ENERGY SOLUTIONS CENTER

Energy Industry Fundamentals

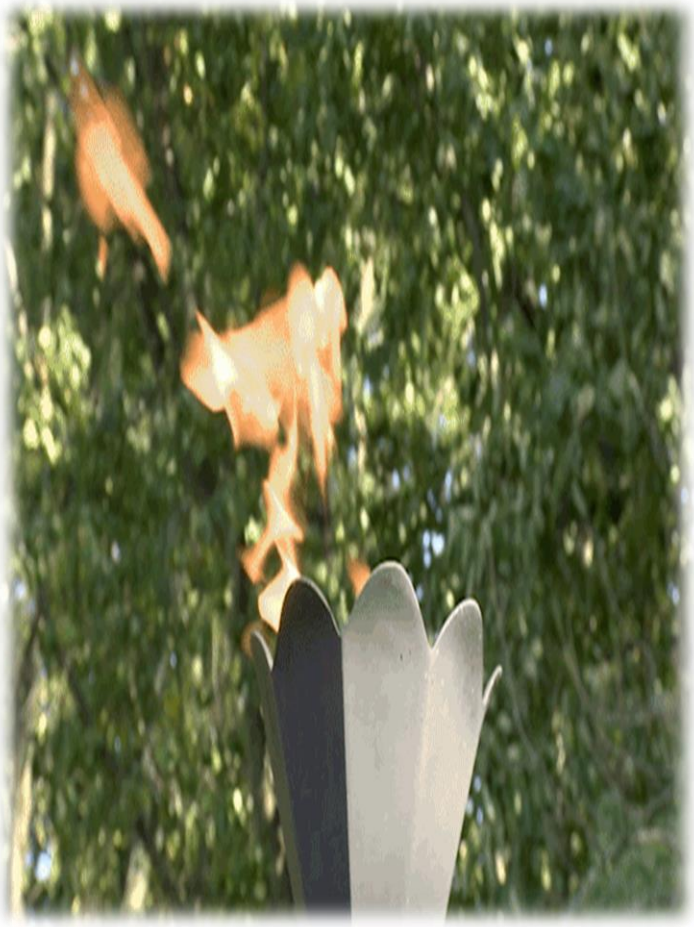
Natural Gas 101: Wells, Storage, Delivery, Measurement & Fracking

Eric Burgis, Energy Solutions Center

This unit is part of Energy Solutions Center's: Energy Industry Fundamentals Training Program

Presentation Outline

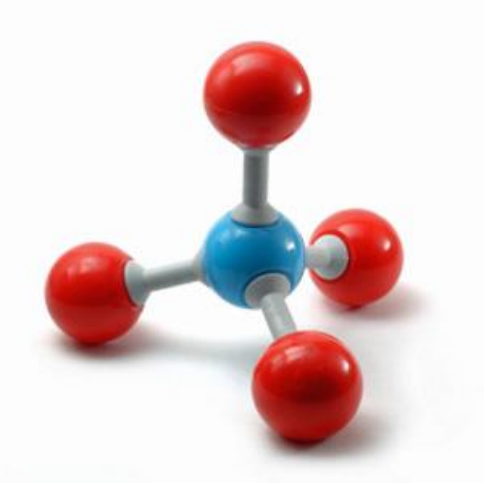
- What is natural gas?
- Lower Carbon Gas
- Gas wells
- Gas storage and delivery
- Gas measurement
- Natural gas advantages



What is Natural Gas?

Natural Gas

- Natural gas is a nonrenewable source of energy used primarily for heating and generating electricity
- Combustible hydrocarbon
- Primarily Methane (CH_4)
- Found in underground reservoirs

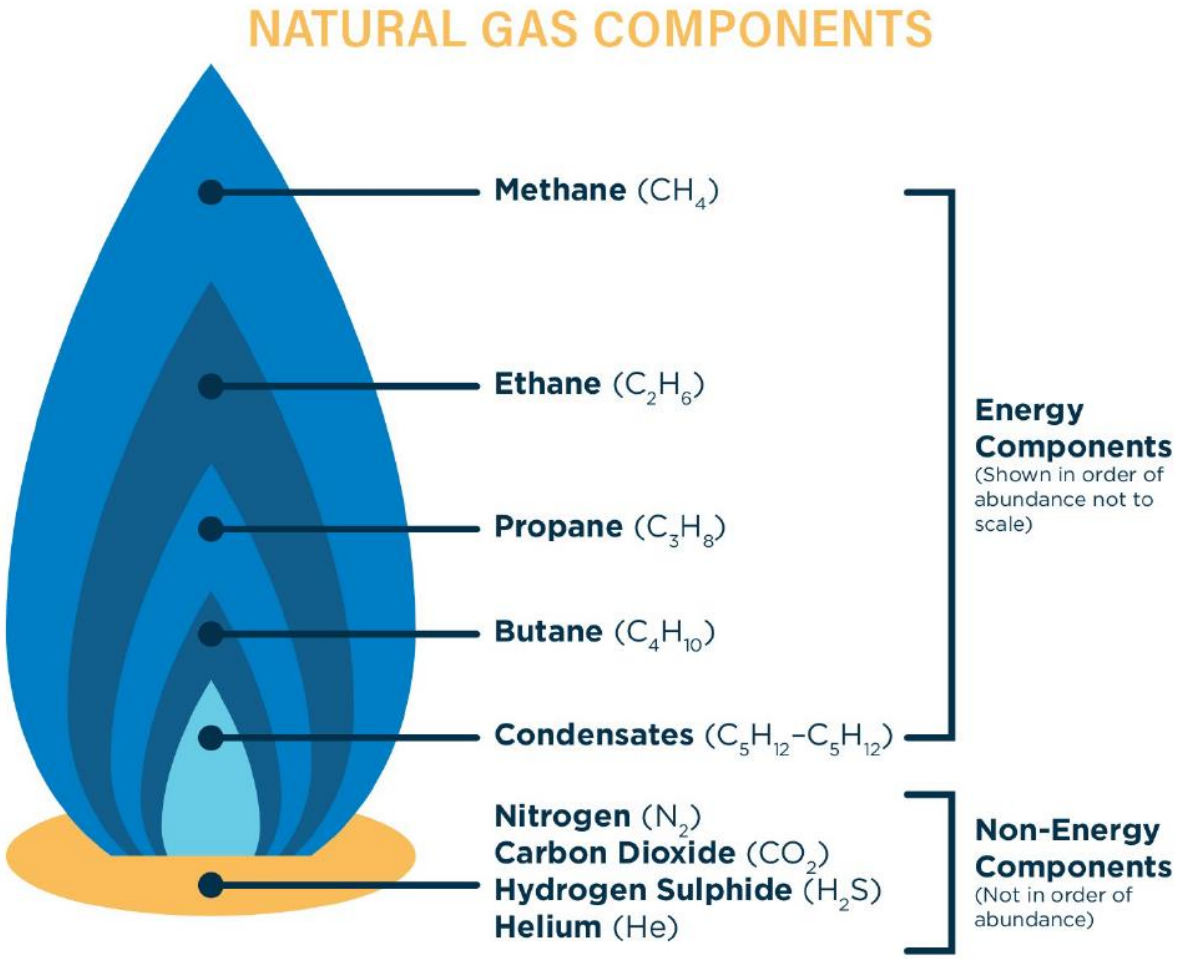


Properties of Natural Gas

Natural gas is 94% Methane with other trace elements.

Trace elements in Natural Gas:

Ethane -	3.60%
Nitrogen -	1.80%
Carbon Dioxide -	1.00%
Propane -	.80%
Butane -	.29%
Pentanes -	.13%
Hexane -	.08%
Water -	.01%



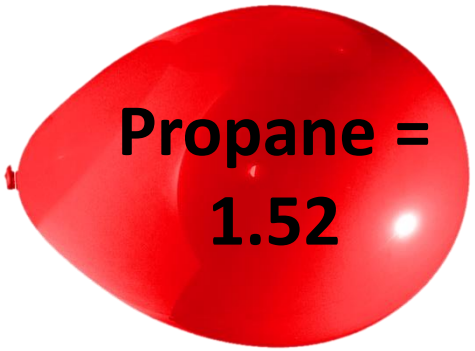
Properties of Natural Gas Vapor Density

Natural Gas is lighter than air and rises and dissipates into the atmosphere

30% lighter than air

Propane is heavier than air and falls

(Firemen do not like propane leaks as the propane collects at floor level.)



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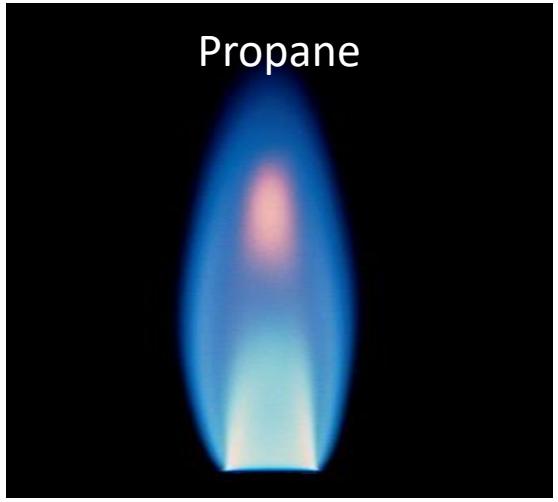
Properties of Natural Gas

- Measured by B.T.U. (British Thermal Unit)
  - Amount of energy required to raise one lb. of water 1 degree Fahrenheit
  - Natural Gas approximately 1037 BTU/CF
  - Propane approximately 2500 BTU/CF

~1037 Btu's per cubic foot



2500 Btu's per cubic foot

https://www.eia.gov/dnav/ng/ng_cons_heat_a_EPG0_VGTH_btucf_a.htm

Approximate Gas Comparisons

	Approx. Range of Flammability (% mix with air)	Vapor Density (Air = 1.0)	Approximate Ignition Temperature
Natural Gas	5.0 - 15.0	.60	1163ºF
Hydrogen	4.0 – 7.5	.07	1076ºF
Propane	2.15 – 9.6	1.52	957ºF
Butane	1.55 – 8.6	2.01	912ºF
Gasoline	1.4 – 7.6	3.00	632ºF

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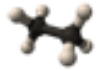
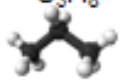
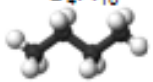
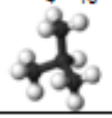
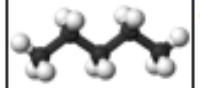
Natural Gas Liquid Attributes

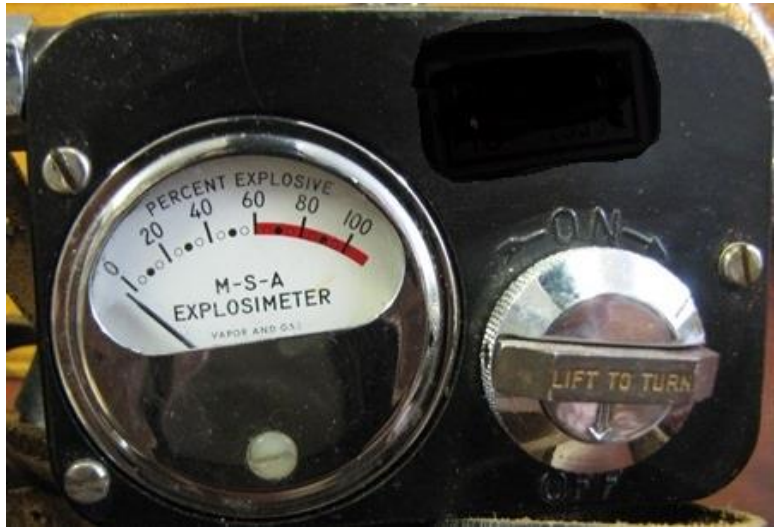
NGL Attribute Summary				eia
Natural Gas Liquid	**Chemical Formula**	**Applications**	**End Use Products**	**Primary Sectors**
Ethane	C_2H_6 	Ethylene for plastics production; petrochemical feedstock	Plastic bags; plastics; anti-freeze; detergent	Industrial
Propane	C_3H_8 	Residential and commercial heating; cooking fuel; petrochemical feedstock	Home heating; small stoves and barbeques; LPG	Industrial, Residential, Commercial
Butane	C_4H_{10} 	Petrochemical feedstock; blending with propane or gasoline	Synthetic rubber for tires; LPG; lighter fuel	Industrial, Transportation
Isobutane	C_4H_{10} 	Refinery feedstock; petrochemical feedstock	Alkylate for gasoline; aerosols; refrigerant	Industrial
Pentane	C_5H_{12} 	Natural gasoline; blowing agent for polystyrene foam	Gasoline; polystyrene; solvent	Transportation
Pentanes Plus*	Mix of C_5H_{12} and heavier	Blending with vehicle fuel; exported for bitumen production in oil sands	Gasoline; ethanol blends; oil sands production	Transportation

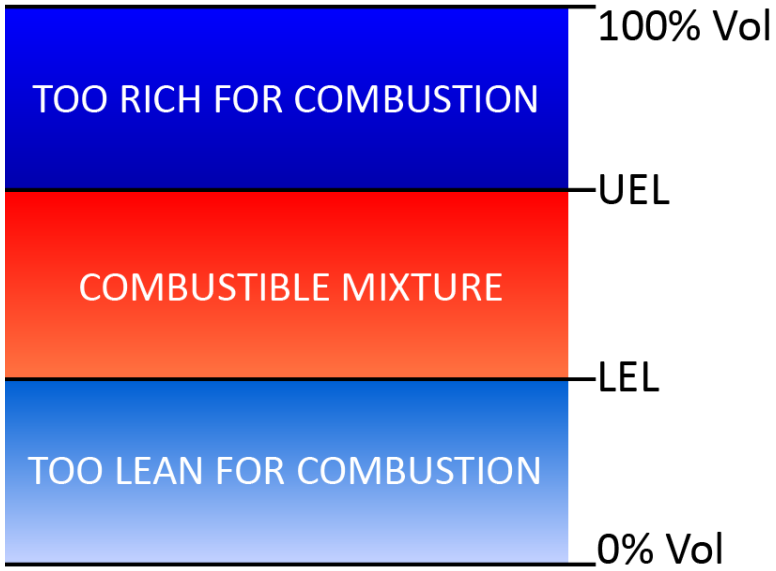
C indicates carbon, H indicates hydrogen; Ethane contains two carbon atoms and six hydrogen atoms
*Pentanes plus is also known as "natural gasoline." Contains pentane and heavier hydrocarbons.

https://www.eia.gov/todayinenergy/detail.php?id=5930

Natural Gas Safety

- Natural Gas Upper Explosive Limit (U.E.L) is ~15% gas in air
- Natural Gas Lower Explosive Limit (L.E.L) is ~5% gas in air





Natural Gas will not ignite in air if there is less then 5% gas or more than 15% gas in that air.

https://www.enggcyclopedia.com/2011/10/gases-explosive-levels/

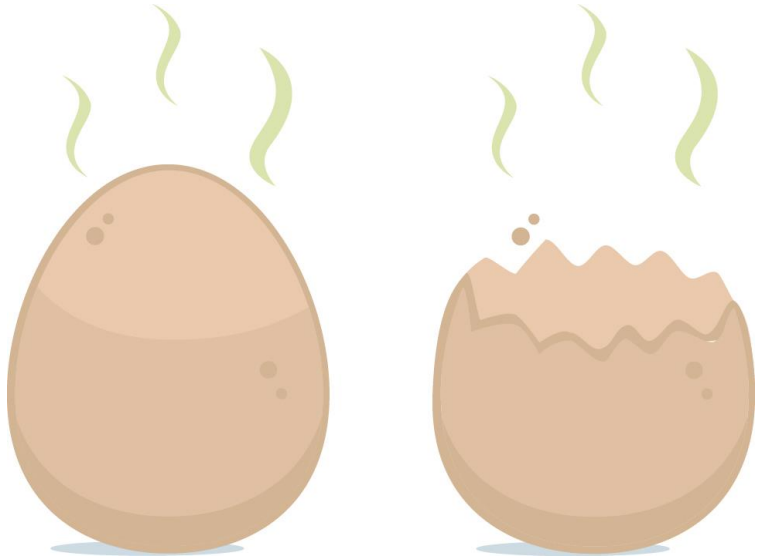
Characteristics of Natural Gas

Mercaptan is a foul-smelling gas that is added to natural gas.

Since natural gas is colourless and odourless, mercaptan acts as an odorant to make it easier to detect.

It is added as a safety measure to ensure that natural gas leaks do not go undetected.

- 1 lb. Per 10,000 gallons for propane
- ½ lb. Per million cubic feet of natural gas



Smells like rotten eggs.

