ENERGY SOLUTIONS CENTER

Energy Industry Fundamentals

Energy 101: Terminology & Factors

Eric Burgis, Energy Solutions Center

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

Outline

- Primary Sources of Energy
- Terminology
- The Natural Gas System
- Other Energy Sources
- Heating Values / BTUs
- Energy Storage & Reliability
- Average Energy Pricing
- Efficiencies and Environmental Issues

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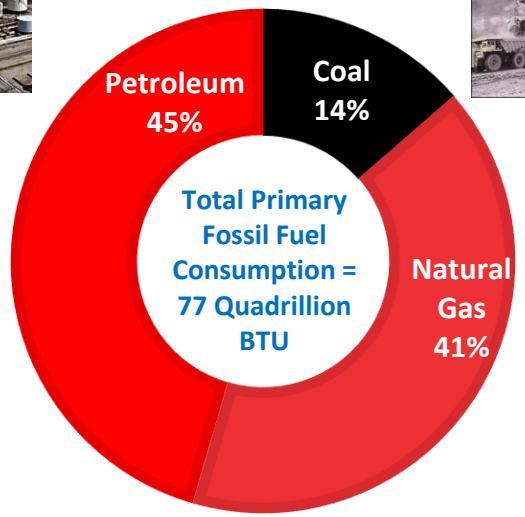
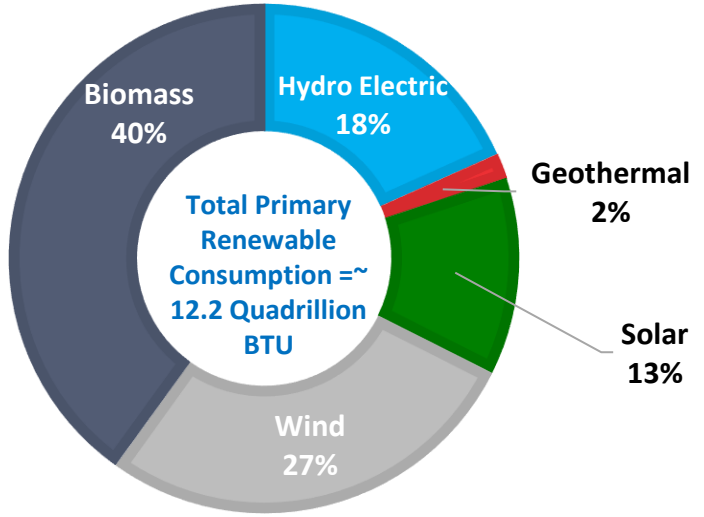
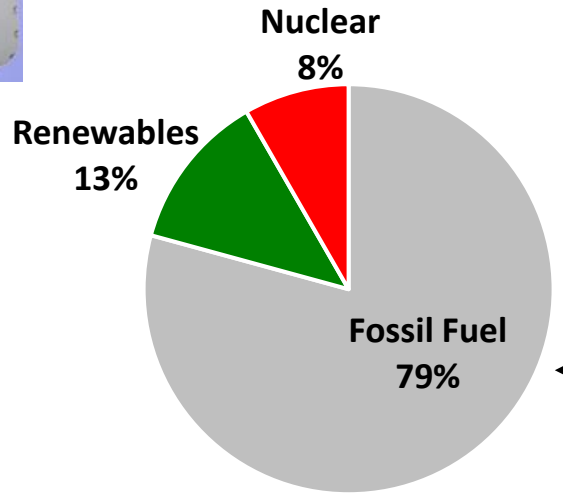
Primary Sources of Energy

TOTAL FOSSIL FUEL CONSUMPTION 2021 (QUADRILLION BTUS)



TOTAL RENEWABLE ENERGY CONSUMPTION 2021 (QUADRILLION BTUS)



