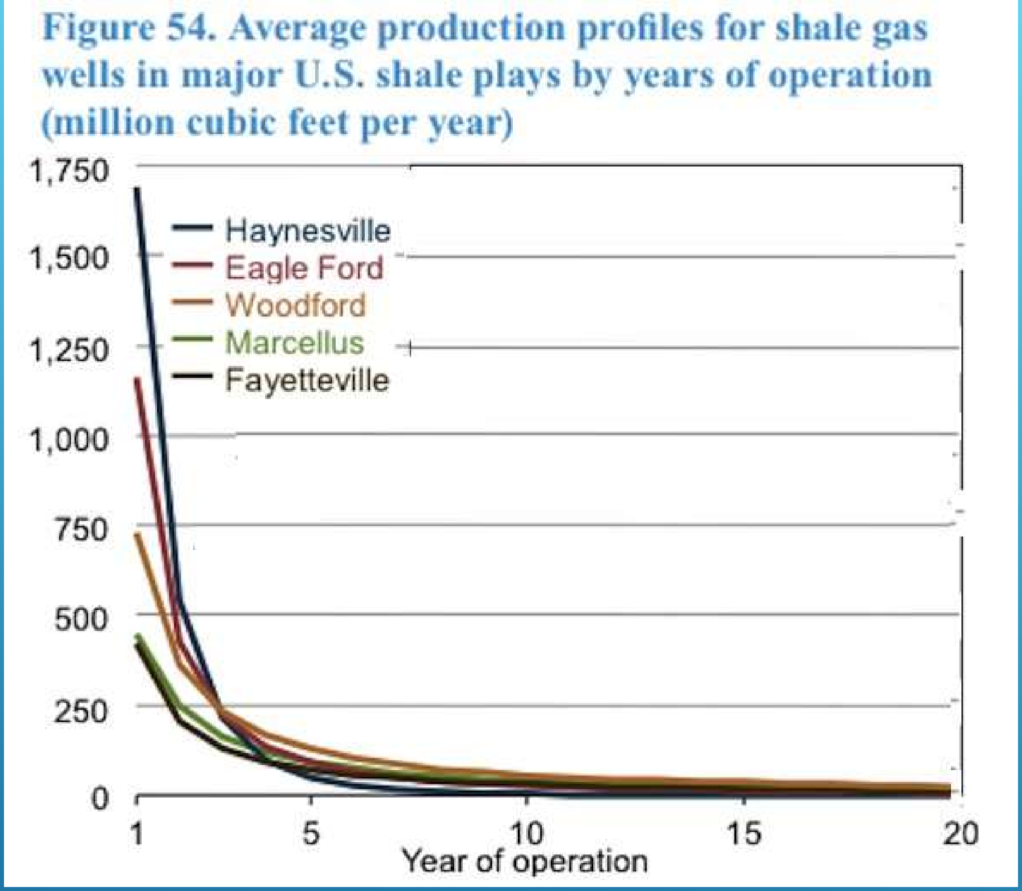
RENEWABLE NATURAL GAS (RNG) FACTS

Ref: BCSE 2020 Factbook



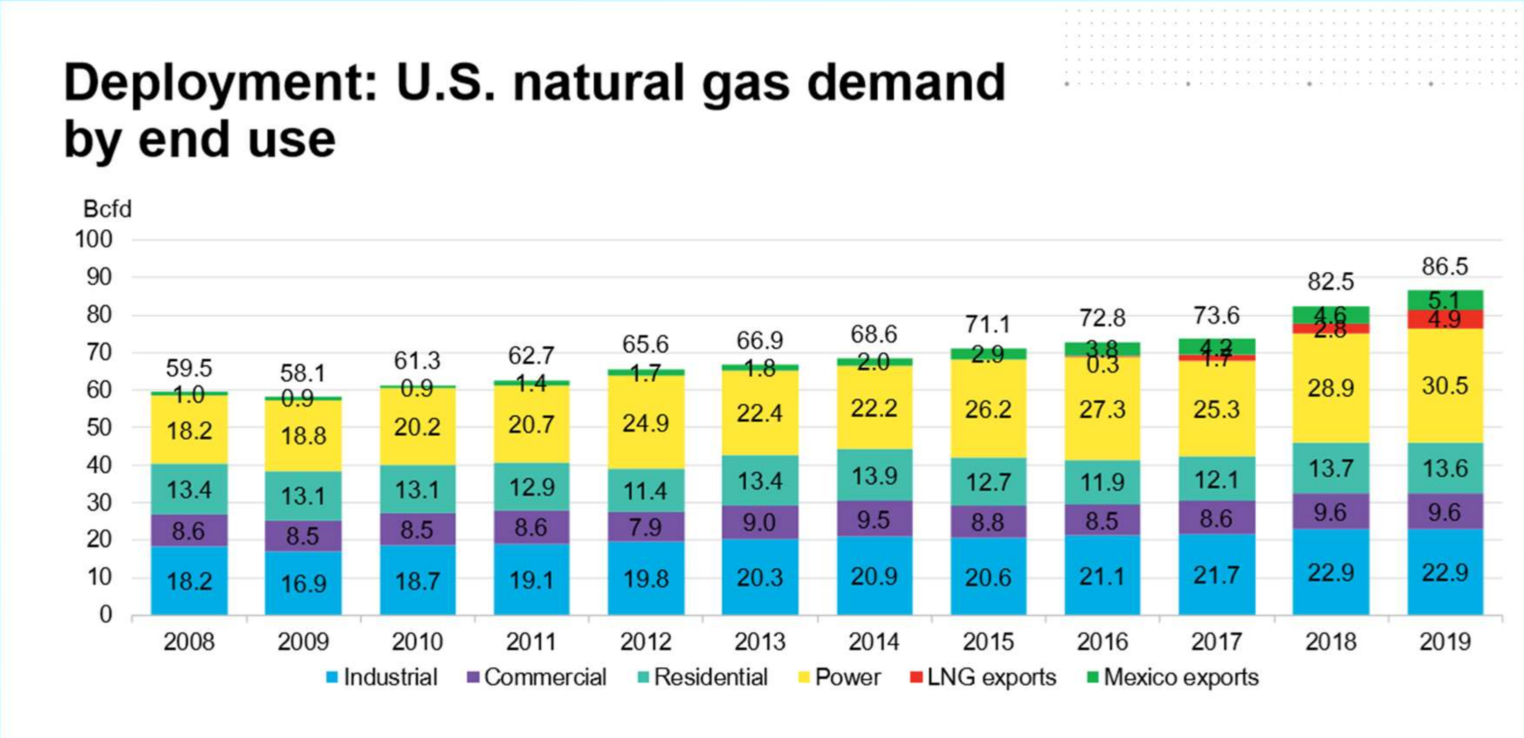