Helps people identify a gas leak.

https://www.columbiagasohio.com/stay-safe/what-to-do-when-you-smell-gas/what-is-mercaptan-

Natural Gas Safety

Complete combustion = heat, carbon dioxide & water vapor

Incomplete combustion produces carbon monoxide

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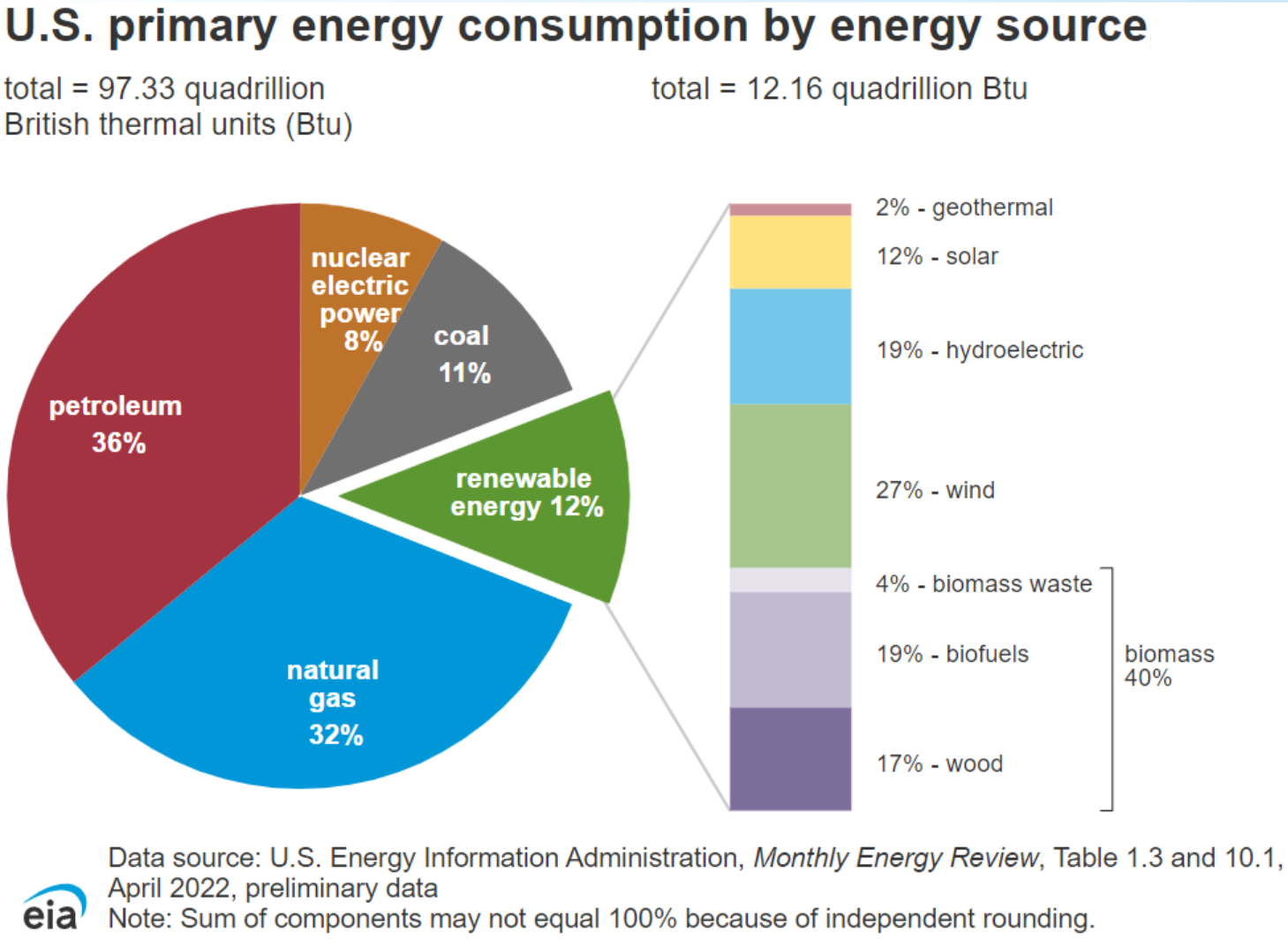
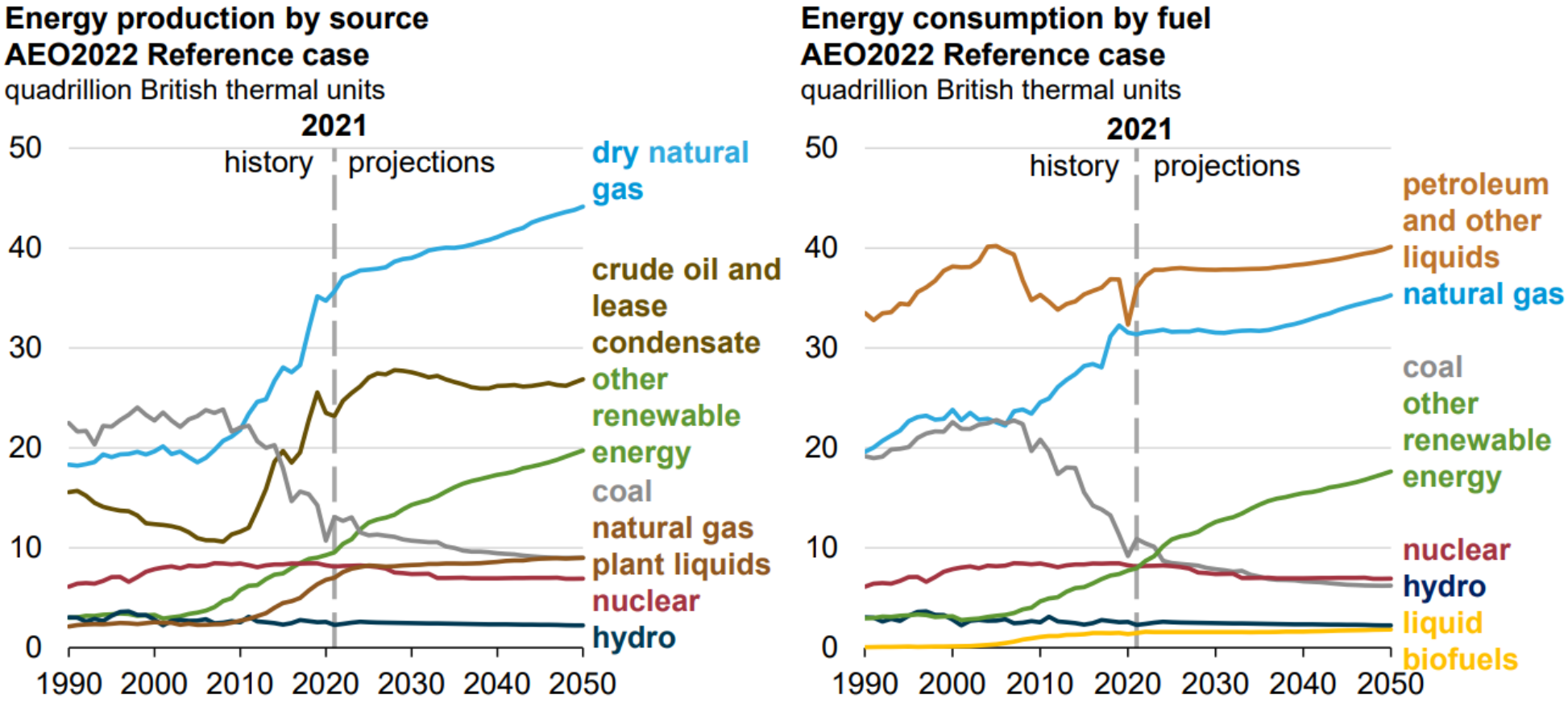
Natural Gas Accounts for Almost 1/3 of Energy Consumption



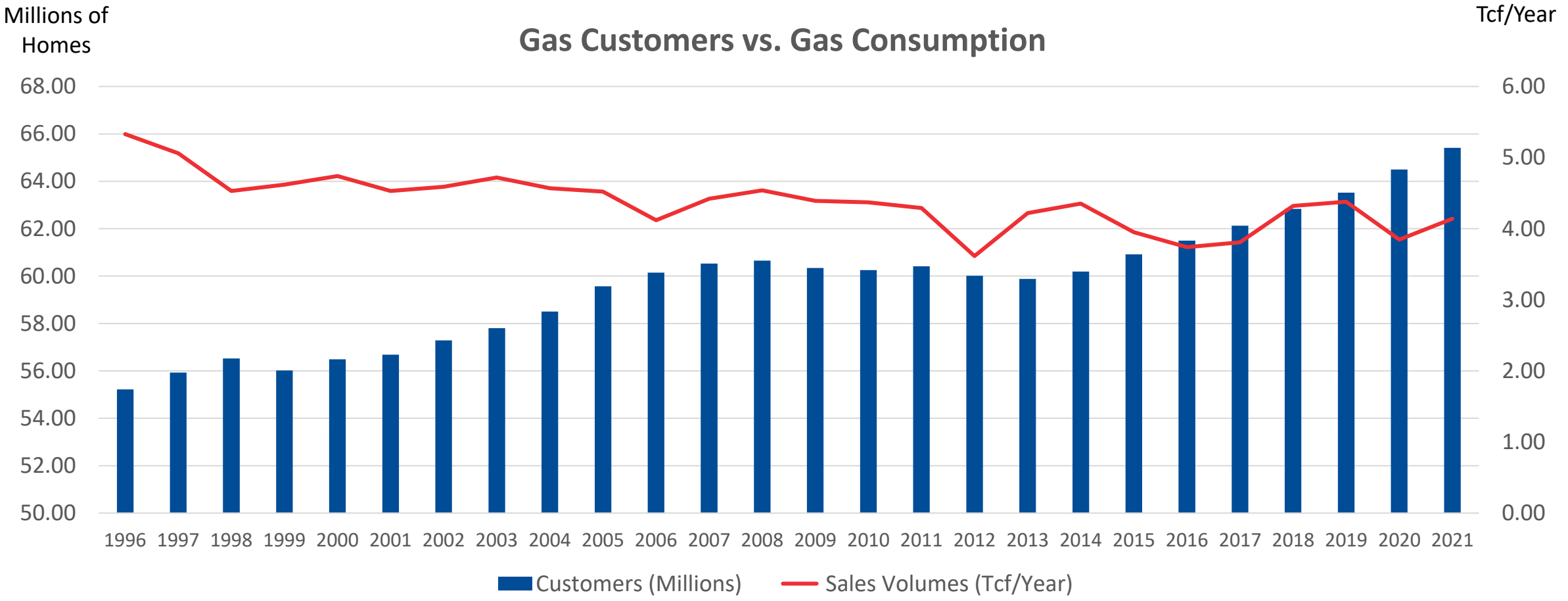
Source: Dept. of Energy, Energy Information Administration, AEO
https://www.eia.gov/energyexplained/?page=us_energy_home

Natural Gas Accounts for Almost 1/3 of Energy Consumption



Note: Biofuels are shown separately and included in petroleum and other liquids.

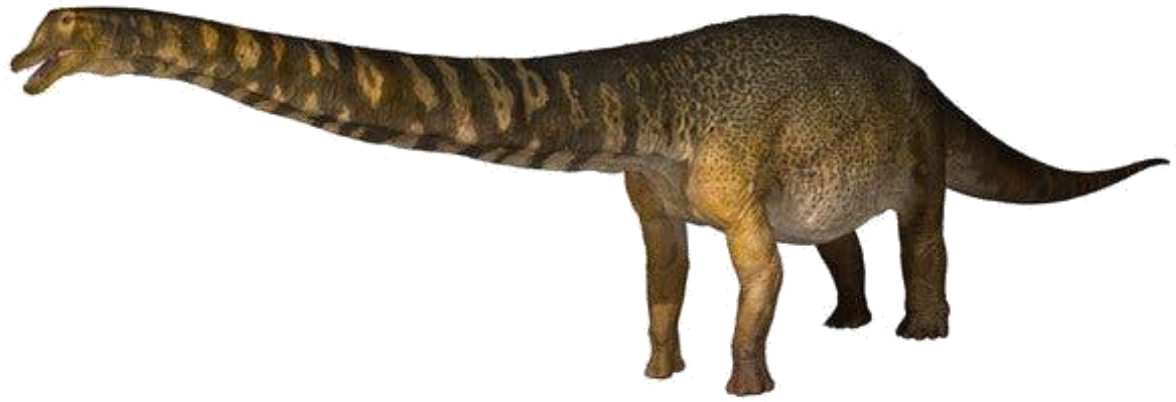
Per Household Gas Use Decreasing
(Energy Efficiency Success Story)



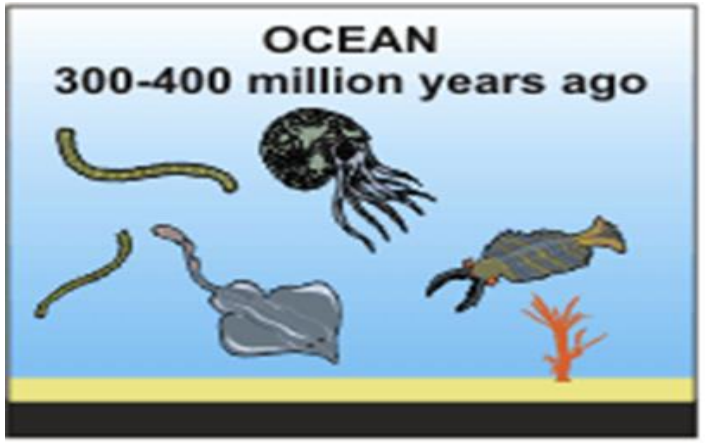
AGA Data

How Gas Is Formed

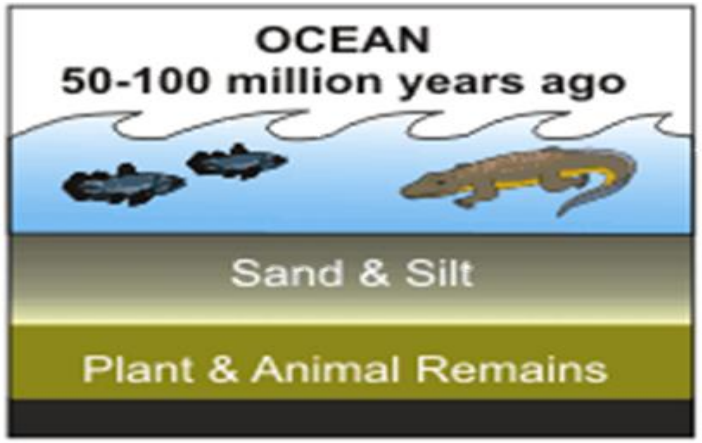
- Millions of years ago remains of plants & animals decayed and built up in thick layers
- Mud & soil changed to rock, covered & trapped the organic material beneath the rock
- Pressure & heat changed some of this organic material into coal, oil & gas



What is Natural Gas



Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of silt and sand.

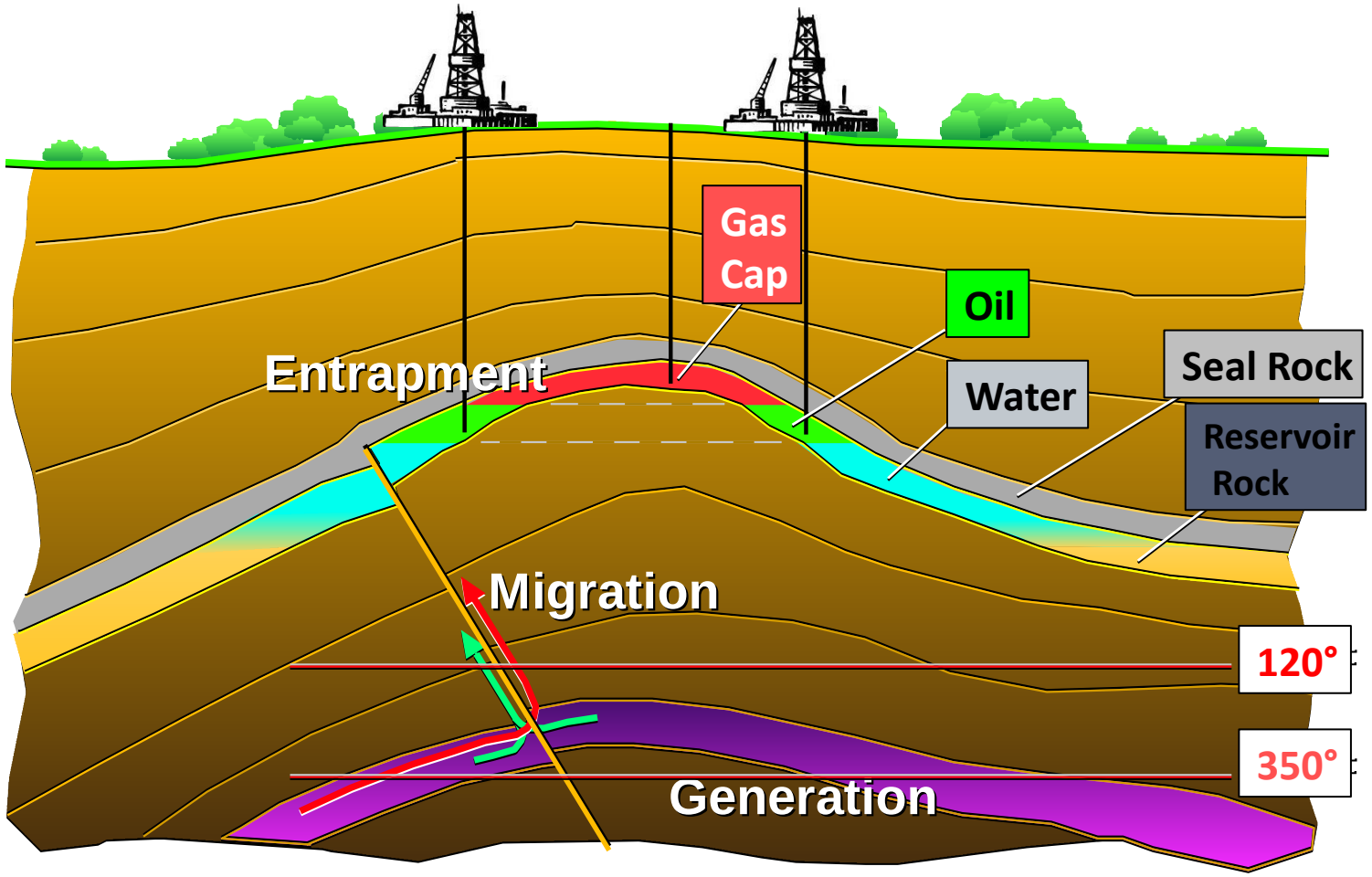


Over millions of years, the remains were buried deeper & deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through layers of sand, silt & rock to reach the rock formations that contain oil & gas deposits.