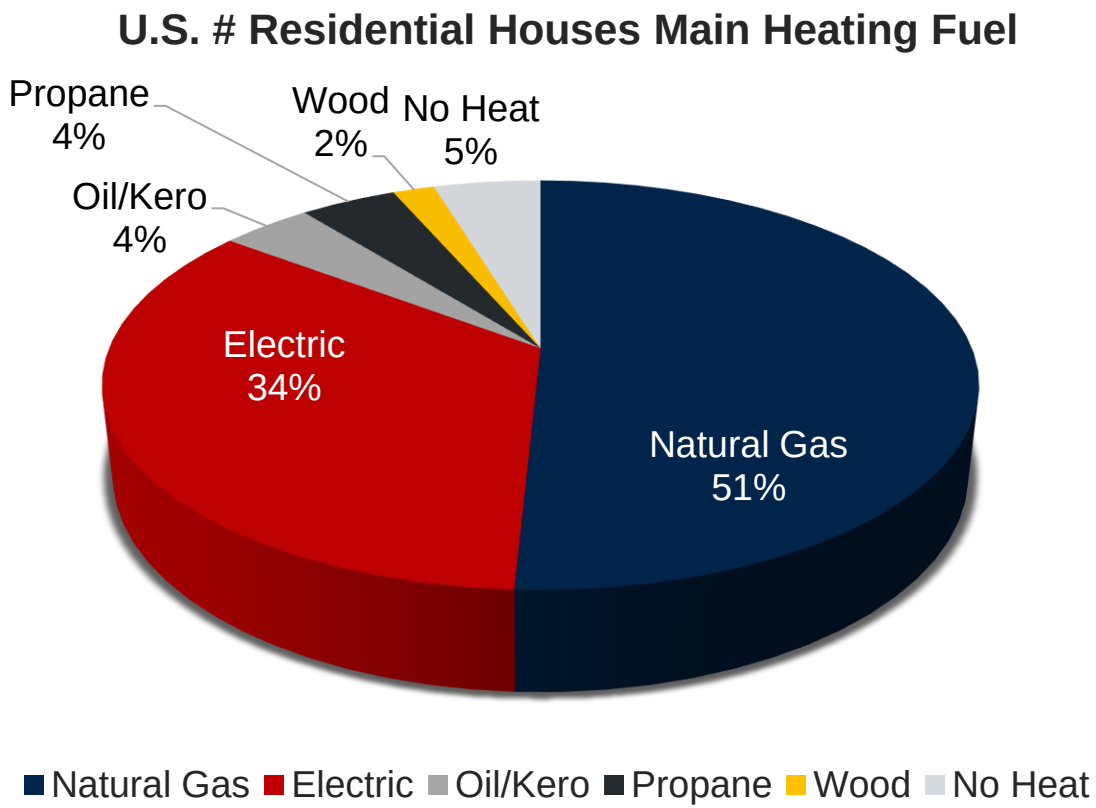


27% of Fossil Fuel Consumption is consumed in Electric generation

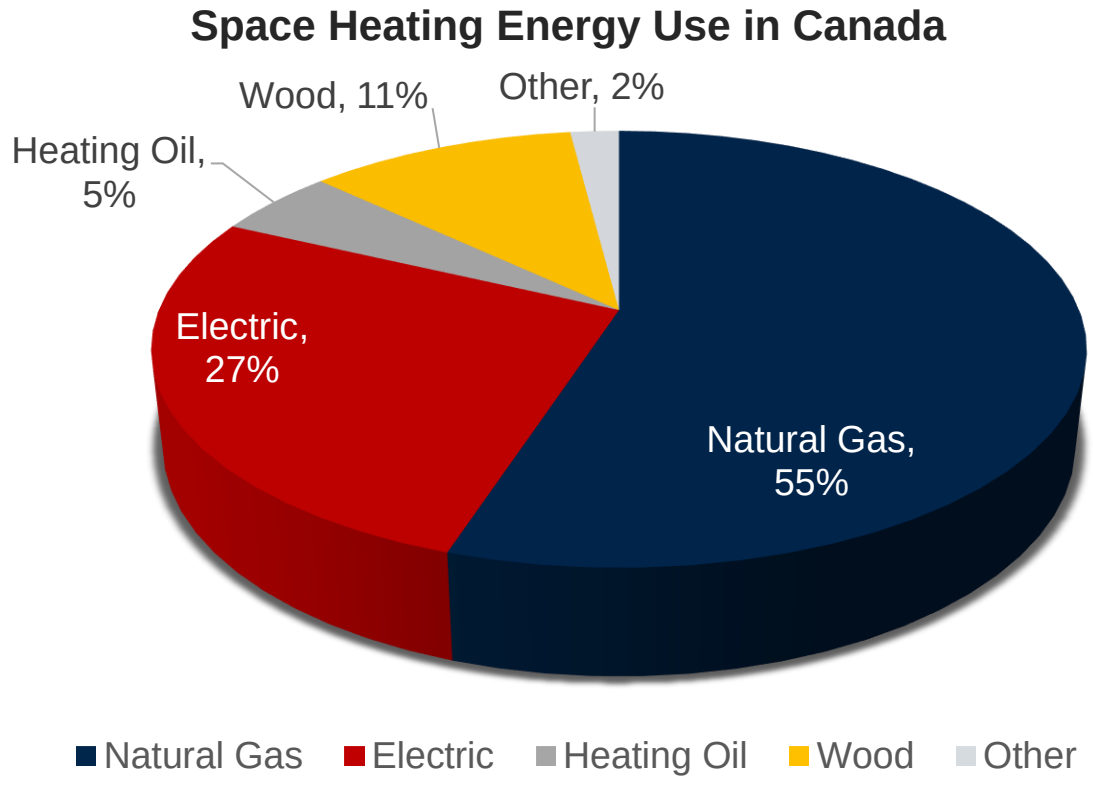
Total Primary Energy Consumption 2021 (Quadrillion BTUs)

https://www.eia.gov/totalenergy/data/annual/#summary , Table 1.3 & 2.1f(2.6)

Residential Main Heating Fuel



Source: 2020 Residential Energy Consumption Survey, Table HC6.1
https://www.eia.gov/consumption/residential/data/2020/hc/pdf/HC%206.1.pdf



Source: Natural Resources Canada – Energy Fact Book 2022-2023, Pg 47
https://publications.gc.ca/collections/collection_2022/rncan-nrcan/M136-1-2022-eng.pdf