BRIDGE TO THE FUTURE? NATURAL GAS/RNG/RENEWABLES TO ENERGY

Ref: GTI, 2020



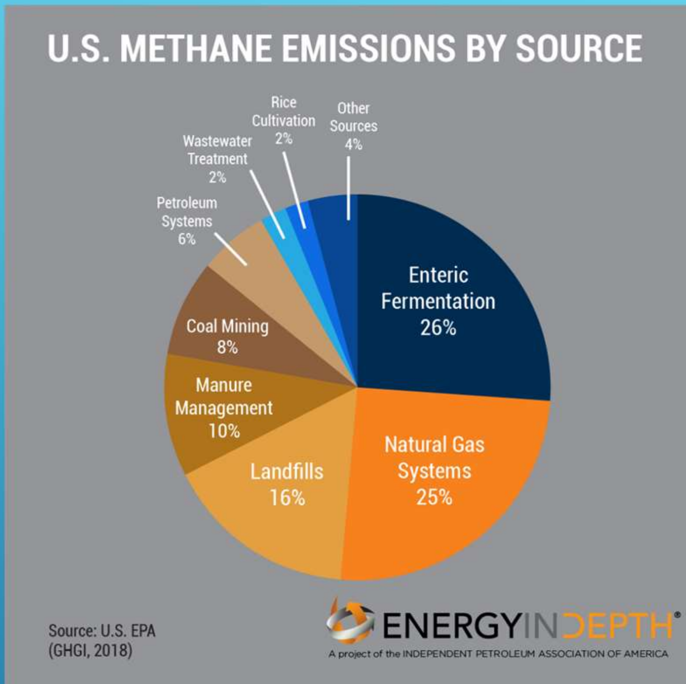
"DRILL BABY DRILL":