https://www.eia.gov/energyexplained/natural-gas/

Hydrocarbon Creation

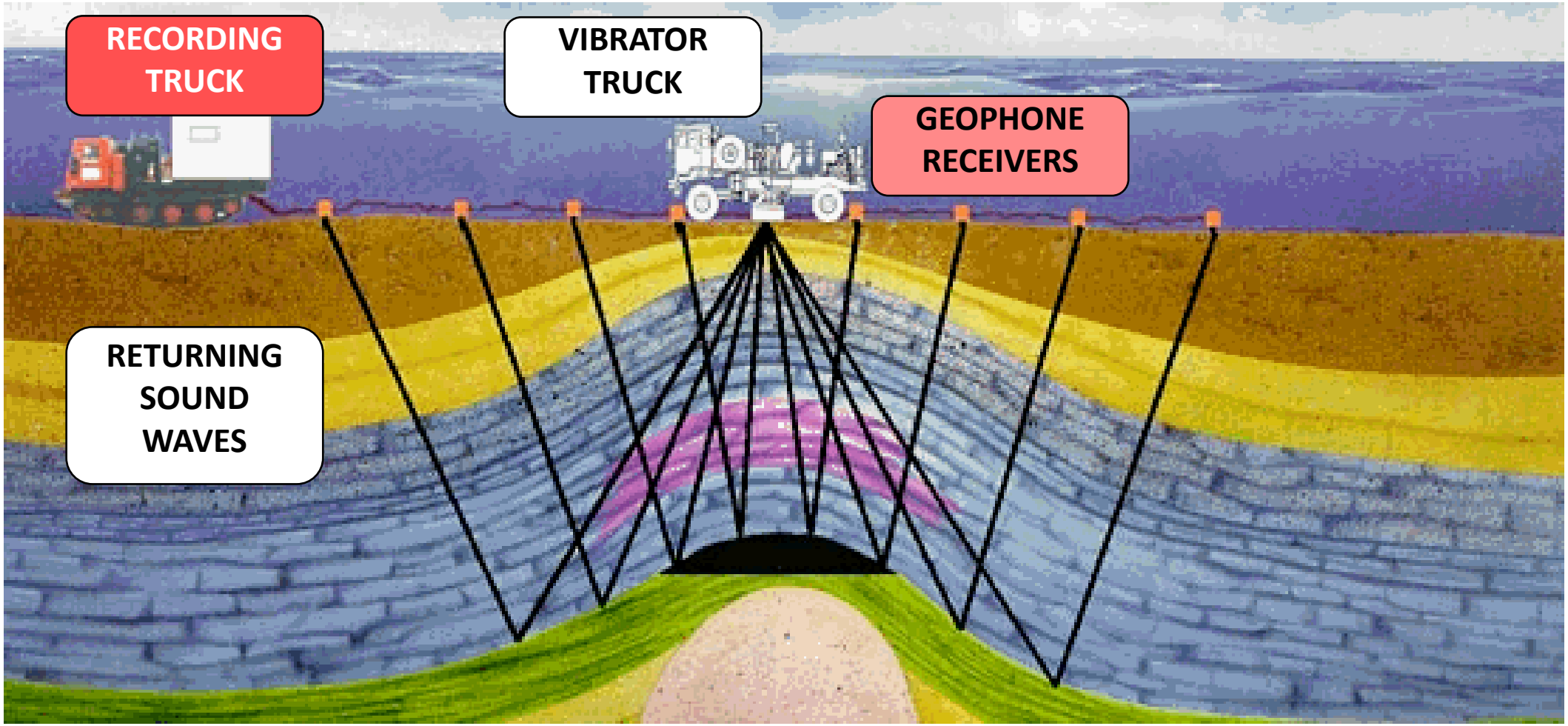


https://www.eia.gov/energyexplained/natural-gas/

Locating Natural Gas

- Locating the gas
  - Geologists and Scientists look for types of rocks typically found near natural gas deposits and then use seismic surveys to try and pinpoint areas to drill

Hydrocarbon Creation



Source: Terrex Seismic

Lower Carbon Gas

- Renewable Natural Gas
- Hydrogen
- Responsibly Sourced Gas

Renewable Natural Gas

RNG is made by capturing and refining biogases released from decomposing organic waste material. Unutilized agricultural byproducts such as manure and plant matter emit methane while they decay, with agriculture accounting for 36% of methane emitted annually in the United States.[1] Using these biogases as RNG feedstock directly displaces fossil fuel consumption and prevents the greenhouse gas methane from entering the atmosphere. RNG is considered a carbon neutral fuel

RNG is interchangeable with conventional natural gas and can be used in residential, commercial, industrial, and transportation applications. In high feedstock availability scenarios, RNG production could be enough to cover 59 percent of industrial or 93 percent of residential natural gas demand.[2]

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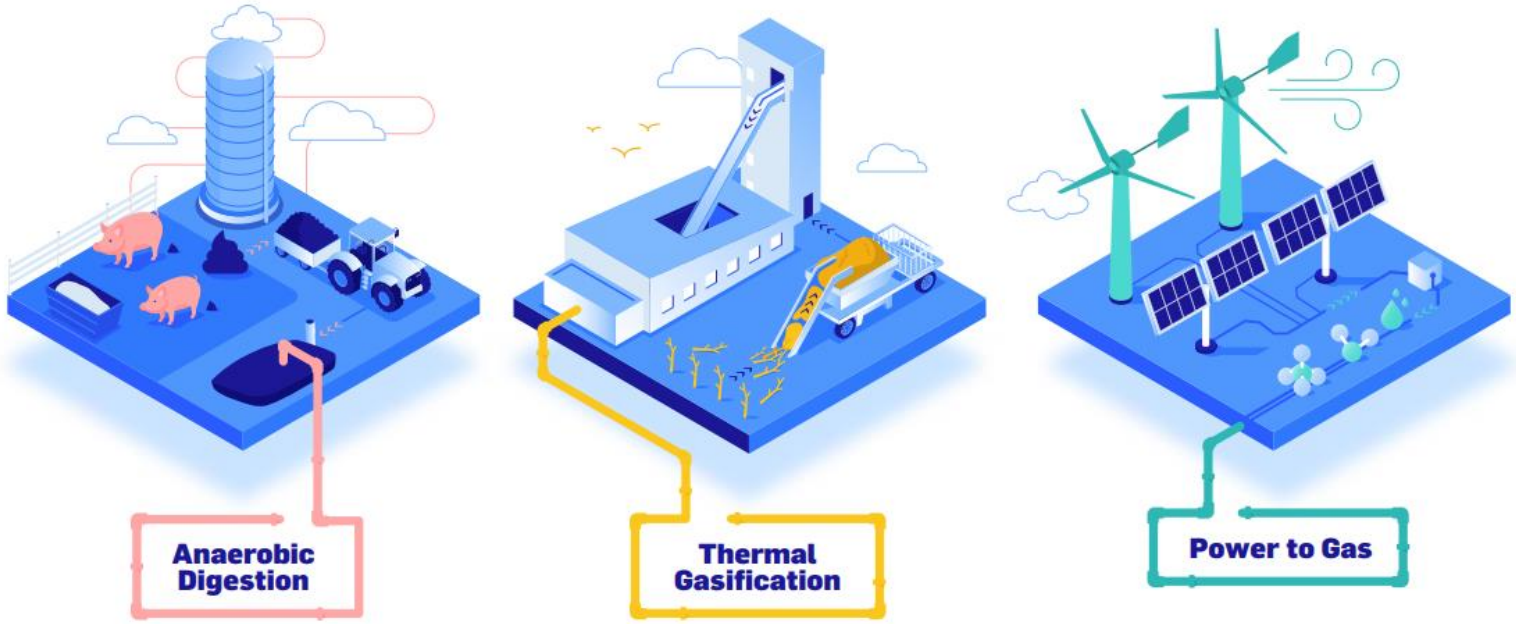
1. https://www.epa.gov/sites/default/files/2019-06/documents/methane_emissions_overview_may2019.pdf
2. https://gasfoundation.org/wp-content/uploads/2019/12/AGF-2019-RNG-Study-Full-Report-FINAL-12-18-19.pdf

RNG Production Technologies



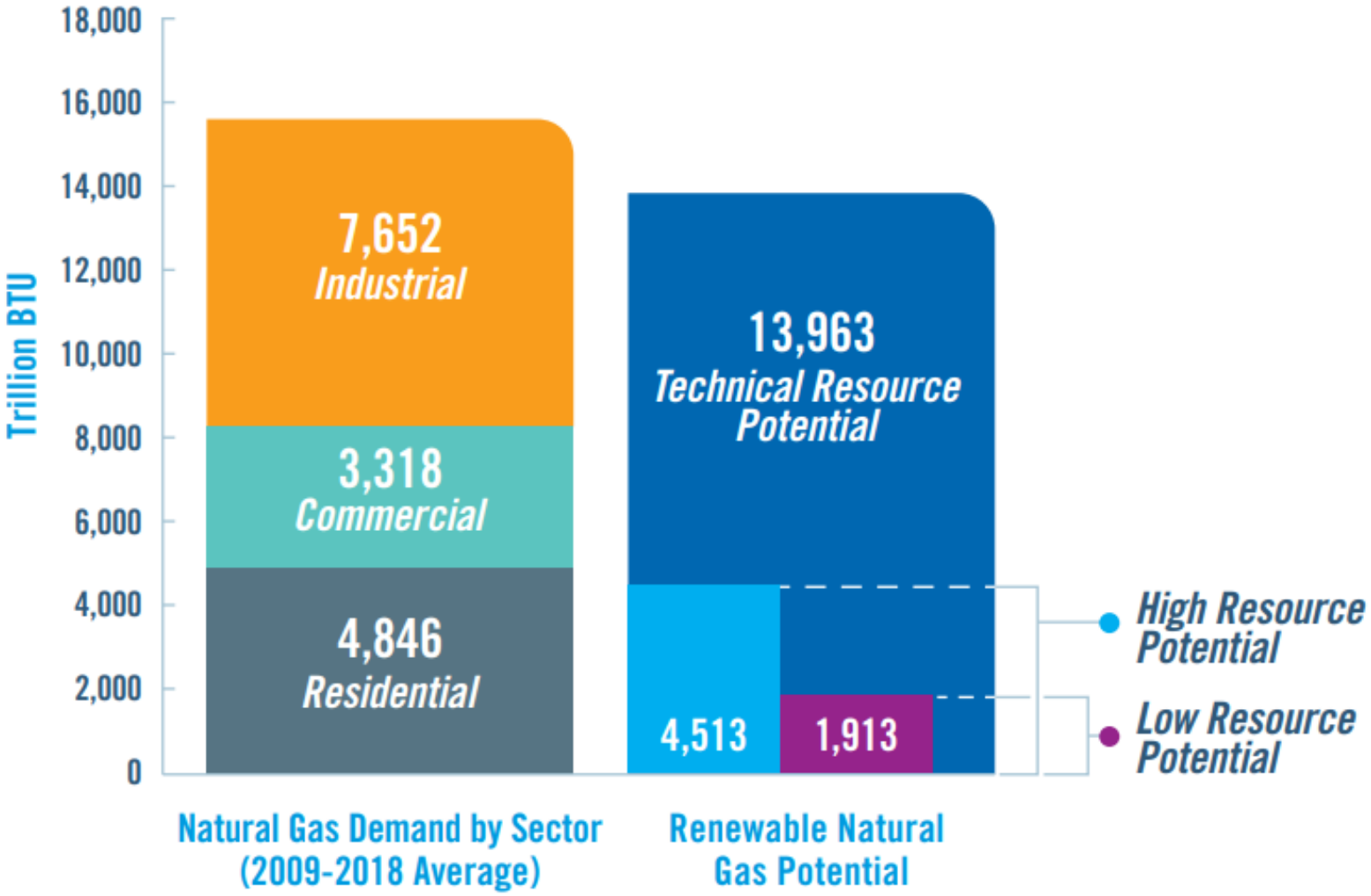
- *Landfill gas (LFG)*
- *Animal manure*
- *Water resource recovery facilities (WRRF)*
- *Food waste*

- *Agricultural residue*
- *Forestry and forest product residue*
- *Energy crops*
- *Municipal solid waste (MSW)*

- *Renewable electricity*

https://gasfoundation.org/wp-content/uploads/2019/12/AGA_3894-RNG-2-Pager_V-11.pdf

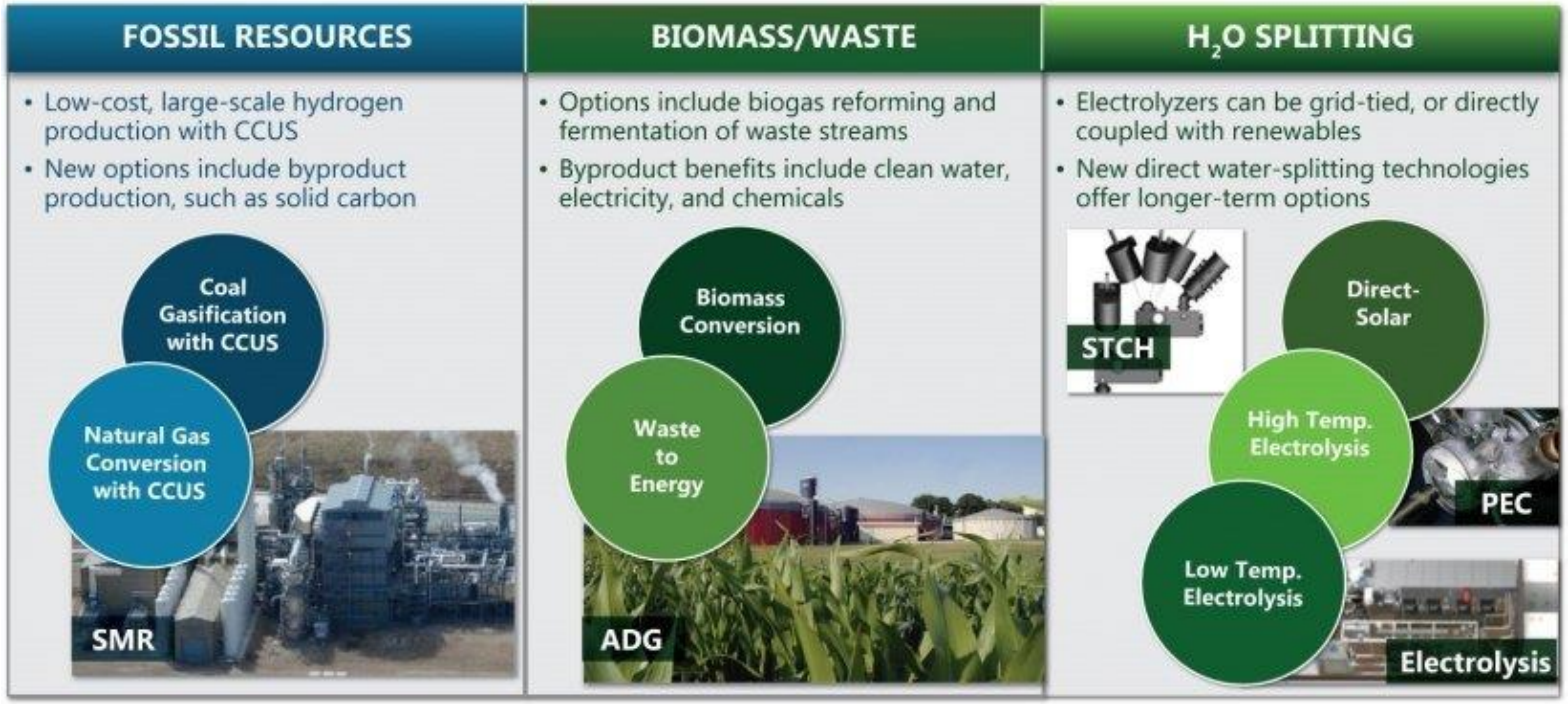
RNG Resource Potential



Source: American Gas Foundation, "Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment", 2019

Hydrogen

Hydrogen can be produced in several ways. The most common method is through steam-methane reforming (SMR), which uses high-temperature steam to heat methane from natural gas, producing hydrogen and carbon dioxide. More than 90% of hydrogen produced today is through SMR[1]. Alternatively, hydrogen can be produced via electrolysis, which uses an electrical current to split water molecules into oxygen and hydrogen. Natural gas pipelines and combustion equipment can incorporate hydrogen in blends up to 30%, depending on equipment design and application.[2]



https://www.energy.gov/eere/fuelcells/hydrogen-production-pathways

1. https://fsr.eui.eu/hydrogen-in-the-energy-transition/
2. https://www.energy.gov/sites/default/files/2021-08/hyblend-tech-summary.pdf