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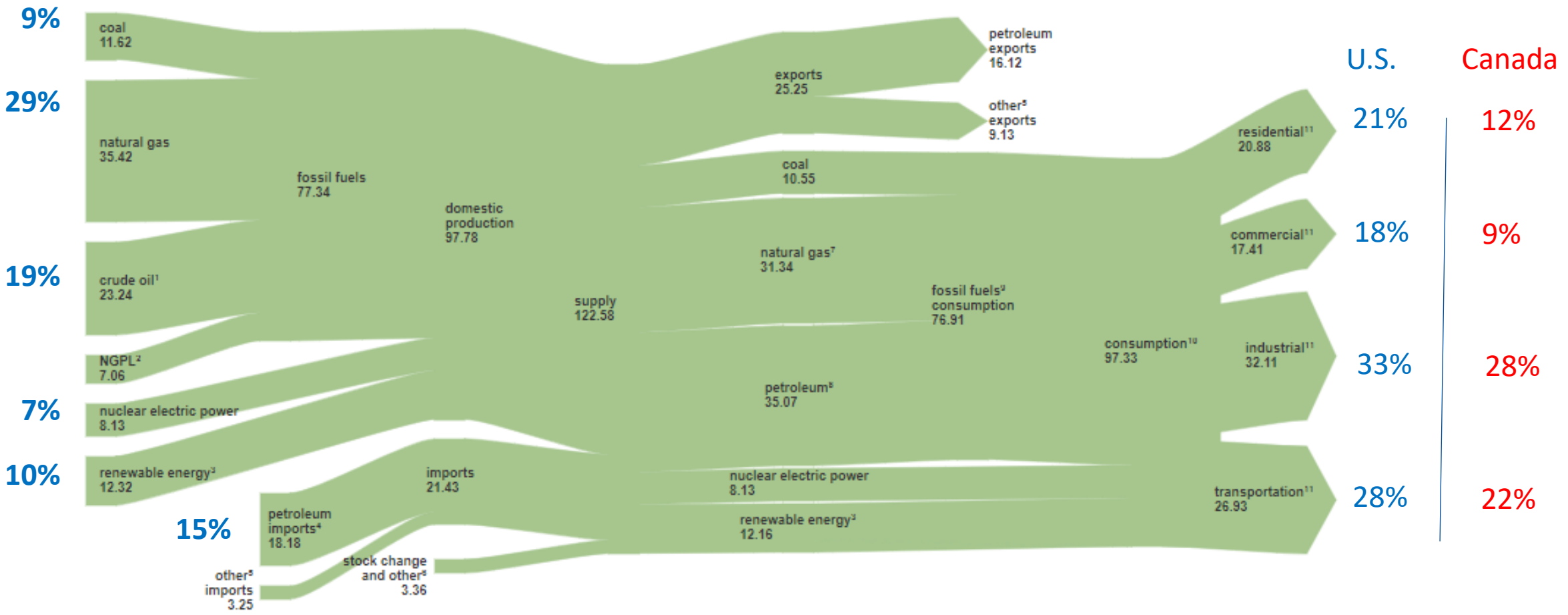
https://www.eia.gov/totalenergy/data/annual/#summary , Table 1.3 & 2.1f(2.6)

U.S. Energy Flow (quadrillion BTU)



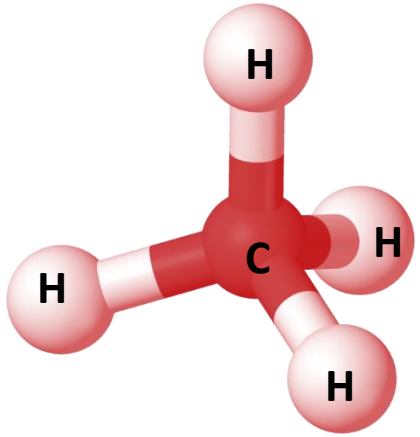
https://www.eia.gov/totalenergy/data/flow-graphs/total-energy.php

Canada 201: https://publications.gc.ca/collections/collection_2022/rncan-nrcan/M136-1-2022-eng.pdf

Terminology

What is Natural Gas

- Natural gas is a fossil fuel formed when layers of buried plants, gases, and animals are exposed to intense heat and pressure over thousands of years
- The energy that the plants originally obtained from the sun is stored in the form of chemical bonds in natural gas



CH_4

General Energy Terminology

Gas

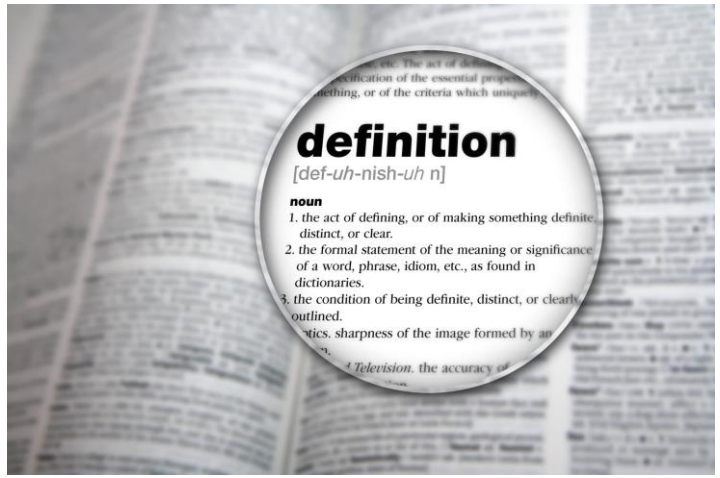
- BTU
- MCF
- Therm
- Gallons (Propane)