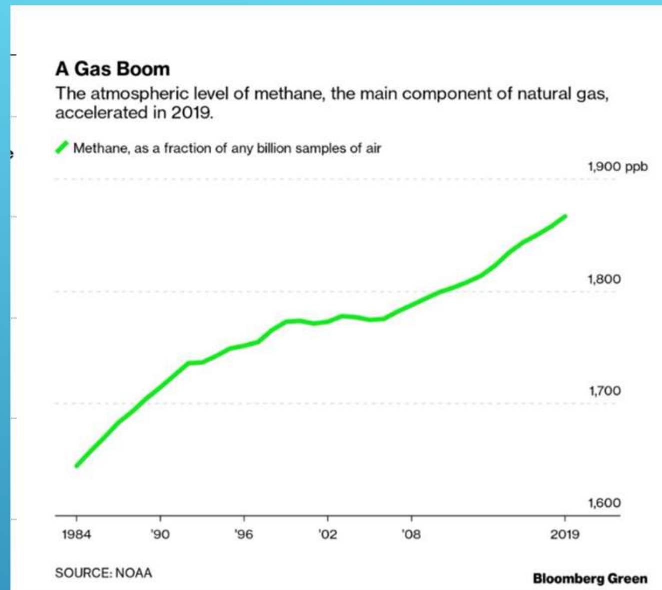
DUE TO HIGH DEPLETION RATES, HYDRAULICALLY FRACTURED WELLS DEPLETE RAPIDLY, SO MORE DRILLING IS NECESSARY TO KEEP UP PRODUCTION RATES