Colors of Hydrogen

	Terminology	Technology	Feedstock/ Electricity source	GHG footprint*
PRODUCTION VIA ELECTRICITY	Green Hydrogen	Electrolysis	Wind | Solar | Hydro Geothermal | Tidal	Minimal
	Purple/Pink Hydrogen		Nuclear	
	Yellow Hydrogen		Mixed-origin grid energy	Medium
PRODUCTION VIA FOSSIL FUELS	Blue Hydrogen (SMR + Carbon Capture)	Natural gas reforming + CCUS Gasification + CCUS	Natural gas | coal	Low
	Turquoise Hydrogen	Pyrolysis	Natural gas	Solid carbon (by-product)
	Grey Hydrogen (SMR)	Natural gas reforming		Medium
	Brown Hydrogen	Gasification	Brown coal (lignite)	High
	Black Hydrogen		Black coal	

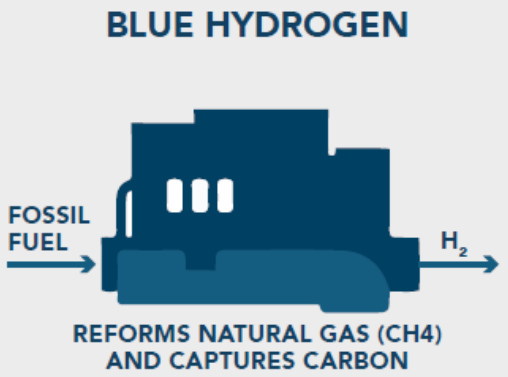
*GHG footprint given as a general guide but it is accepted that each category can be higher in some cases.

https://globalenergyinfrastructure.com/articles/2021/03-march/hydrogen-data-telling-a-story/

Hydrogen Production

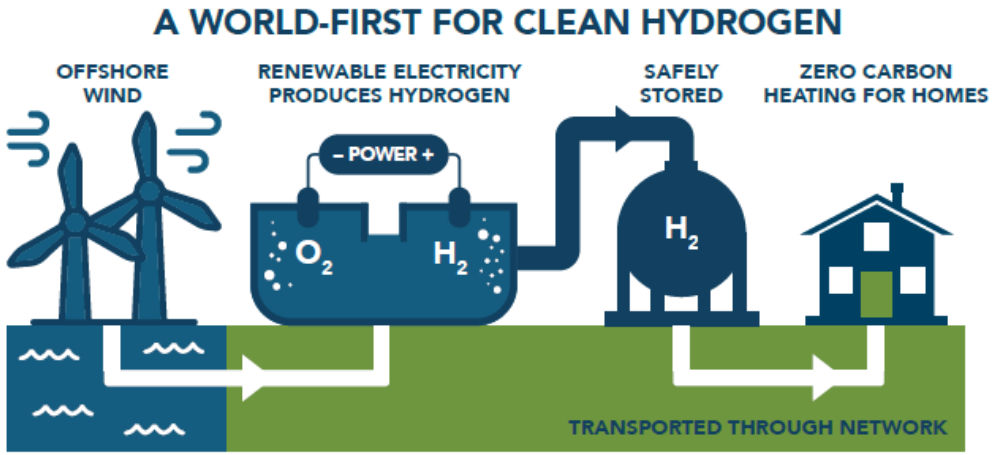
BLUE AND GREEN HYGRODEN

Hydrogen produced through low carbon pathways, such as blue or green hydrogen, can be injected into existing natural gas pipelines to lower the carbon content of the fuel.



HYDROGEN PRODUCTION FROM EXCESS RENEWABLES

Excess renewable energy can be used to power electrolyzers and produce hydrogen. Existing natural gas infrastructure can be used to provide long-duration storage of hydrogen, complementing shorter-duration battery storage systems.



Source: DOE, "How Wind Energy Can Help Hydrogen Contribute to a Zero-Carbon Future"

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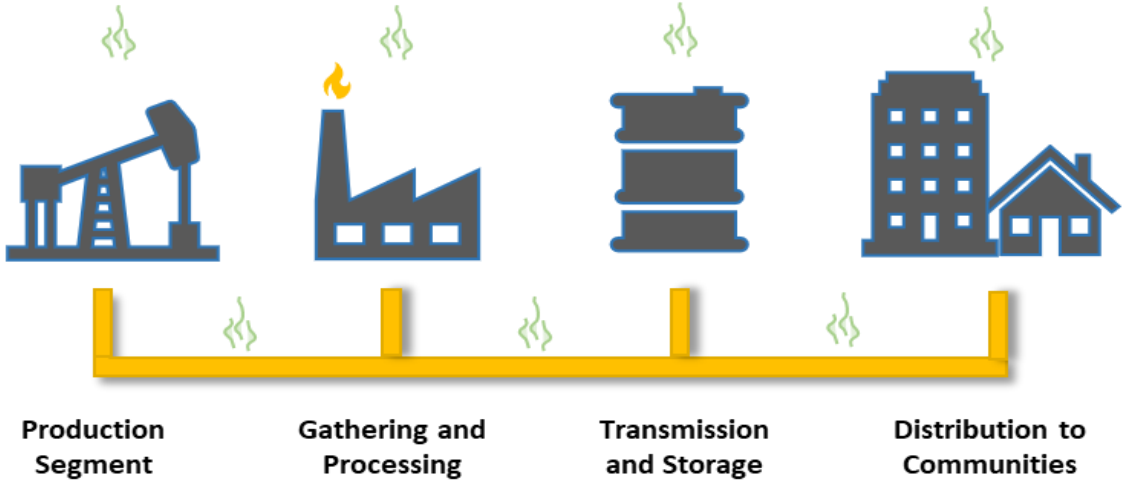
Responsibly Sourced Gas (RSG)

A core concern for the natural gas industry is methane emissions from unintentional leaks when natural gas is extracted, processed, and transported. Responsibly sourced gas (RSG) is conventional natural gas that has been certified by a third party to verify that its procurement, i.e., the collection and delivery of the gas, meets a set of environmental criteria. RSG is also referred to as certified natural gas, differentiated gas, green gas, independently certified gas, and reduced-carbon natural gas.



In order to certify natural gas as responsibly sourced, it must undergo a formal process that uses technology to quantify and monitor emissions. Certifications help organizations ensure their gas is sourced with minimal environmental and societal impacts.

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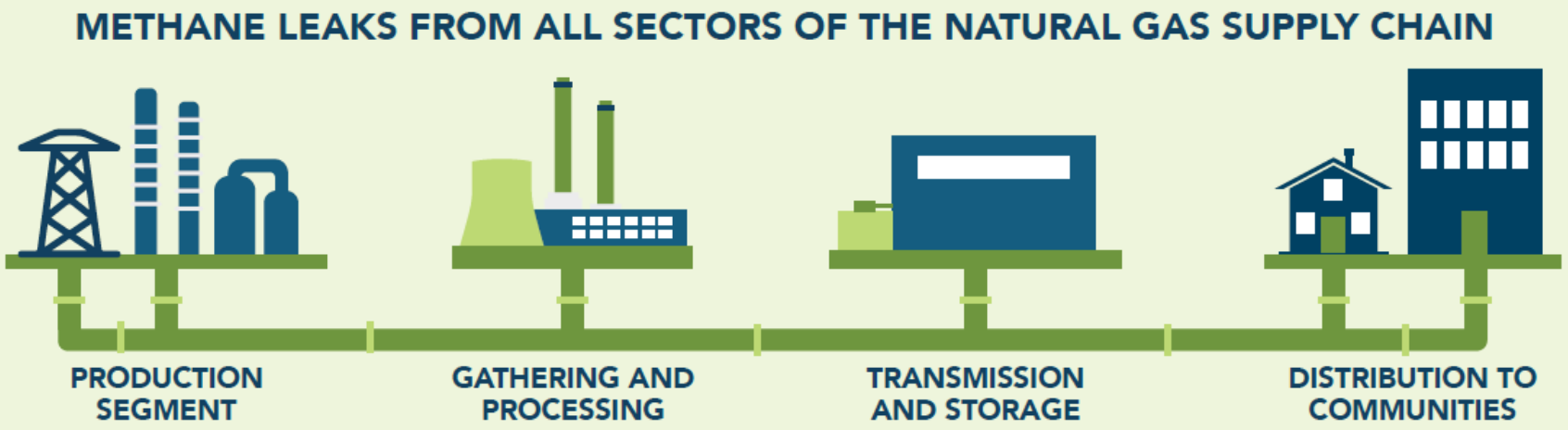
RSG Certification Processes

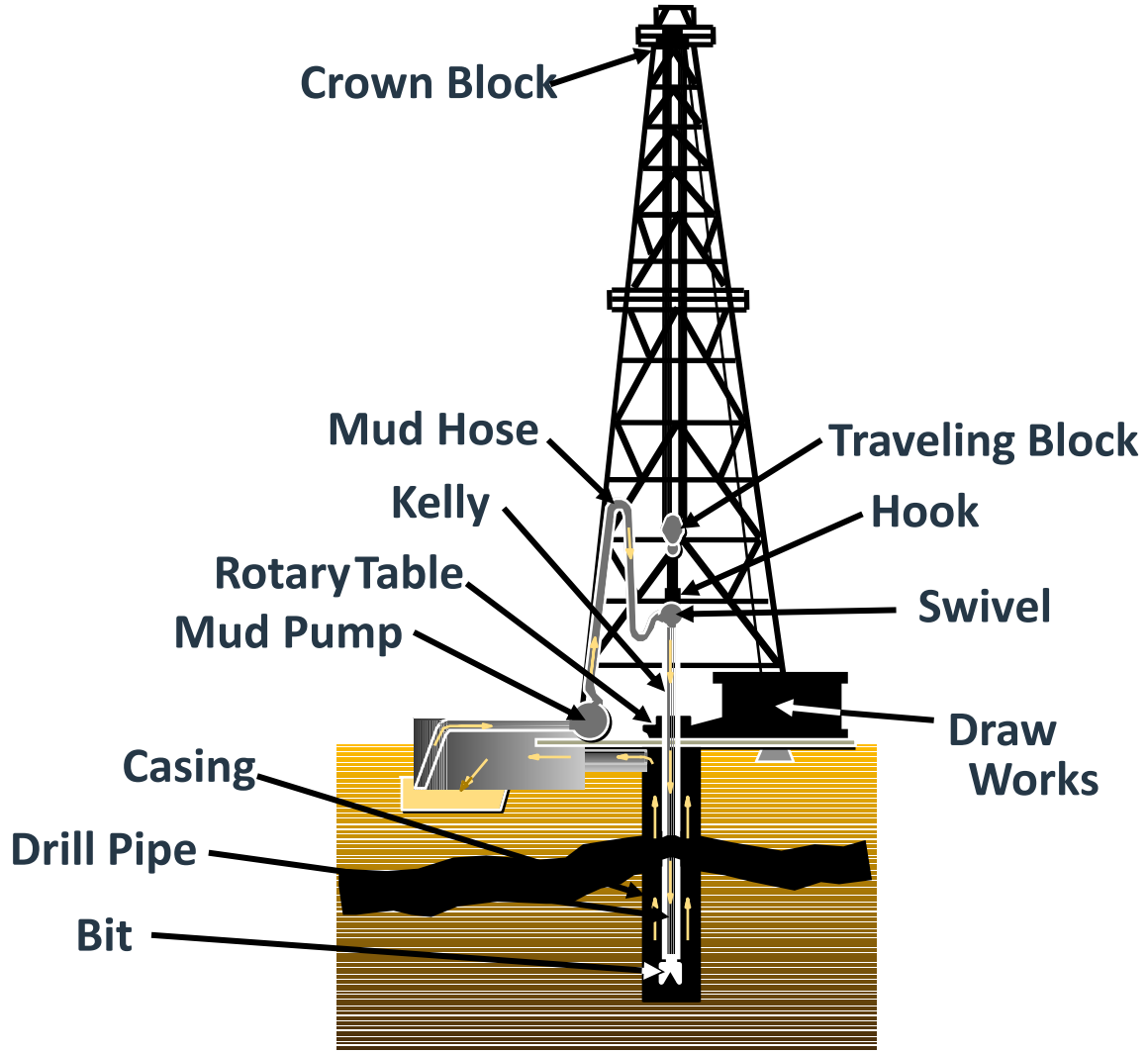
MIQ	EO100	TRUSTWELL
MiQ is a methane emissions certification standard that currently certifies over 4% of the global gas supply.[2]	The Equitable Origin also certifies natural gas producers by assessing their methane emissions across their respective supply chains.	TrustWell (through Project Canary) offers similar certificates, but they differ from E0100 and MiQ in that they require continuous monitoring of emissions data.[3]



Source: Breaking Energy, "Want to Cut Emissions? Go Where the Emissions Are"