Oil

- Gallons
- Barrel

Coal

- Tons



Terms: Natural Gas Units of Measure

- **Natural Gas**
  A domestic product that is mostly methane, CH_4
- **CF**
  1 Cubic Foot of Natural Gas, Usage Component
- **CFH**
  Cubic Feet per Hour, Demand Component
- **CCF**
  100 Cubic Feet of Natural Gas
- **MCF**
  1,000 Cubic Feet of Natural Gas
- **BTU**
  British Thermal Unit

Tip

The Natural Gas industry uses Roman Numerals.
C = 100
M = 1,000

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Terms: Natural Gas Units of Measure

- **MBH**
  1,000 BTU per Hour
  Typically Natural Gas is sold in CCF, MCF, Therm or DTH
- **Therm**
  100,000 BTU's
- **DTh**
  Deca Therm 1,000,000 BTU's
- **LDC**
  Local Distribution Company or gas utility
- **w.c.**
  Pressure in inches of water column (27.68 Inch w.c. = 1 PSI)
- **PSI**
  Pounds Per Square Inch

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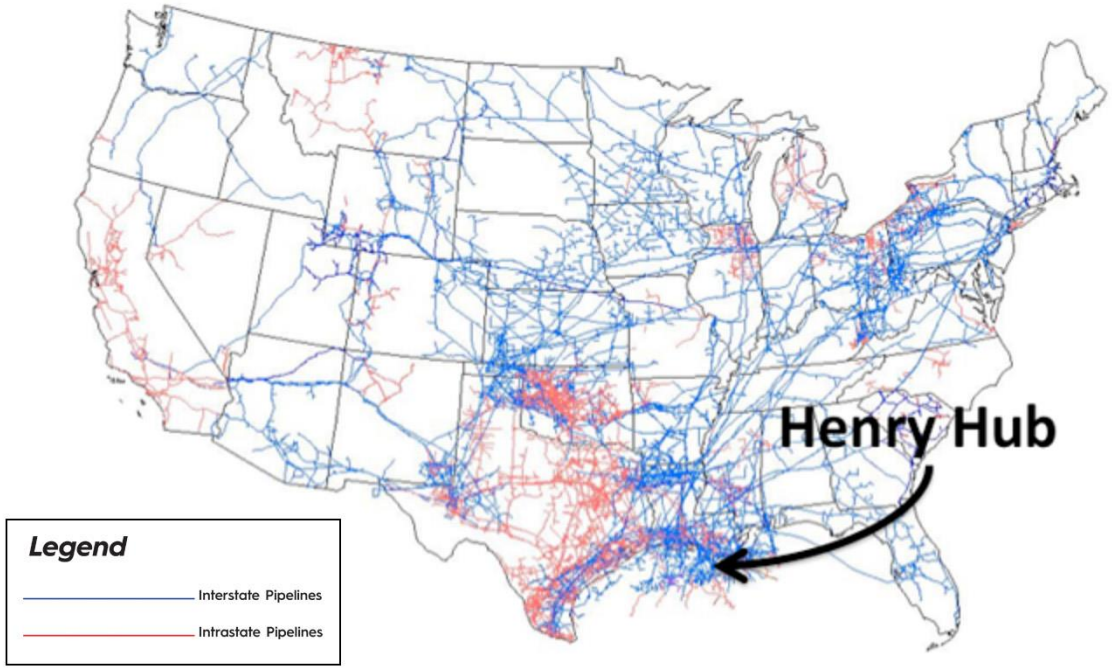
Terms: Natural Gas Distribution

- **Henry Hub**
  - Central location where natural gas from the Well Heads is managed, sold, and re-distributed to the LDC's
- **City Gate**
  - Location point where the transmission lines end, and the local utility gas mains begin
- **Basis**
  - Differential pipeline costs associated with various entry points along the transcontinental pipeline. Often used to describe the pipeline transportation cost to City Gate including differential costs.



Terms: Natural Gas Purchasing

- **1,037 BTU/CF (per EIA for 2021)**
  - The heating value fluctuates daily and varies differently at different gate stations across varying regions
  - The gas industry buys gas in BTUs and sells in volume
- **NYMEX**
  - New York Mercantile Exchange is the place where futures contracts for natural gas are traded daily
- **Contract**
  - 10,000 Deca Therms of Natural Gas
- **Transportation Charges**
  - Typical charge to transport gas from the city gate to the end user or ‘Burner Tip’

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Terms: Natural Gas Transportation

- **Bundled Service**

  The LDC buys, pays basis and transports the gas to the end user for a bundled cost

- **Un-Bundled Service**

  The end user buys their own gas and pays all cost to have it delivered to the City Gate, and pays the LDC only for transportation service from city gate to their facility

Miscellaneous Terms / Definitions

- **BTU**
  - The most common denominator in energy
  - One British Thermal Unit is the amount of energy required to raise 1 pound of water by 1 Degree Fahrenheit at base pressure and temperature conditions
- **Horsepower**
  - Horsepower can be a relationship to boiler heating output capability or brake horsepower in an electric motor
    - 1 Boiler Horsepower is equal to 33,472 BTU's of output energy off of the boiler
- **CHP**
  - Combined Heat and Power, also known as Co-Generation

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Miscellaneous Terms / Definitions