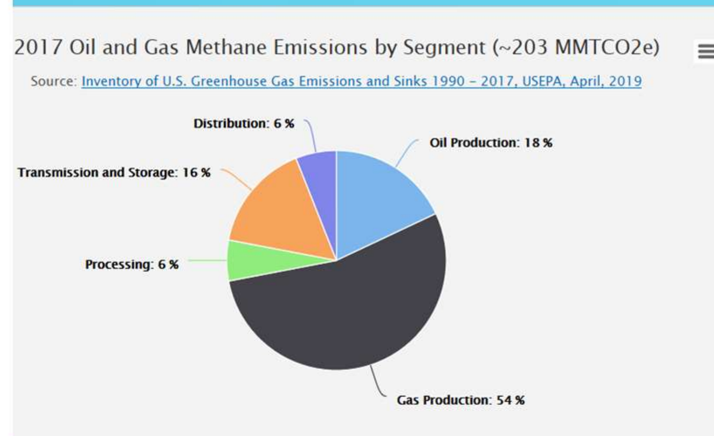


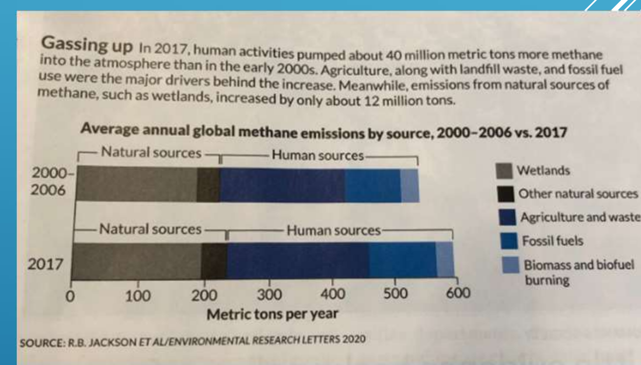
NATURAL GAS DEMAND BY END USE SECTOR

Ref: BCSE 2020 Factbook





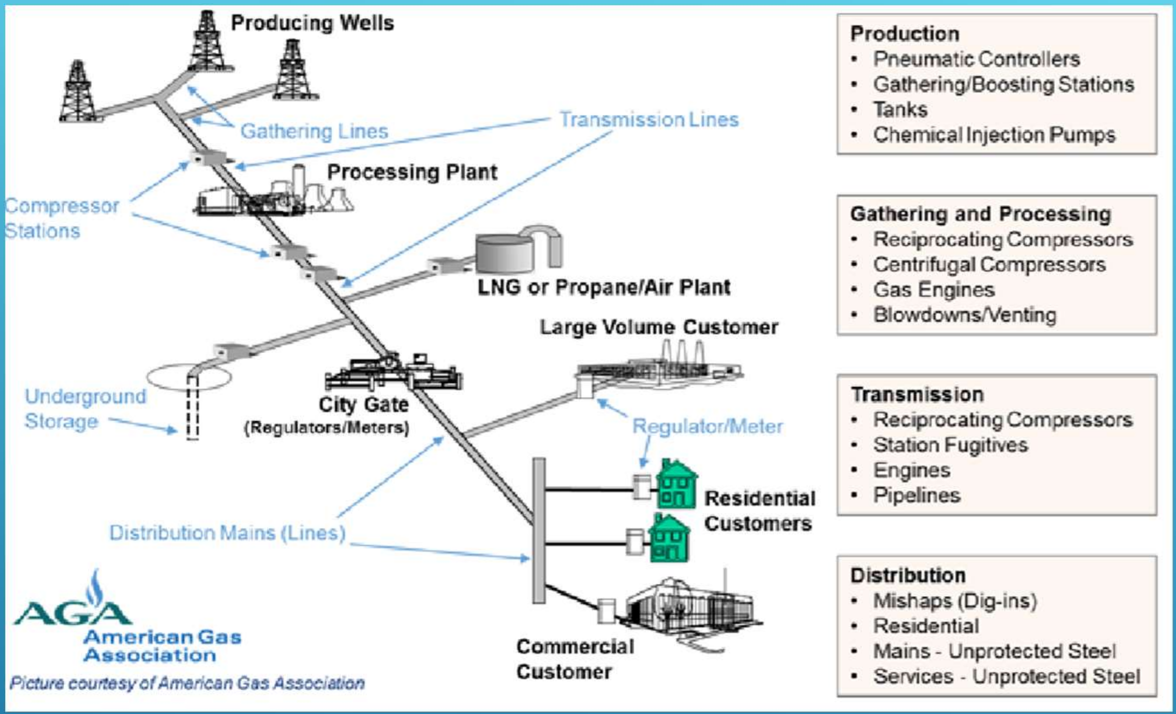




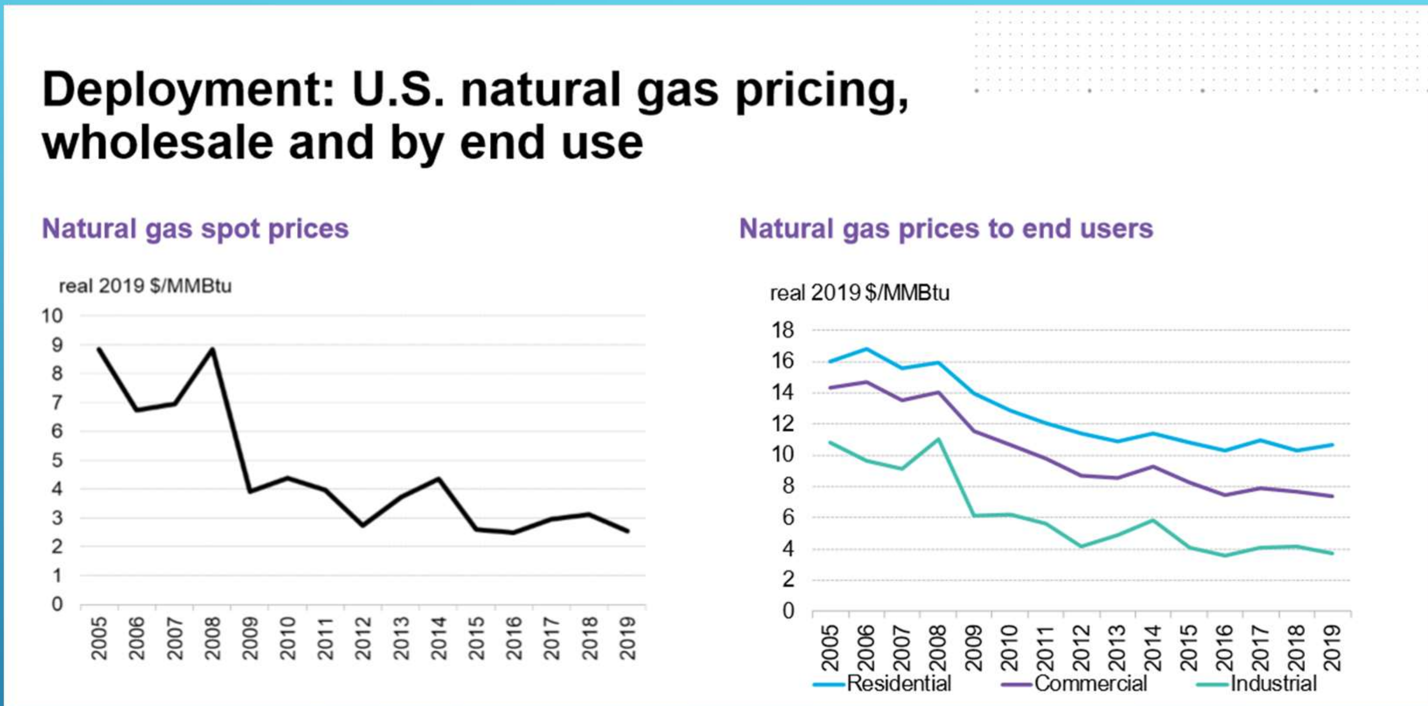
METHANE EMISSIONS BY SOURCE, FROM THE U.S. NATURAL GAS SYSTEM, 2017 AND WORLDWIDE METHANE EMISSIONS

Total: 166MM tons of CO2e for natural gas systems

Ref: U.S. EPA, Bloomberg 4/20
Science News 8/15/20



METHANE EMISSIONS SOURCES FROM THE NATURAL GAS SYSTEM



SHALE GAS REVOLUTION AND INCREASED SUPPLIES LED TO LOW NATURAL GAS PRICES

- Mostly methane, cooled to -260F and liquefied, with *600 times* the energy density of methane gas
- 1915 – Godfrey Cabot invented a *method* for storing liquid gas at very low temperatures
- 1918 – first large-scale liquefaction of natural gas in the U.S., to extract helium for dirigibles
- 1940 – East Ohio Gas built a full-scale peak-shaving LNG pilot plant. The Cleveland plant failed in 1944, with subsequent fires
- In 1959 the first LNG shipment by the *Methane Princess* occurred, from the Gulf Coast to the U.K.
- 1964 – First large-scale LNG sales, Algeria to France and U.K.
- 1965 – U.S. LNG industry started up again, with the building of LNG facilities for *importing* LNG *and* for storing LNG on site Importing facilities built on the mistaken impression that we were “running out of natural gas”
- 1970 – LNG international trade reaches 0.1 quads
- 2003 – imported natural gas reaches 18% of total U.S. natural gas consumption
- 2005 – Shale gas revolution begins
- 2011 – LNG trade reaches 11.9 quads
- 2016 – U.S. LNG exporting started
- 2019 – 19 LNG exporting countries. Top LNG exporters, - Qatar, Australia, U.S., Malaysia U.S. exported 3.6 Tcf of LNG. Top importers – Japan, China, South Korea, India
- 2/2022 – U.S. held its ranking as the top LNG exporter for the second month in a row, topping Qatar. Out of 101 shipments In January, more than a third went to Europe, helping to deal with the volatile natural gas market there