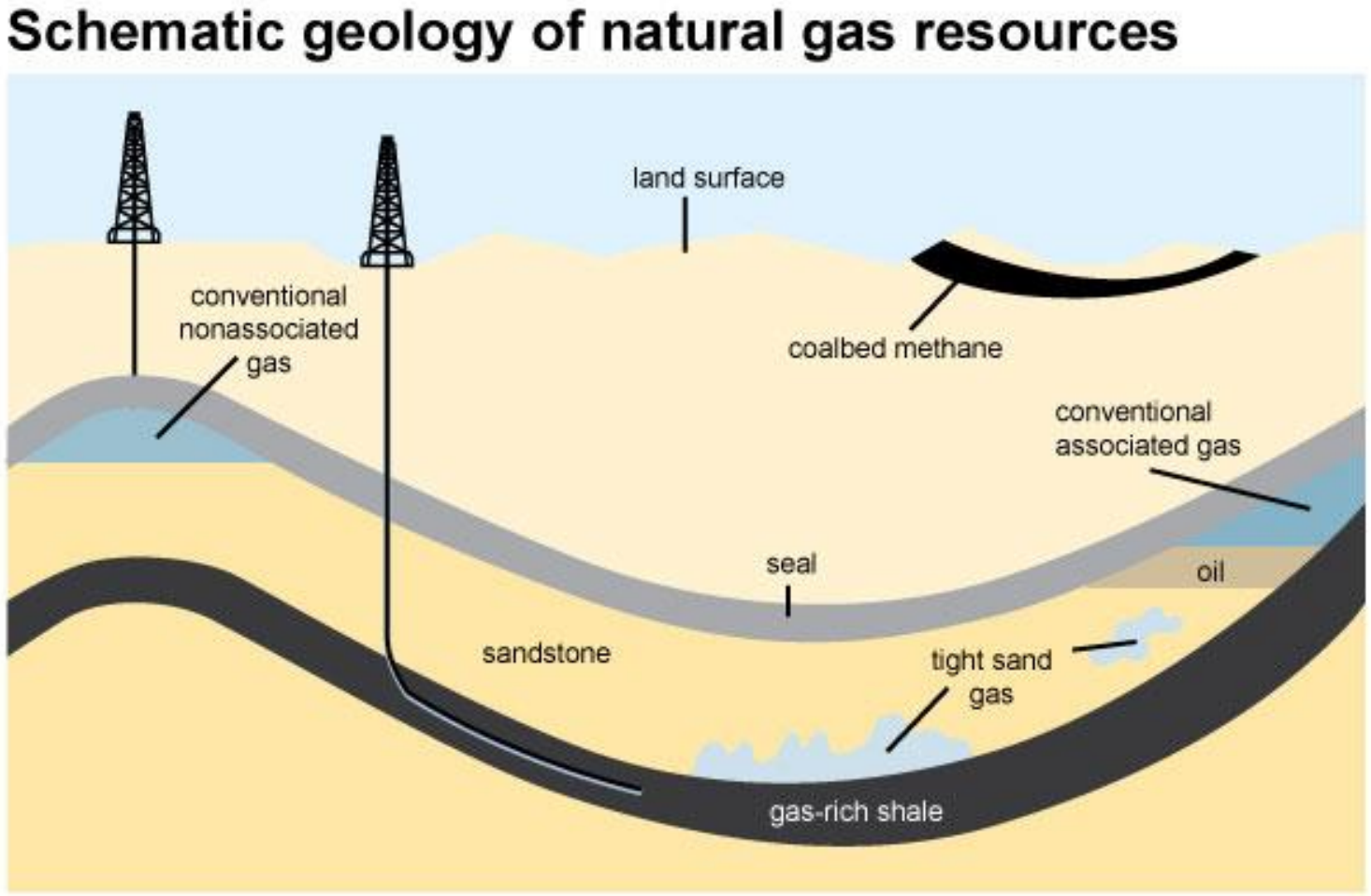
Gas Wells

Drilling Rig



Source: AGA

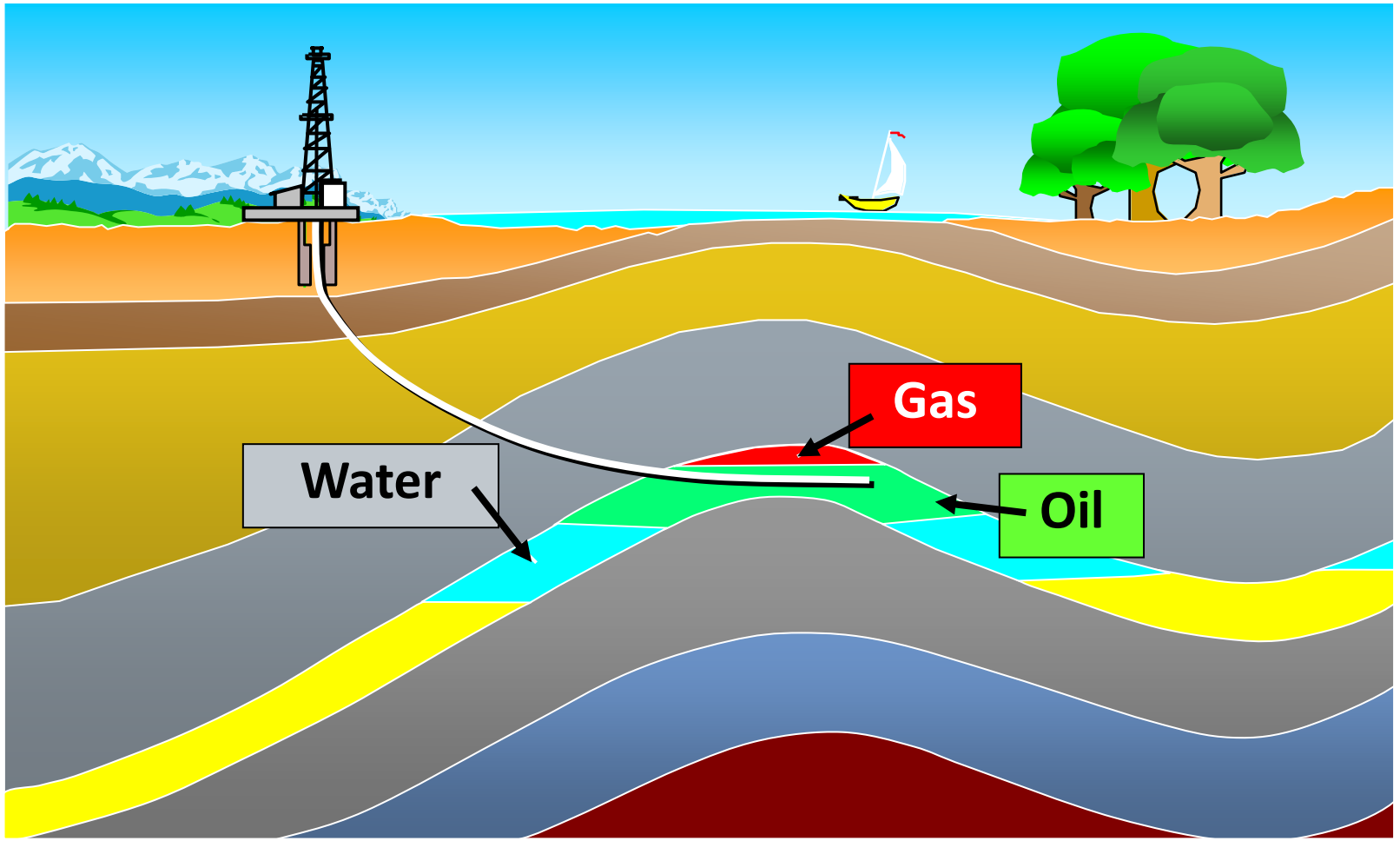
Natural Gas Resources



Source: Adapted from *United States Geological Survey factsheet 0113-01* (public domain)

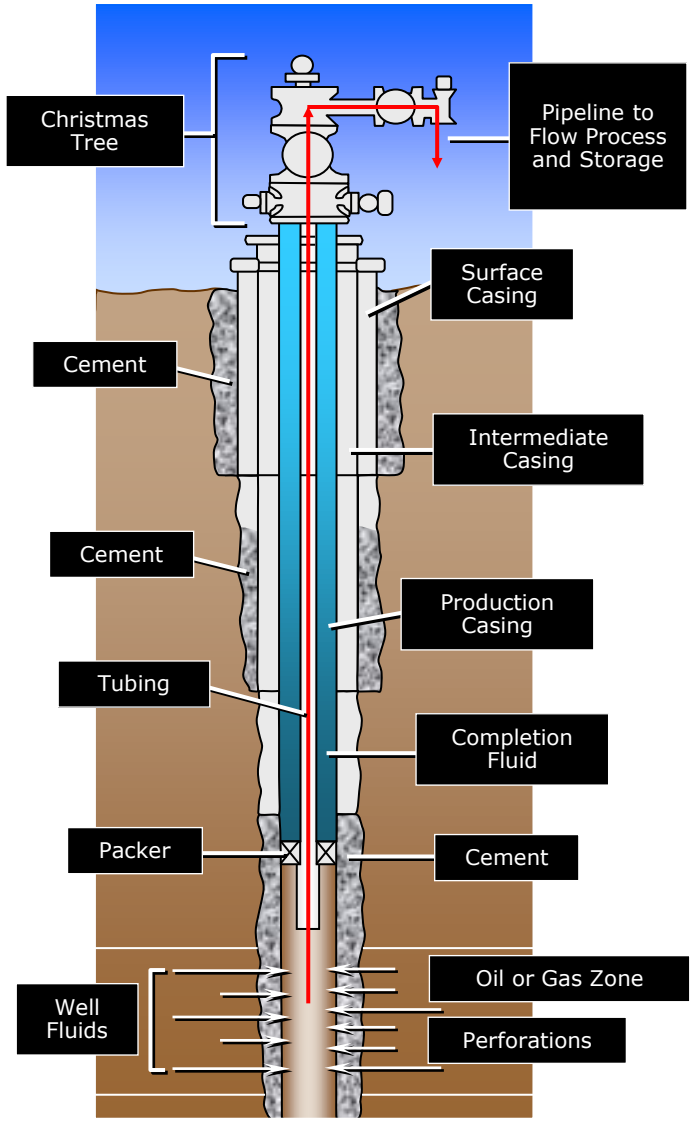
https://www.eia.gov/energyexplained/natural-gas/

Directional Drilling



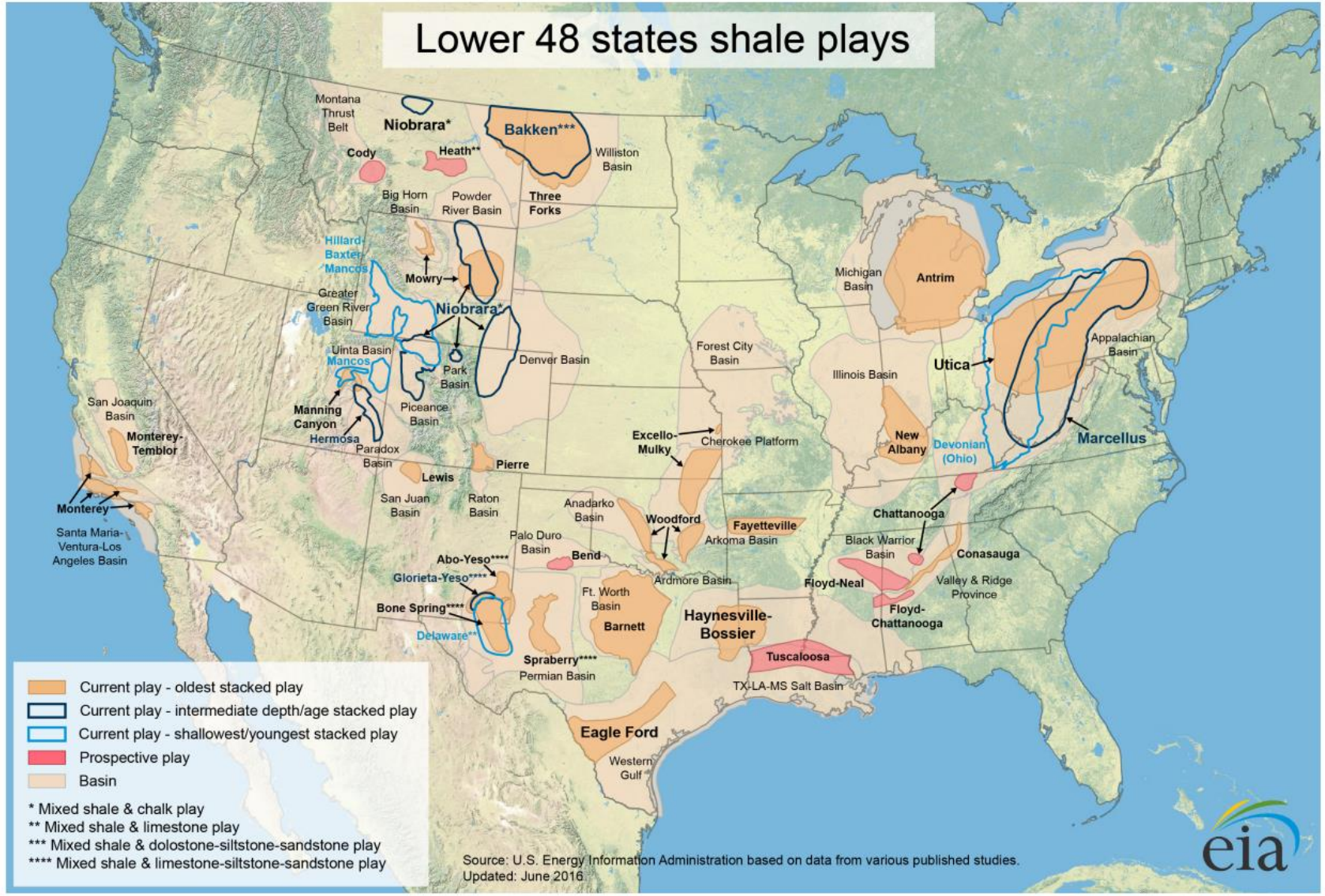
Source: American Petroleum Institute

Completed Well



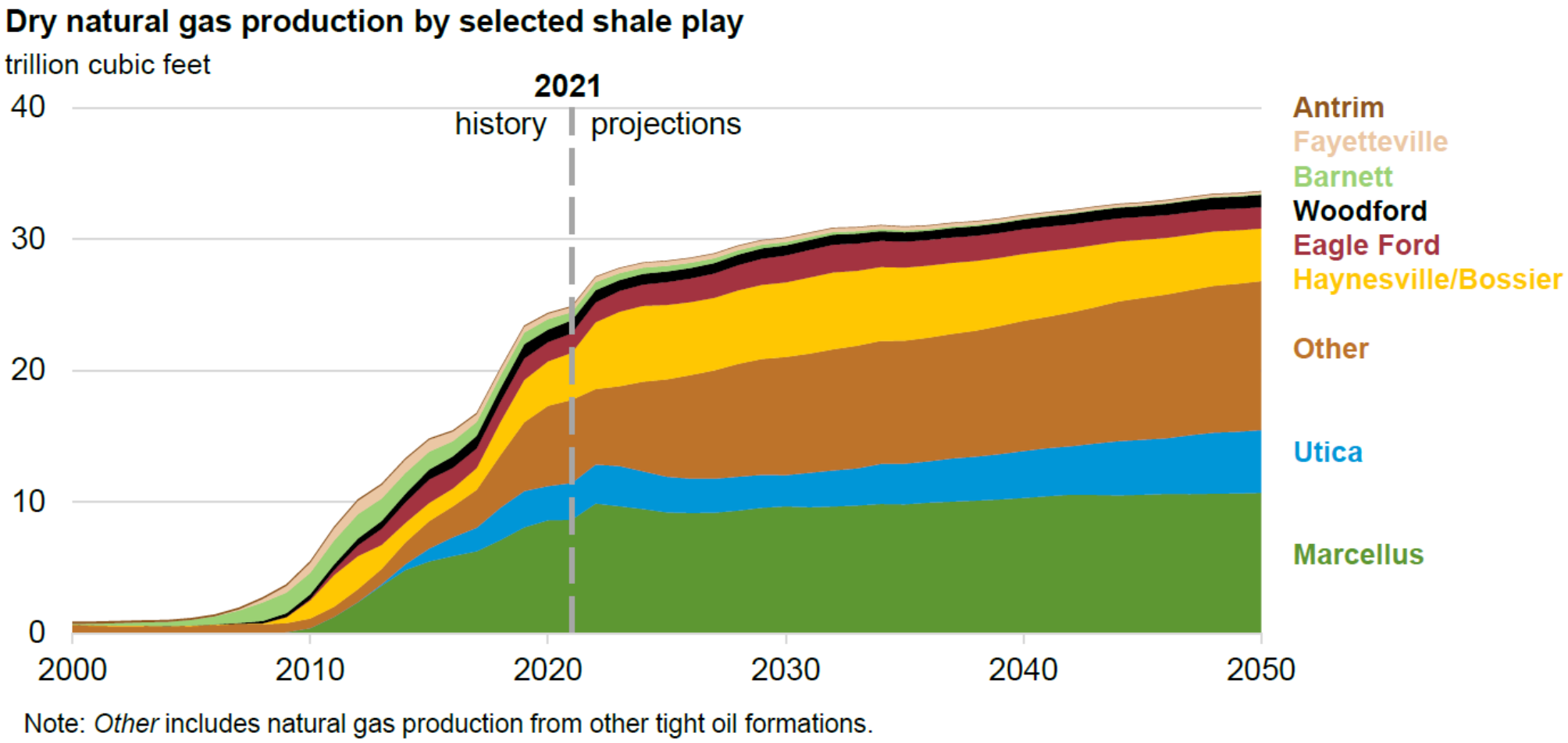
- Gas wells must be closed off or sealed when they are finished being used

U.S. Shale Gas Deposits



https://www.eia.gov/maps/images/shale_gas_lower48.pdf

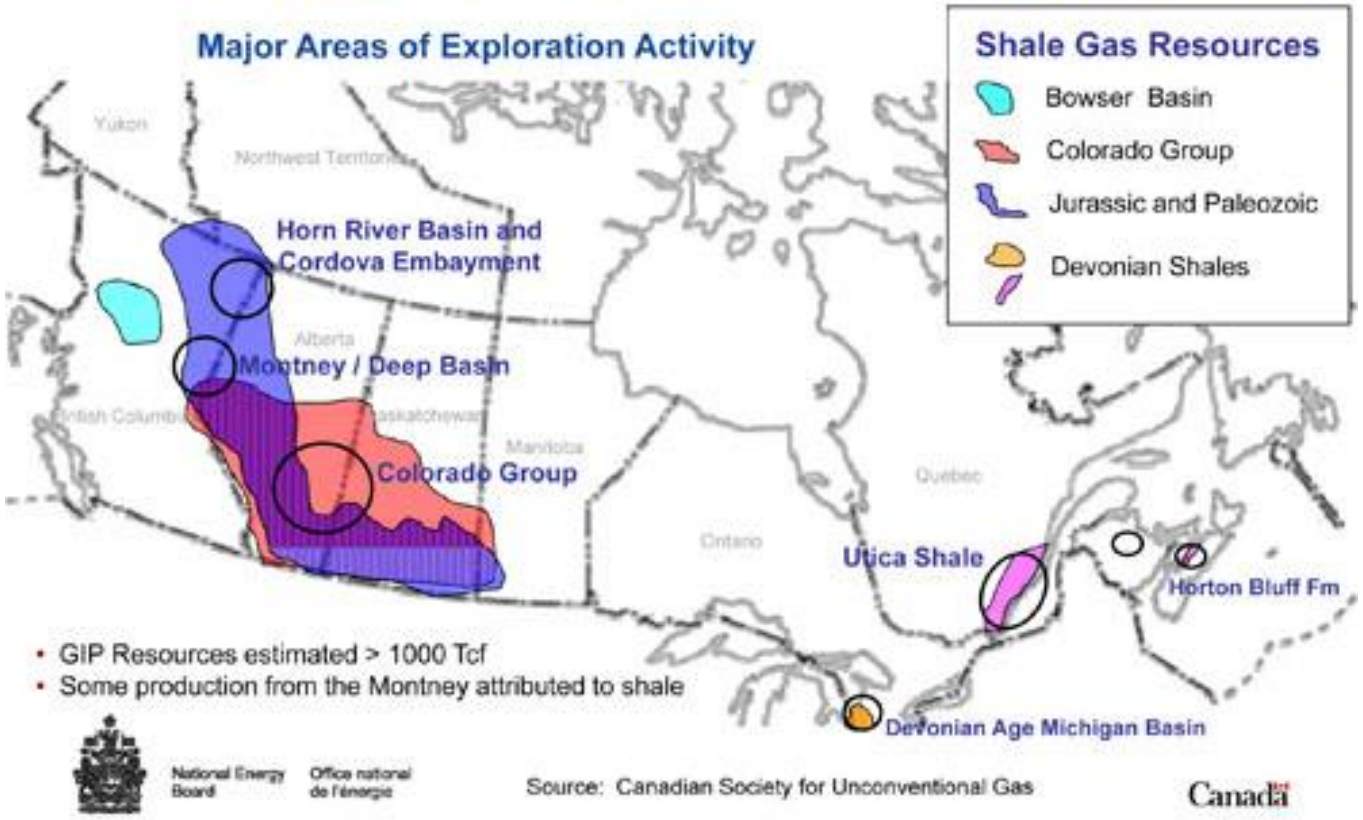
U.S. Shale Production



Note: *Other* includes natural gas production from other tight oil formations.

https://www.eia.gov/outlooks/aeo/

Shale Gas Deposits in Canada



https://kaymor.ca/2015/02/02/liquid-natural-gas-albertas-saving-grace/

Shale- One Source of Natural Gas

- Sedimentary Rock - combination of clay, silica, carbonate and organic materials
- Typically collects at the bottom of large lakes, deep seas or oceans
- Bacteria feeds on the organic material, producing oil and natural gas

Dark layers are shale, light layers are limestone.
A writing pen is shown for scale.