- **HVAC**
  - Heating, Ventilating, and Air Conditioning
- **Cooling Ton**
  - The equivalent of melting one ton of ice over 24 hours
  - The term originated during the transition from stored natural ice to mechanical refrigeration
  - One ton = 12,000 BTU's
- **Life Cycle Costing**
  - a way to view two different options where the total costs for each option are reviewed side by side over the expected life of the equipment (typically 20 years). Included in the analysis are: Capital Costs (including interest rates), Energy Costs (including inflation factors) and Maintenance Costs expected for each option

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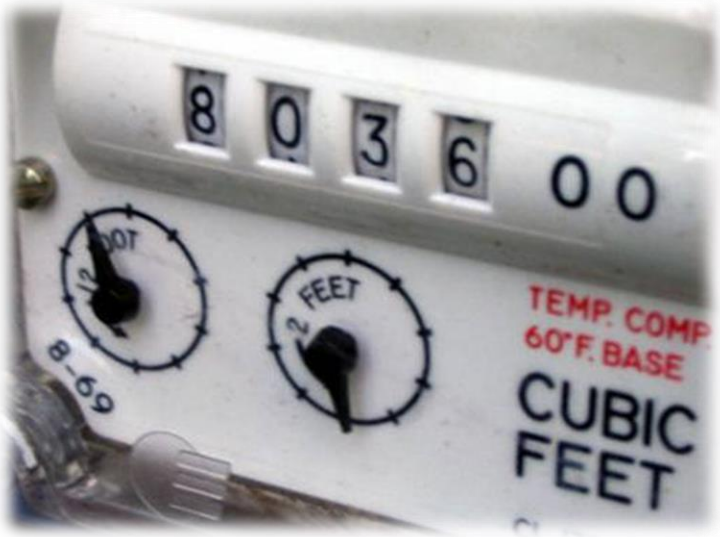
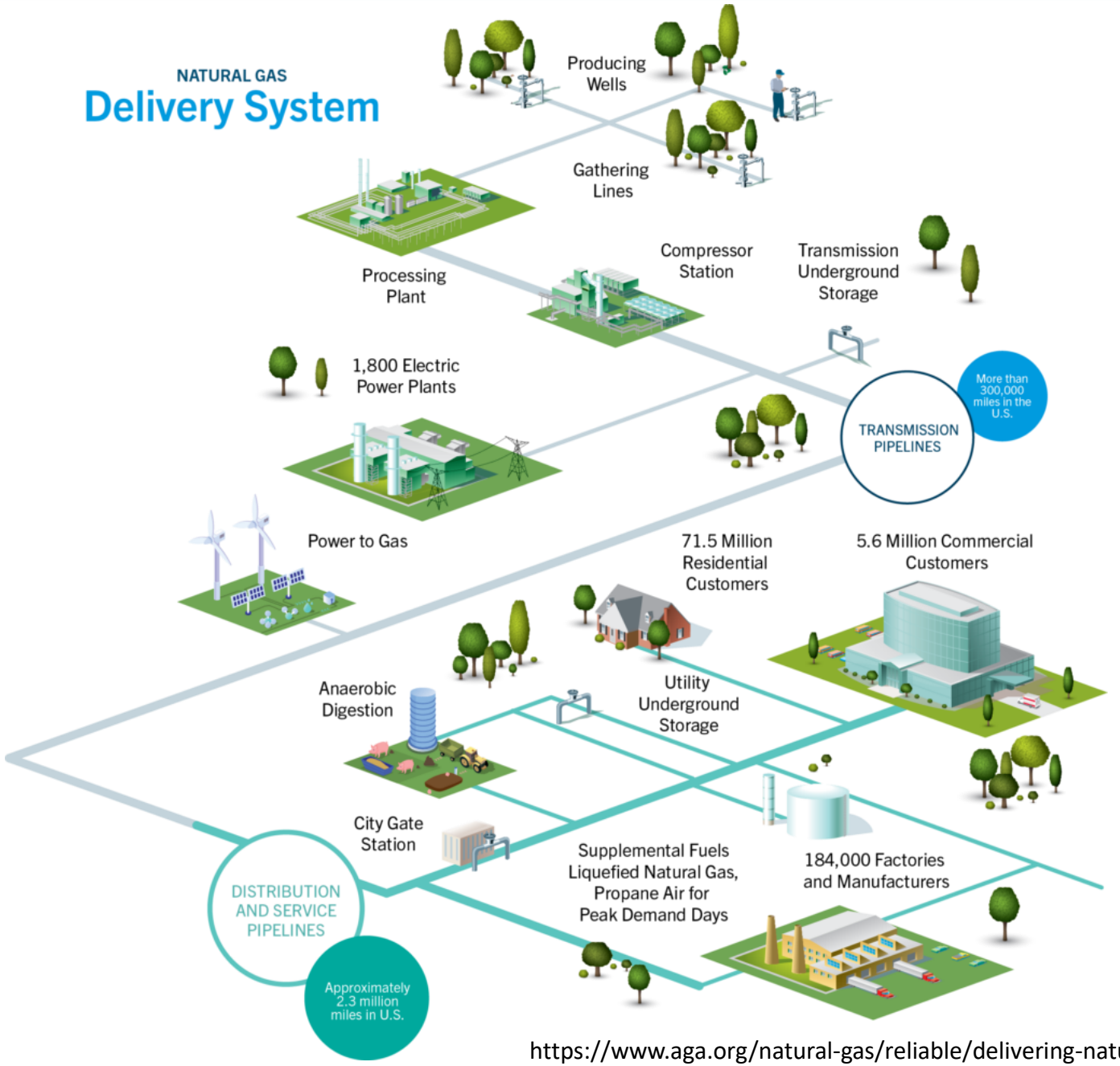
Factors that Impact the Number of BTUs in a CF of Gas