HISTORY OF LIQUEFIED NATURAL GAS (LNG)

Living near or downwind of unconventional gas and oil development (UOGD) linked to increased risk of early death, Science Daily, 1/27/22

- **Elderly people living near or downwind of UOGD – which involves extraction methods including directional drilling and hydraulic fracturing – are at higher risk of early death compared with individuals who don't live near such operations**
- **The results suggest that airborne contaminants emitted by UOGD and transported downwind are contributing to increased mortality, researchers suggest**
- **Since 2015, more than 100,000 wells were drilling using directional drilling and hydraulic fracturing. Roughly 17.6 million people live within one kilometer of at least one active well**
- **Researchers studied 15 million Medicare beneficiaries. Those who lived closer to wells had a statistically significant elevate mortality risk (2.5% higher) than those who didn't live close to the wells**
- **Support for the study came from the EPA and the NIH**

Homes near
Gas well

HEALTH EFFECTS OF NATURAL GAS EXPLORATION & PRODUCTION

New Mexico methane leaks far higher than expected, N.Y. Times, 3/25/22

- **There is a longstanding discrepancy between top-down (satellite or airplane) measurements of methane emissions by EDF and others and bottoms-up site-by-site calculations of methane emissions by GTI and EPA**
- **This latest study by Stanford University estimates that oil and natural gas production in New Mexico's Permian Basin have a 9.4% leakage rate, compared to EPA estimates of a 1.4% leakage rate industrywide for natural gas, wellhead to burner tip**
- **Of course, top-down methane measurements would include emissions from coal mines, abandoned gas and oil wells, and "swamp gas"**
- **If the leakage rate nationwide is found to be 9.4%, it would put natural gas on par or exceeding coal GHG emissions**
- **The only "good news" in the study is that the majority of methane leakage is concentrated at just a few sites, so if those leaks can be identified, the leakage can be brought down quickly**
  - **And preventing leakage or venting of the natural gas will economically benefit the industry**
- ***Which number is correct, top-down or bottoms-up?***

NEW MEXICO METHANE LEAKS

- **Water use for hydraulic fracturing (3-5 MM gallons/well)**
- **GHGs**
  - **CO_2 for natural gas combustion at 117 lb CO_2/MMBtu**
  - **Methane emissions (1.5% of throughput)**
- **Air pollution: NO_x from combustion**
- **BTEX (benzene, toluene, ethyl benzene, and xylene) in production and processing**
- **Land use issues, but less with shale gas than with conventional wells**
- **Microseismic – disposal of production water**
- **Disposal issues with drilling muds and fluids**
- **Legacy issue– 550,000 abandoned gas wells – methane emissions**

ENVIRONMENTAL ISSUES WITH NATURAL GAS

CONCLUSIONS

- **The U.S. has abundant, affordable natural gas resources, available for many decades to come, thanks to the shale gas revolution**
- **Natural gas is the lowest carbon producing fossil fuel**
- **Methane emissions need to be kept to below 1.5%**
- **R&D was critical to high-efficiency appliances and to shale gas development**
- **New pipelines to carry gas to market are being delayed or cancelled**
- **Future LNG export markets are uncertain**
- **RNG, a zero carbon option, should be considered and encouraged as a source of methane for the U.S. natural gas system, to further reduce CO2 emissions from natural gas systems**
- **If natural gas is to remain a long-term option, a solution to climate change, CCS at natural gas CCT power plants may be needed**