Source: National Energy Board - Canada
A Primer for Understanding Canadian Shale Gas - Energy Briefing Note ISSN 1917-506X

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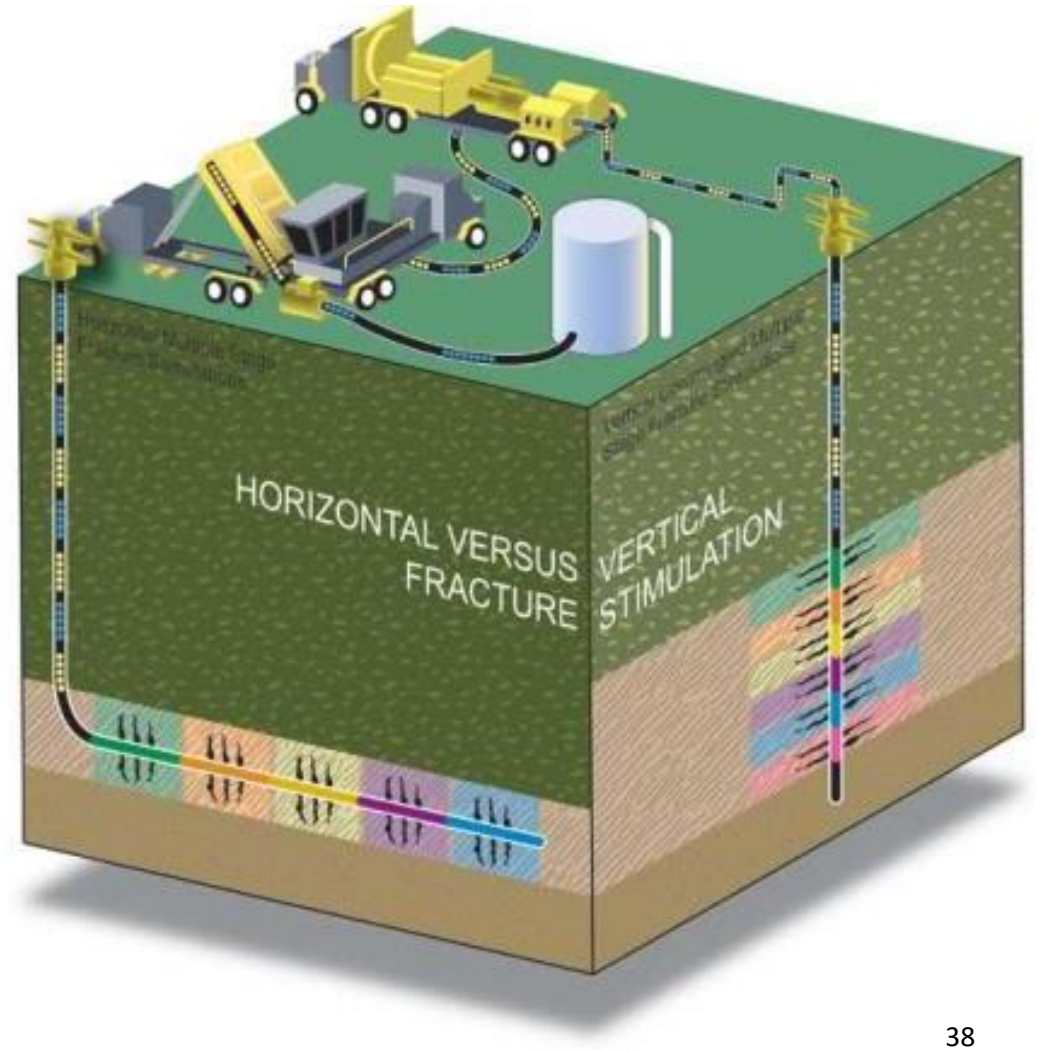
Basics of Fracking

- Pump Fluid into the well at high pressure
- Pressure creates Fractures in the shale
- Filler material mixed with fluid keeps fractures open
- Natural Gas then able to move to the well



Source: National Energy Board - Canada
A Primer for Understanding Canadian Shale Gas - Energy Briefing Note ISSN 1917-506X
https://publications.gc.ca/collections/collection_2011/one-neb/NE4-2-6-2009-eng.pdf

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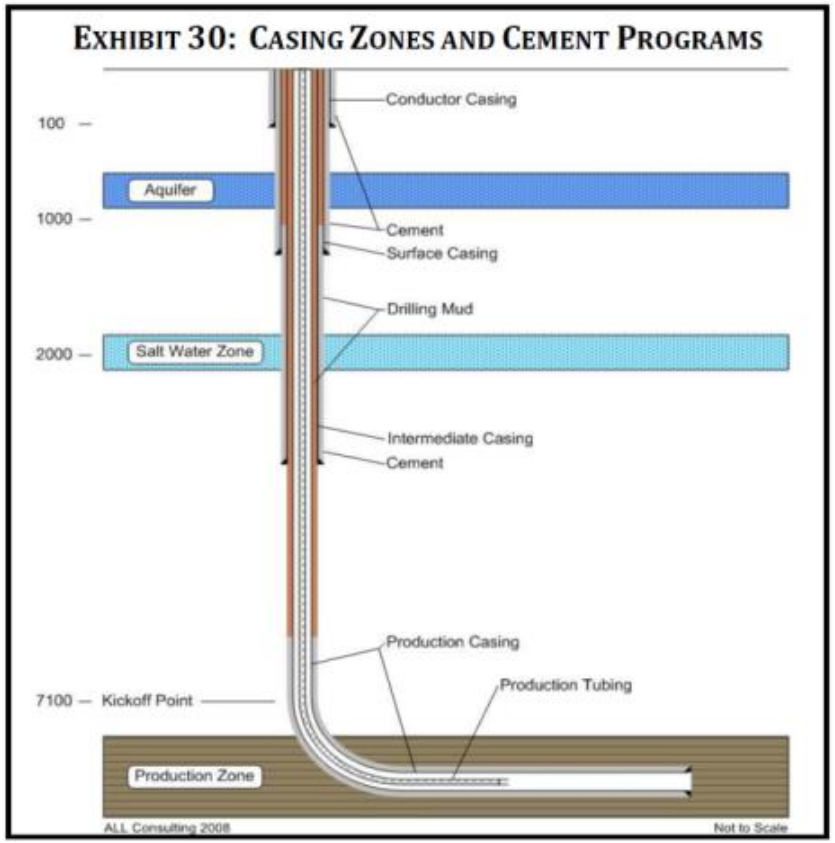
Horizontal Drilling for Shale Gas



Operators have strong economic incentives to ensure that fractures do not propagate beyond the shale

- Waste of materials, time, and money
- Potential loss of the well and the associated gas
- Lead to excess water production from adjacent strata – increasing production costs

Source: www.netl.doe.gov/technologies/oil-gas/publications/EPreports/Shale_Gas_Primer_2009.pdf

Drilling for Shale Gas

Drill Rig

Diamond Drill Bit

Water Storage

Producing Shale Well

Well Heads and Sand Traps

Control Shed

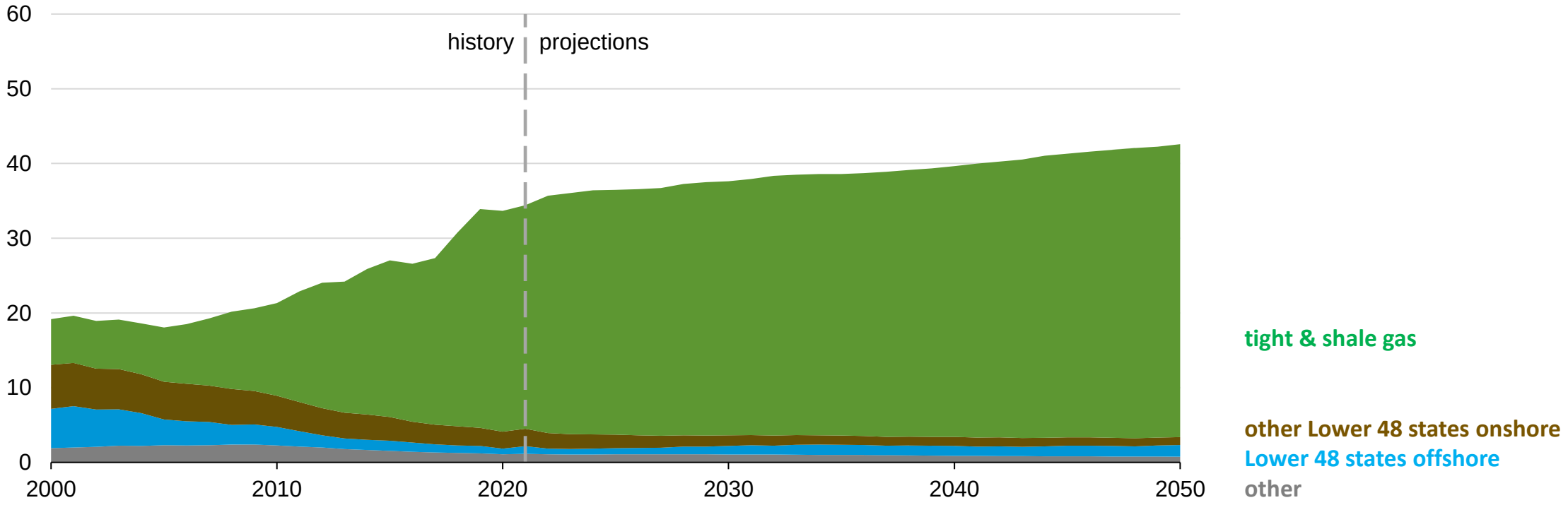
Heaters

U.S. Natural Gas Production

Dry natural gas production, AEO natural gas supply cases

Reference case

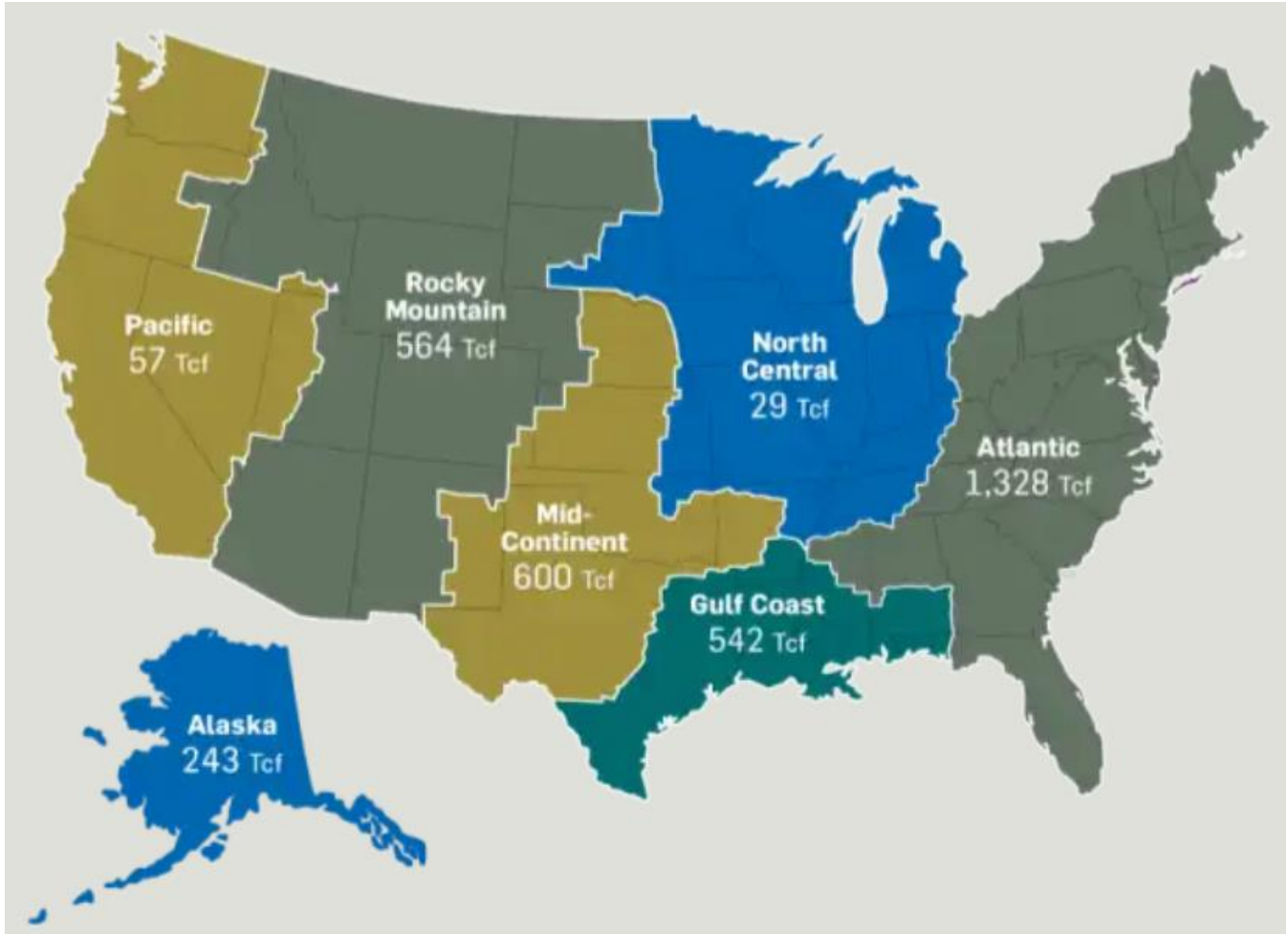
trillion cubic feet



Note: *Tight and shale* gas includes tight gas, shale gas, and natural gas from tight oil formations.

Abundant Gas Supply

- Gas Production = 34.5 Tcf
- LNG from Canada = 2.5 Tcf
- Gas Consumption = 30.7 Tcf
- Known reserves = 473.3 Tcf
- Technically recoverable gas = 3,368 Tcf



2023 AGA Playbook, https://playbook.aga.org/natural-gas-data

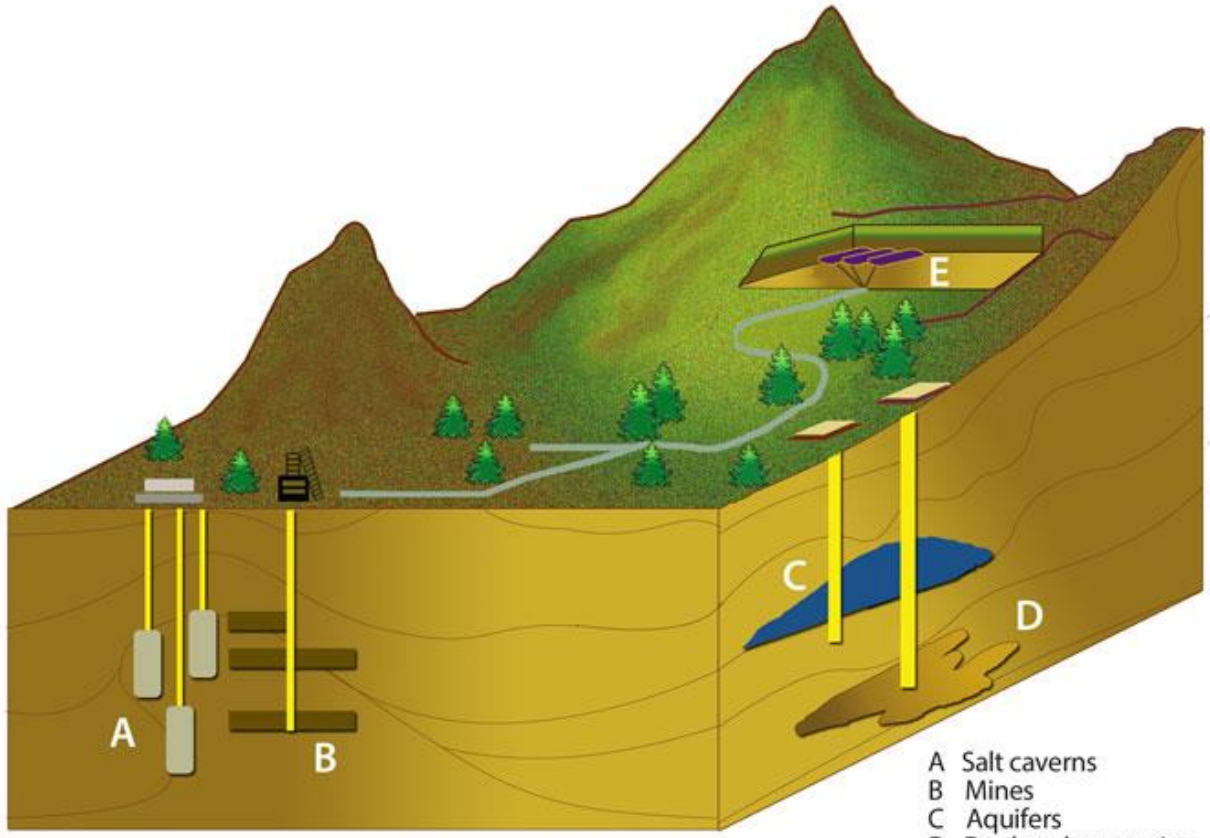
Natural Gas Storage & Delivery

How Gas is Stored and Delivered

- Gas can be stored in huge storage tanks, in underground wells, or in liquefied form