- **Pressure**
  - Natural gas is very compressible, More gas can be fit in the same cubic foot of space by a pressure factor =~ (gas pressure + 14.73 atmospheric pressure) / 14.73
- **Temperature**
  - Natural Gas also compresses with colder temperatures, but minimally



The Natural Gas System

Natural Gas Transportation System

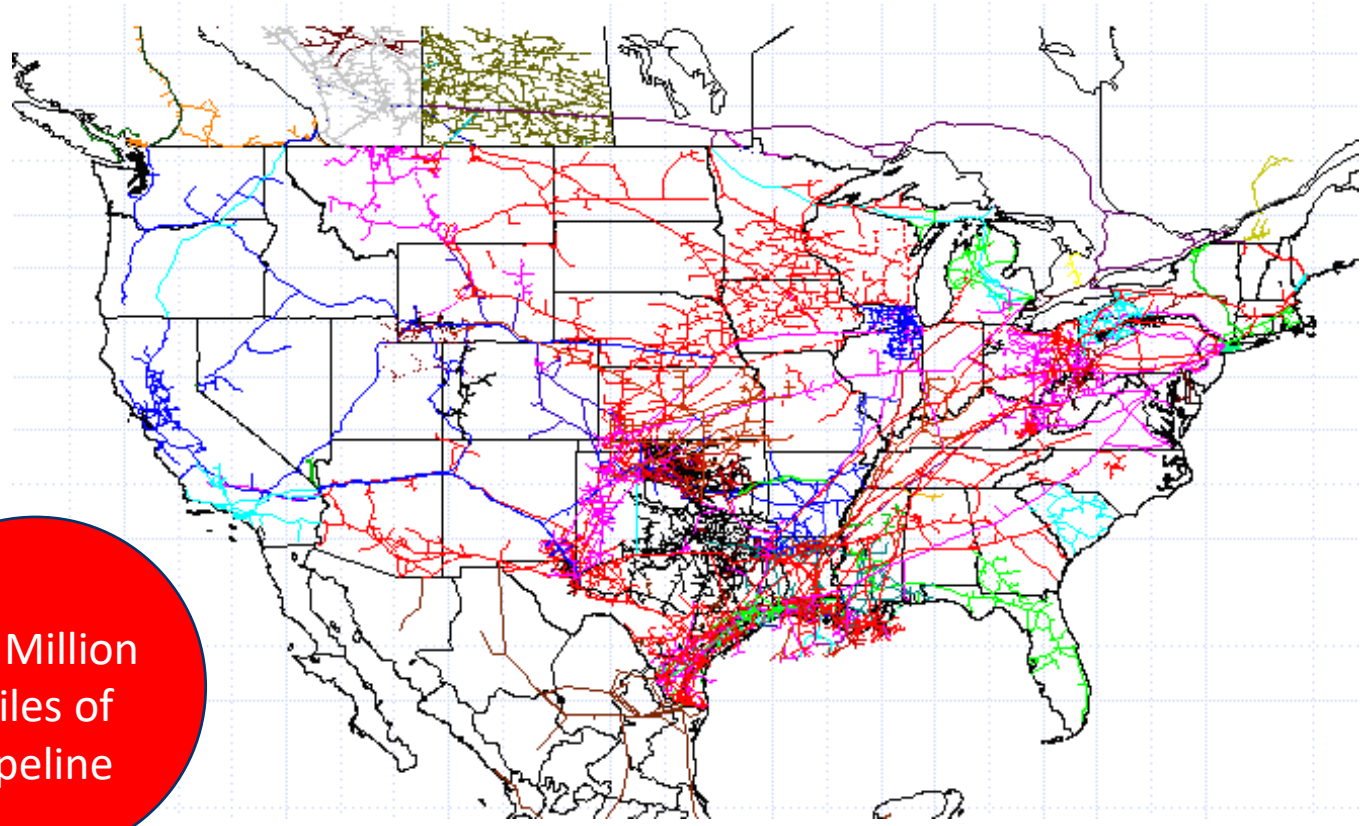


https://www.aga.org/natural-gas/reliable/delivering-natural-gas/

A Vast Network of Pipelines Provides Interstate Gas Transportation

Miles of Pipelines

- Gathering: 17,700
- Transmission: 300,300
- Distribution: 1,286,100
- Services: 922,500