Underground Storage

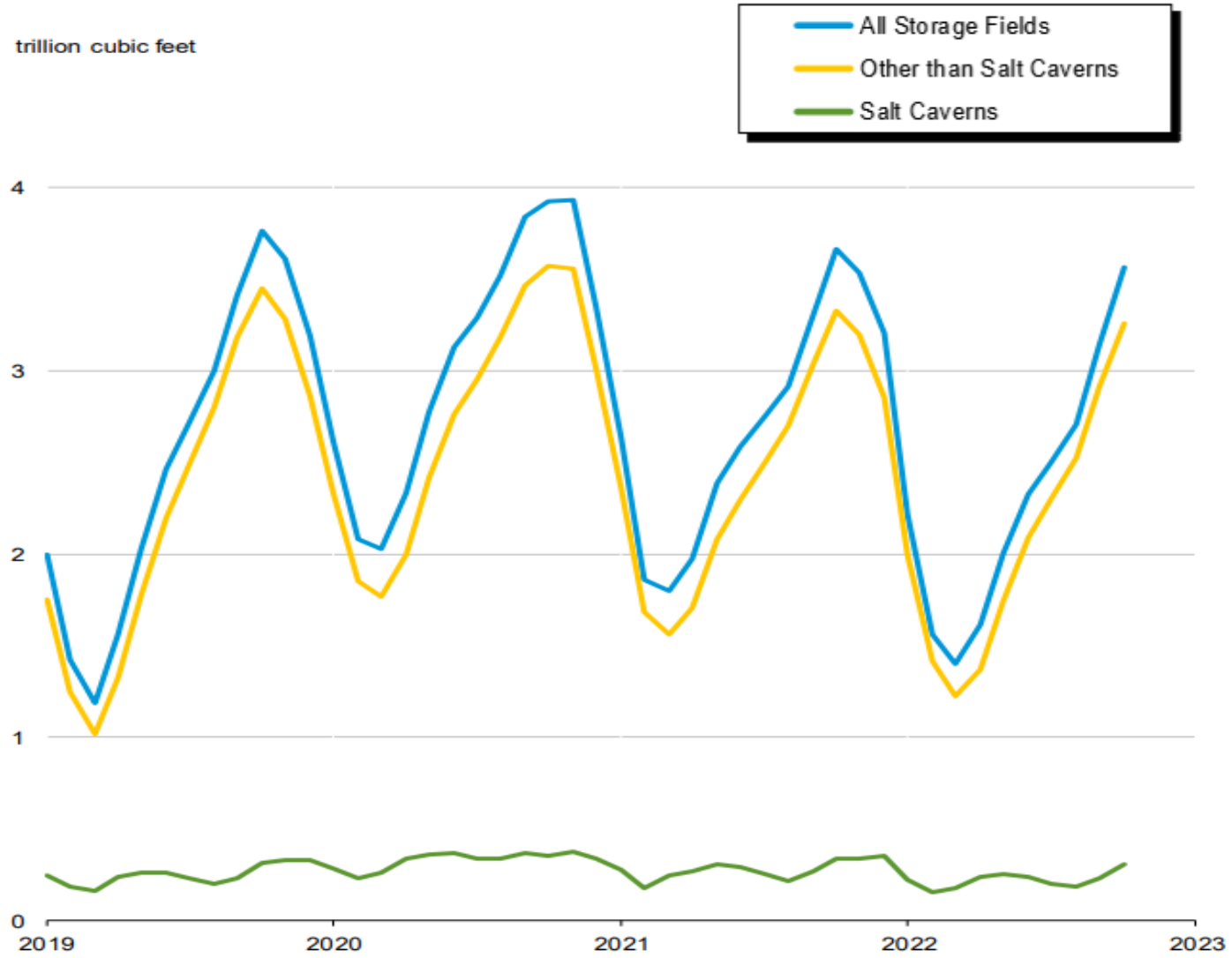
Figure 1. Types of underground natural gas storage facilities



Source: PB-KBB, inc., enhanced by EIA.

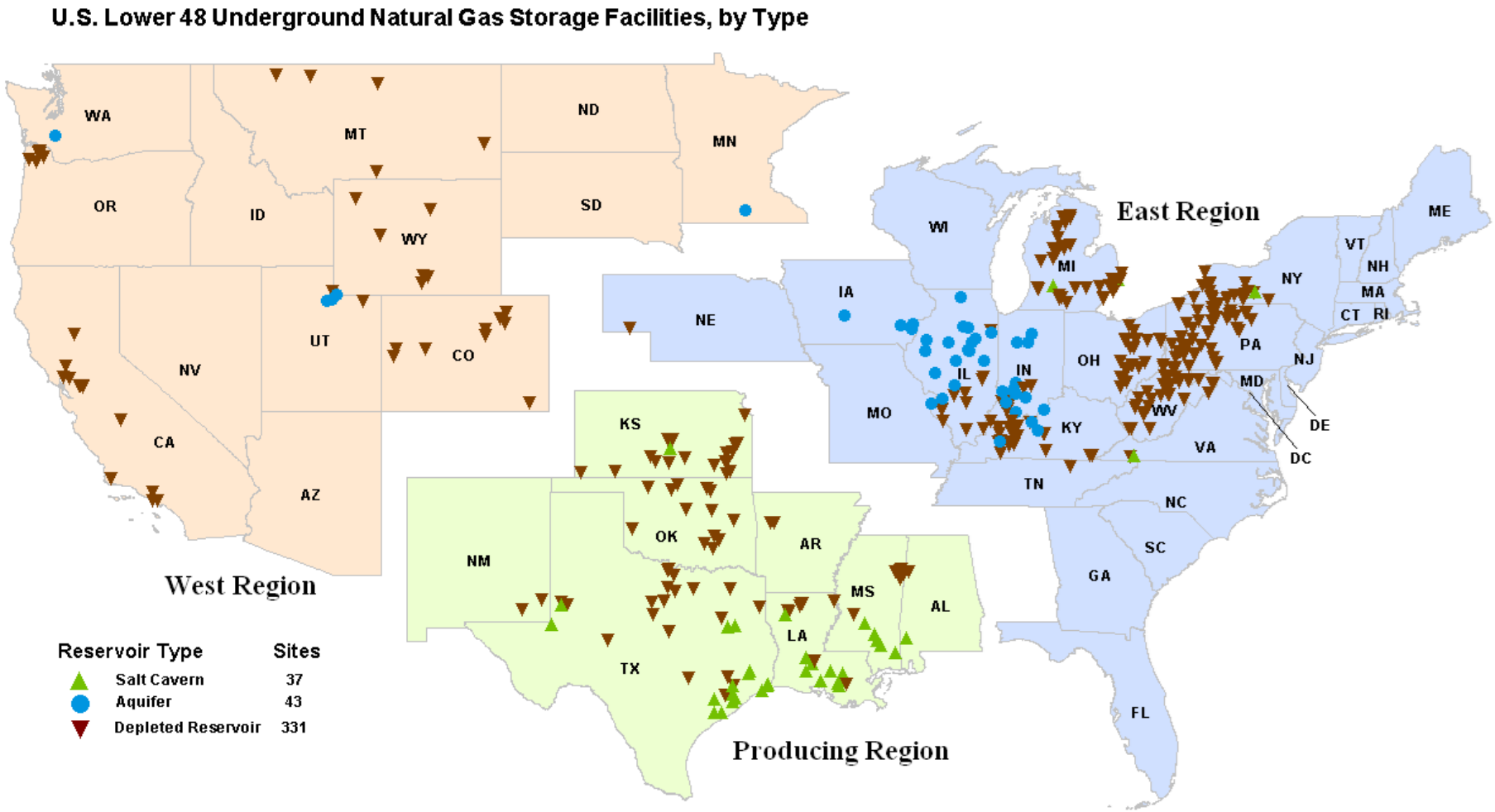
https://www.eia.gov/naturalgas/storage/basics/

Working gas in underground natural gas storage in the United States, 2019-2022



https://www.eia.gov/naturalgas/monthly/pdf/figure_05.pdf

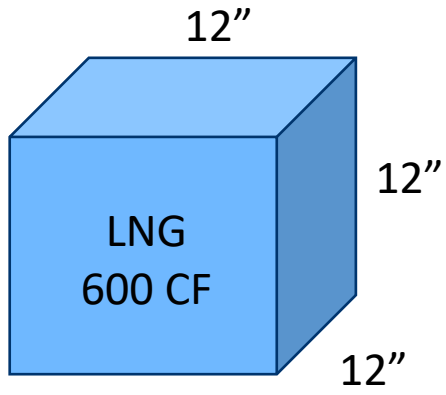
Underground Gas Storage



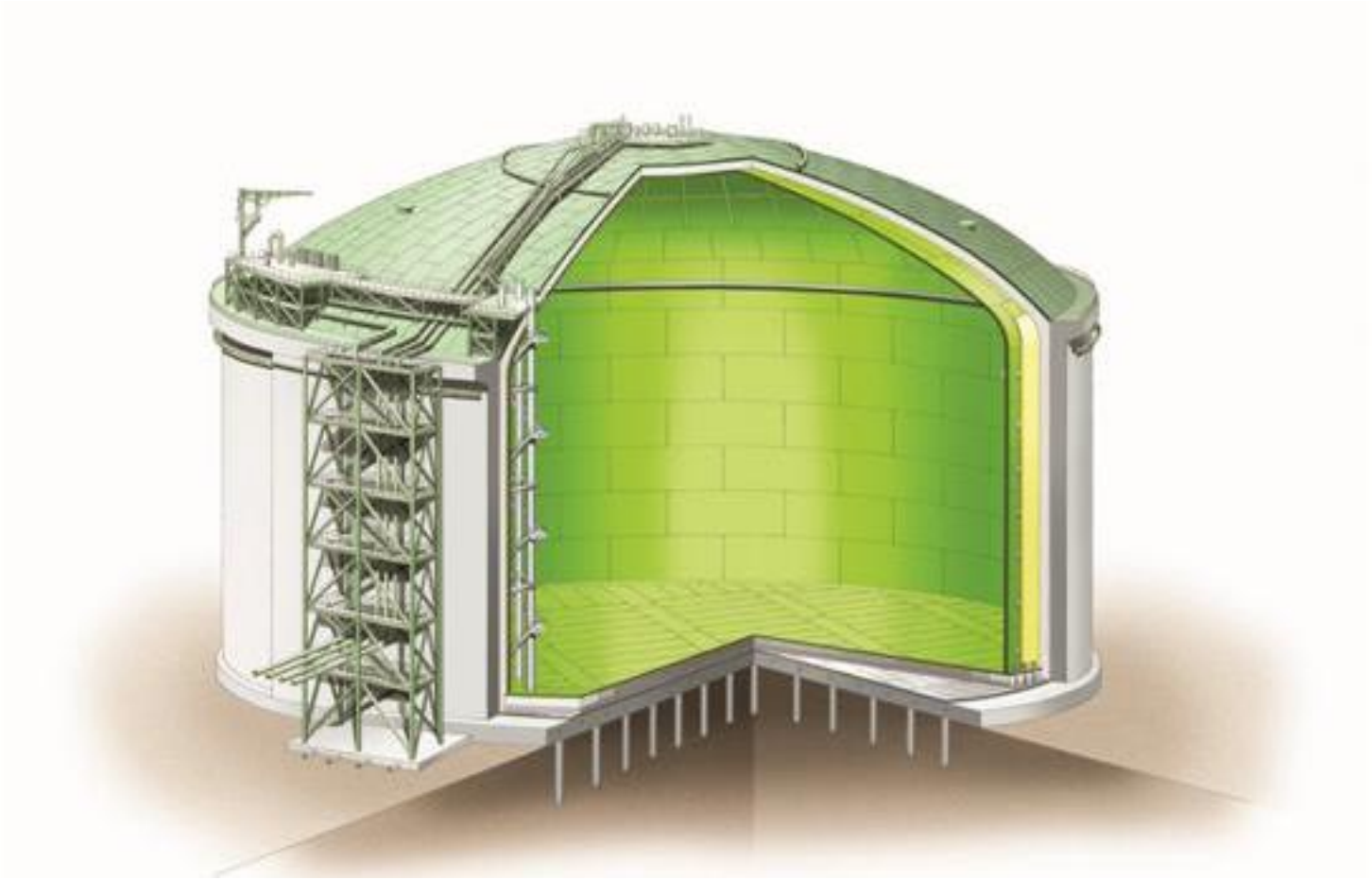
Note: Locations of storage facilities presented in the map are approximate. Some symbols representing storage facilities may overlap.
Source: U.S. Energy Information Administration, Form EIA-191A, "Annual Underground Gas Storage Report"

Liquefied Natural Gas (LNG)

- LNG is natural gas that has been chilled down to minus 160 degrees Celsius and compressed.
- Roughly 600 CF of natural gas can fit in 1 Cubic foot of LNG.
- LNG is constantly boiling off vapor.
- LNG can be stored or transported.
- LNG is often used to meet peak day demands
- LNG must be re-gasified before use with consumers



LNG Storage Tank



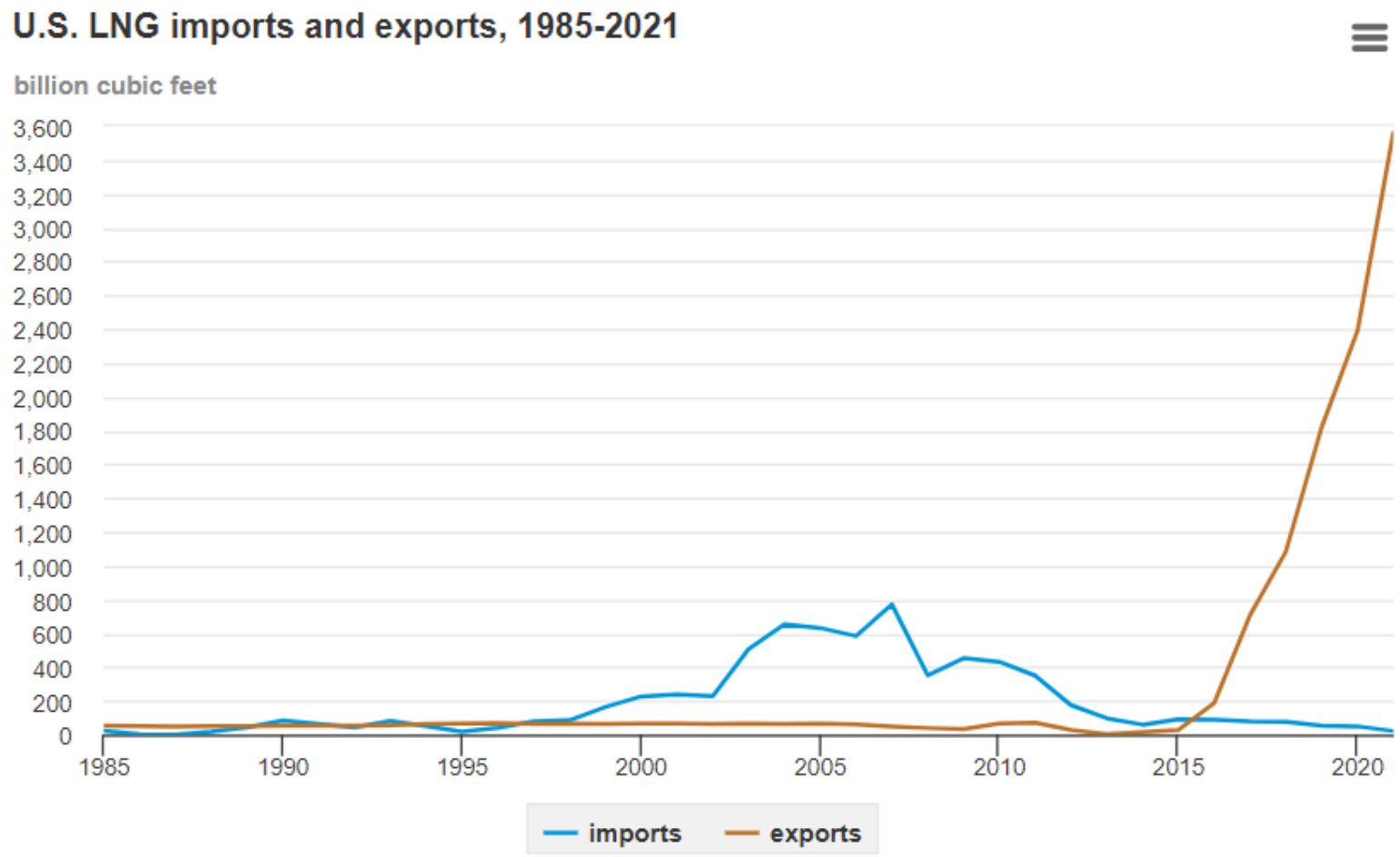
LNG Transportation

Tanker Truck

Rail Car

Tanker Ships

LNG Imports & Exports



eia Data source: U.S. Energy Information Administration, *Natural Gas Monthly*, March 2021; data for 2021 are preliminary

https://www.eia.gov/energyexplained/natural-gas/liquefied-natural-gas.php

Pipeline Construction

- FERC or state approval
  - Submit plans & economic studies
  - Show need
  - Environmental impact statement
- Obtain right-of-way
- Construction
  - Trench & directional drill
  - Install & connect protected pipe
  - Backfill