2.6 Million Miles of Pipeline

Source: AGA Gas Facts and 2021 Playbook

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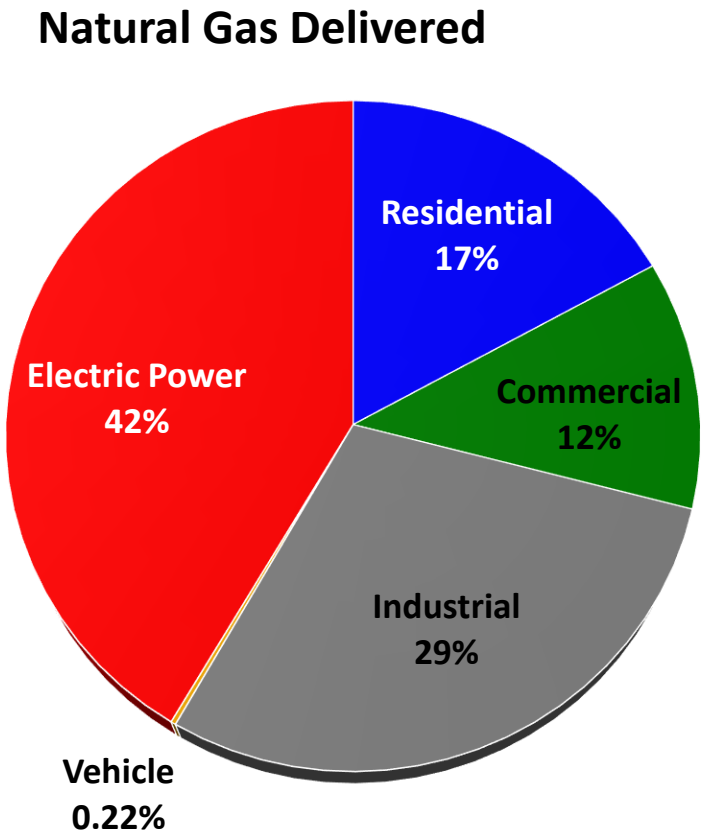
Natural Gas Usage by Sector

Total =29,193,090 Million CF



2022 EIA Data, https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm

Other Energy Sources

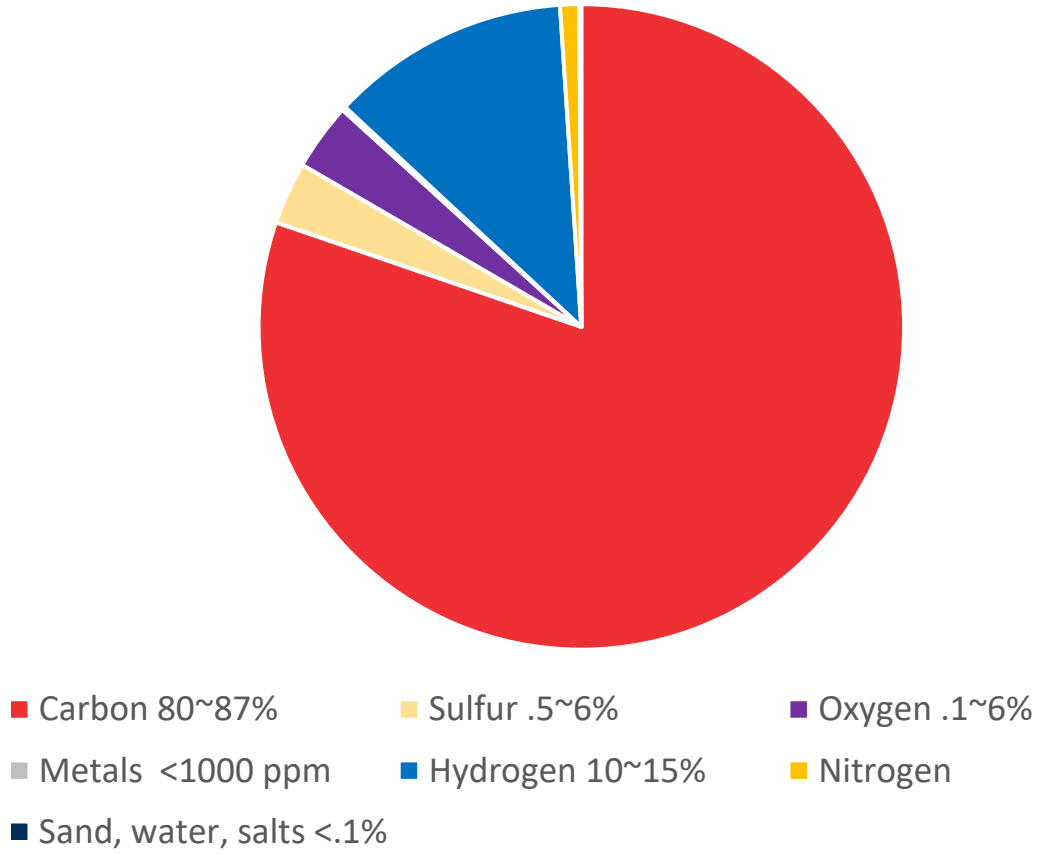
Crude Oil

- America is extremely dependent on Foreign Crude Oil
- Refineries in America separate ‘Crack’ the crude into many more usable fuels:
  - The lightest fuels derived are gaseous – ethane & methane
  - Next – Propane and Gasoline in liquid form
  - A number of different grades of oil are then derived from Kerosene the lightest then #2 oil (Diesel) through #6 oil which is the heaviest oil
  - Lastly comes a product called coke which is either cracked further or used as a solid form of fuel similar to coal