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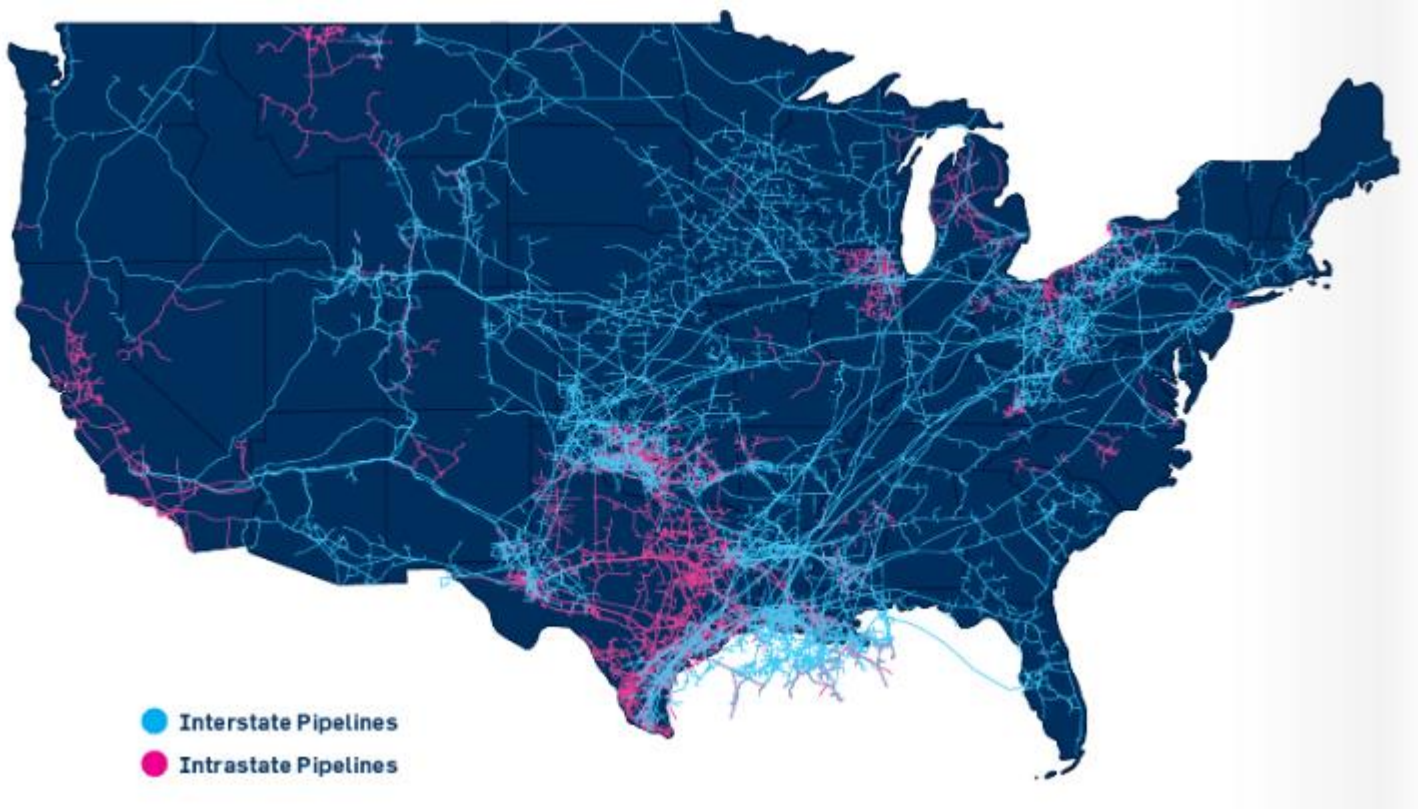
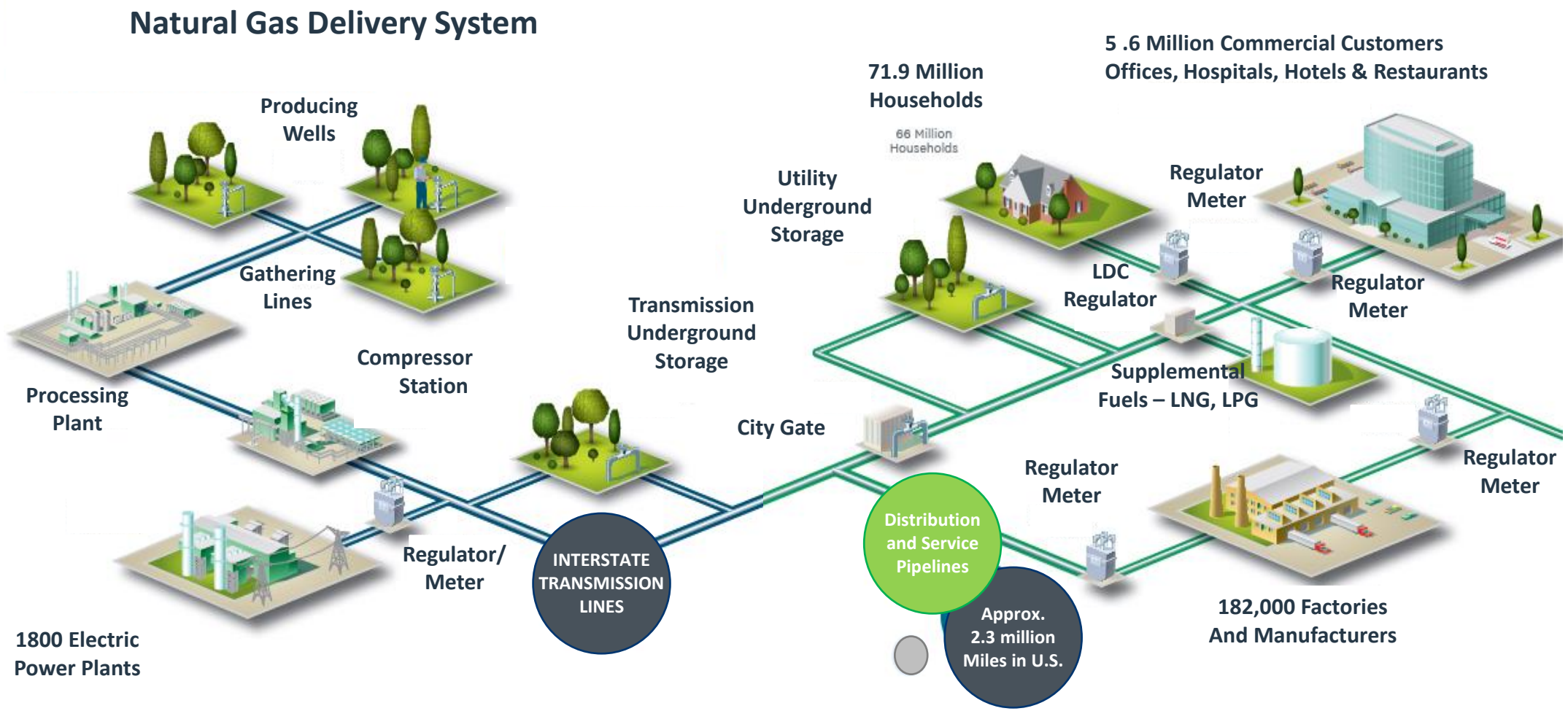
Interstate Pipeline Network



- 2.6 million mile underground system
- ~2.2 million LDC, ~300,000 Transmission

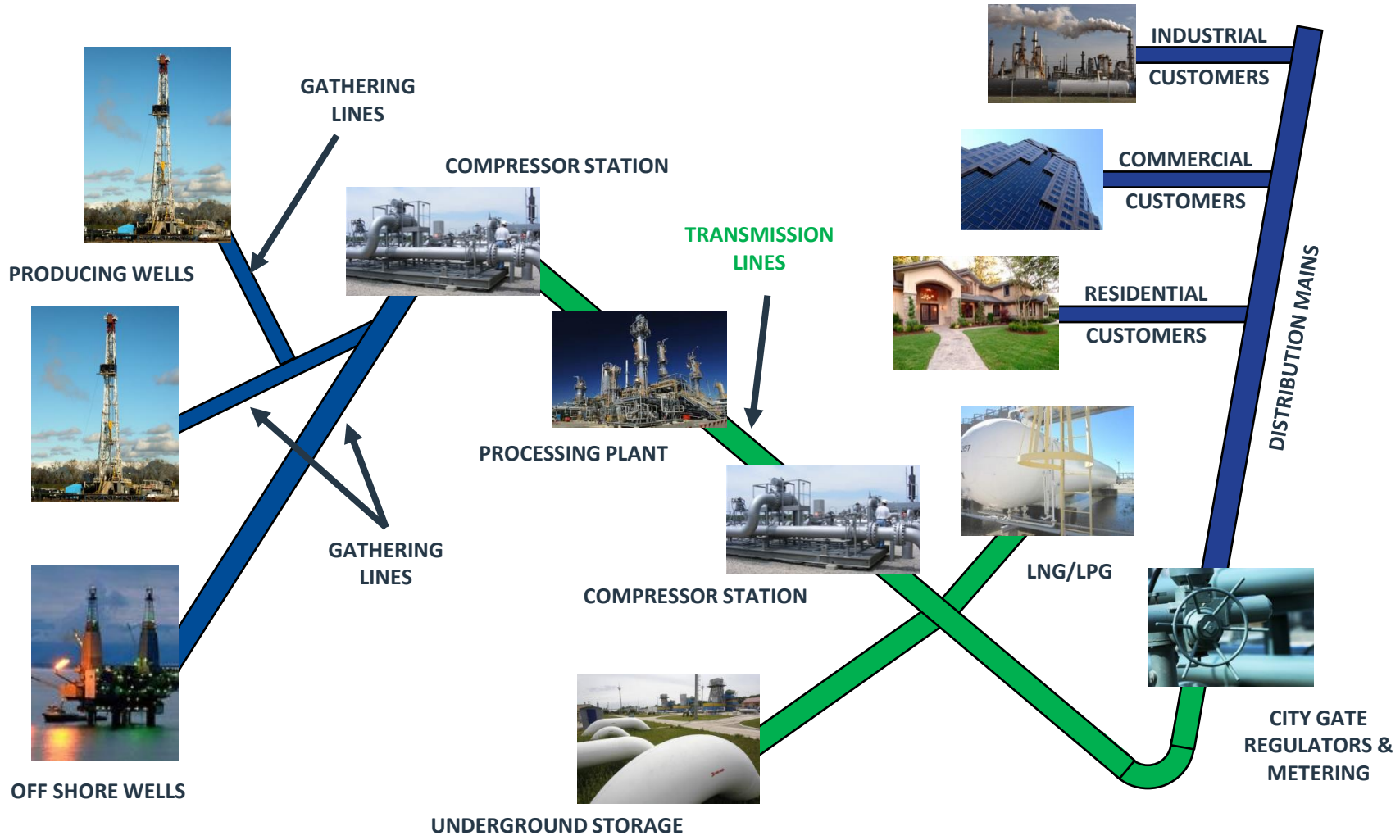
Source: AGA Playbook

How Gas is Stored and Delivered



Data from AGA's 2023 Playbook, https://playbook.aga.org/natural-gas-data , Image from an older Playbook

Transportation System



Natural Gas Measurement

Natural Gas Measurement

- *Get's tricky……*
- LDC (Gas Utility) buys natural gas in Therms
  - Buy on heating value
- LDC often sells gas to consumers in Cubic Feet (U.S.) or Cubic Meters (Canada)
  - Sell on volume

CONTINUED

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Measurement Continued

- 1 British Thermal Unit (BTU) is the amount of heat required to raise 1 Pound of water by 1°F at atmospheric conditions
- 1 Therm = 100,000 BTU
- 1 Deca Therm = 10 Therm or 1,000,000 BTU
- 1 Cubic Foot (CF) = approximately 1,037 BTUs (varies)
- 1 MCF Gas = 1,000 CF = 1,037,000 BTU
- 1 Cubic Meter = 35.31435 CF

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The Utility Cash Register

- Meters
  - Diaphragm/bellows meters
  - Rotary meters
  - Turbine meters
  - Orifice meters

The Utility Metering Function

- The gas meter is a specialized flow meter, used to measure the volume of fuel consumed
- Used at residential, commercial, and industrial buildings
- Gas is more difficult to measure than liquids, as measured volumes are highly affected by temperature and pressure
- Gas meters measure a defined volume, regardless of the pressurized quantity or quality of the gas flowing through the meter
- Temperature, pressure and heating value compensation must be made to measure actual amount and value of gas moving through the meter

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The Utility Metering Function

- The volume of gas flow provided by a gas meter is just that, a reading of volume
- Gas volume does not take into account the quality of the gas, the amount of heat available when burned
- Utility customers are billed according to the heat available in the gas
- The quality of the gas is measured and adjusted for in each billing cycle

The Utility Metering Function

- To convert from volume to thermal energy, the pressure and temperature of the gas must be considered
- Pressure is not a problem; the meter is simply installed downstream of a pressure regulator and is calibrated to read accurately at that pressure
- Pressure compensation occurs in the utility's billing system
- Varying temperatures – some meters are designed with built-in temperature compensation to keep them reasonably accurate over their designed temperature range

The Utility Metering Function

- Any type of gas meter can be obtained with a wide variety of indicators (read outs)
- The most common are indicators that use multiple clock hands (pointer style) or digital readouts similar to an odometer
- Remote readouts of various types are also popular with larger commercial & industrial customers

Advantages of Natural Gas

Gas and the Environment

- Natural gas is the cleanest burning fossil fuel
- When burned, it produces virtually no emissions of sulfur dioxide or particulate matter and far lower levels of "greenhouse" gases and nitrogen oxides than oil or coal
- Unlike the oil, coal and nuclear processes, the natural gas process produces virtually no solid waste
- Natural gas is delivered to the customer with around 92% efficiency, compared to electricity which is around 38%

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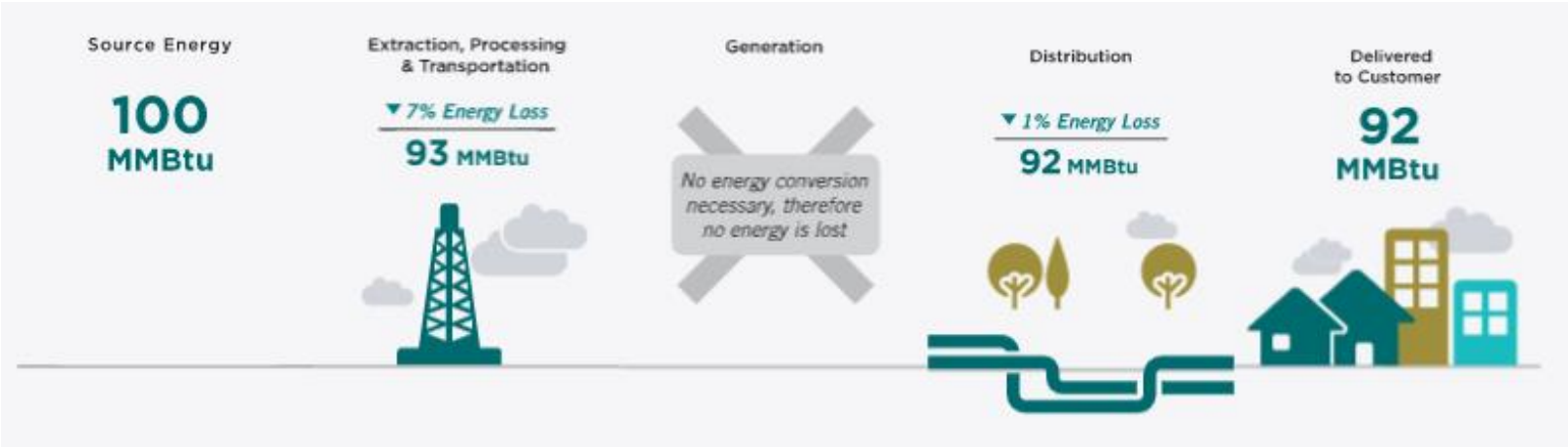
Site vs. Source

Direct Use of Natural Gas:



Converting to Electricity:

2023 AGA Playbook, https://playbook.aga.org/natural-gas-data

Residential Gas vs. Electric Appliances

Less emissions with natural gas than electric on a source basis:

Whole House	Natural Gas	Electric (All Sources)	Electric (Fossil Fuel)
NOx (pounds/year)	6.70	24.14	32.50
SO2 (pounds/year)	0.04	62.41	85.79
CO2 (pounds/year)	8,514.78	15,648.14	21,457.00
Acres of forest to remove add CO2 from electric		0.73	1.33
Number of cars removed (gas vs. electric)		0.59	1.07

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Advantages of Natural Gas

- Domestic Product
  - Approximately 85 % of natural gas is produced in the US with almost all the remainder coming from Canada
- Reliable
- Ample supply
- Competitively priced
- Environmentally friendly
- Greater comfort

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Thank You

ENERGY SOLUTIONS CENTER

400 North Capitol Street, 4th Floor
Washington, DC 20001
escenter.org