Crude Oil

- **Barrel**
  - One barrel = 42 Gallons

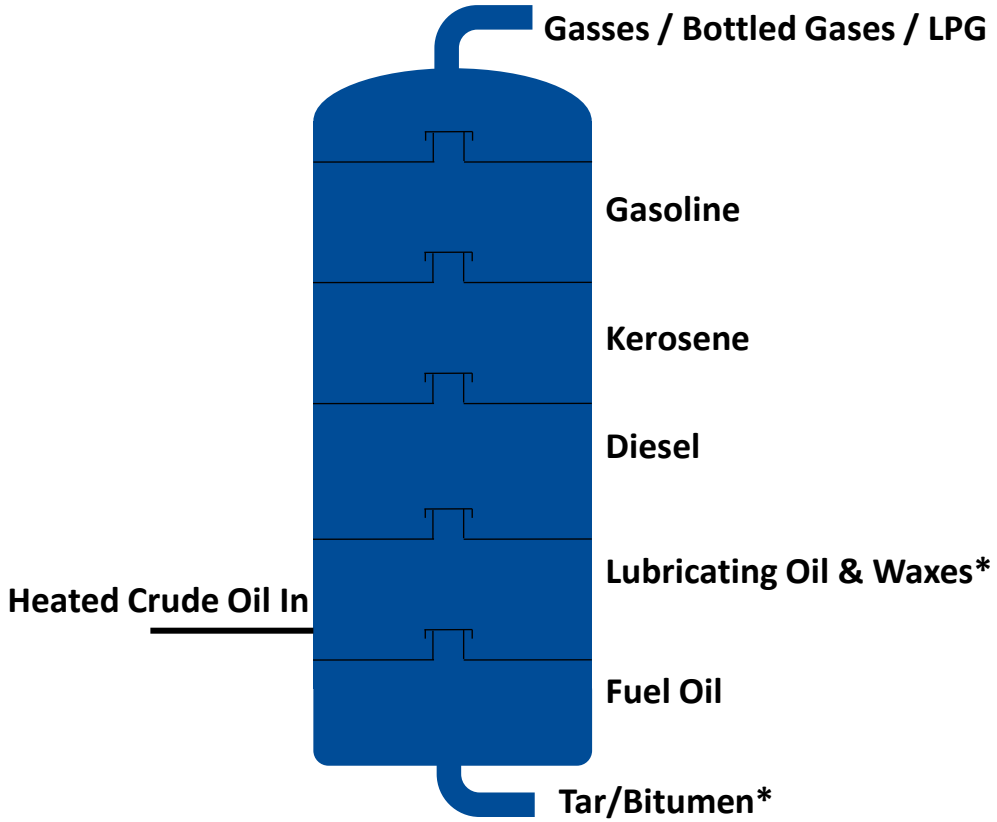
Crude Oil Element Composition



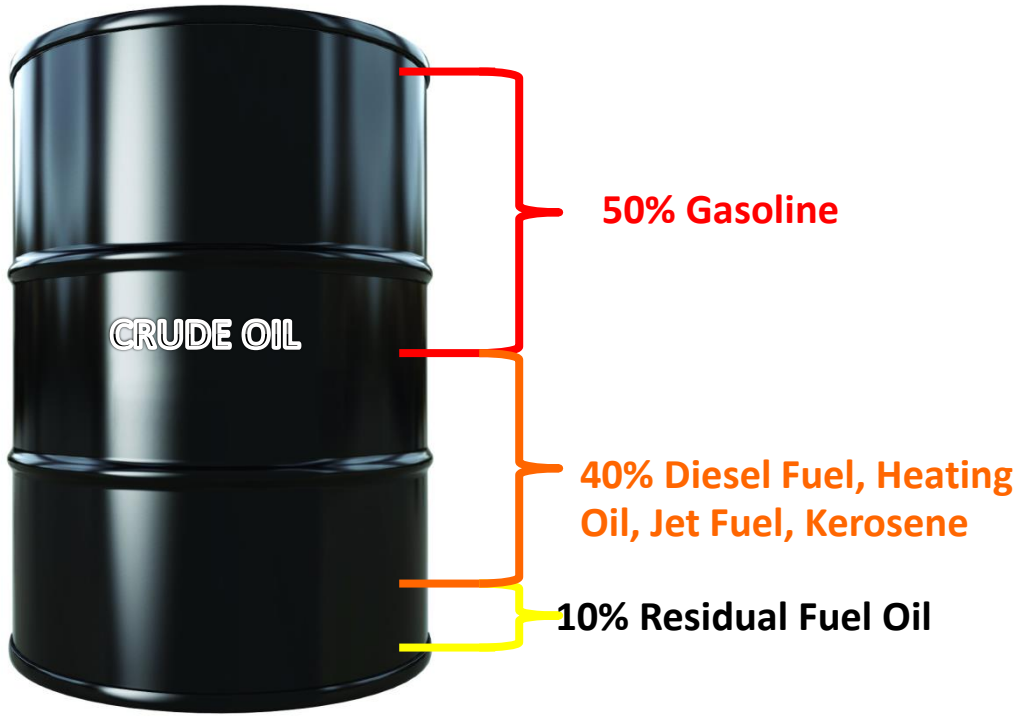
https://thepetrosolutions.com/composition-of-crude-oil/

Crude Oil Refining

Fractional Distillation



Typical Refinery Yield



* These are typically distilled in a separate tower under vacuum

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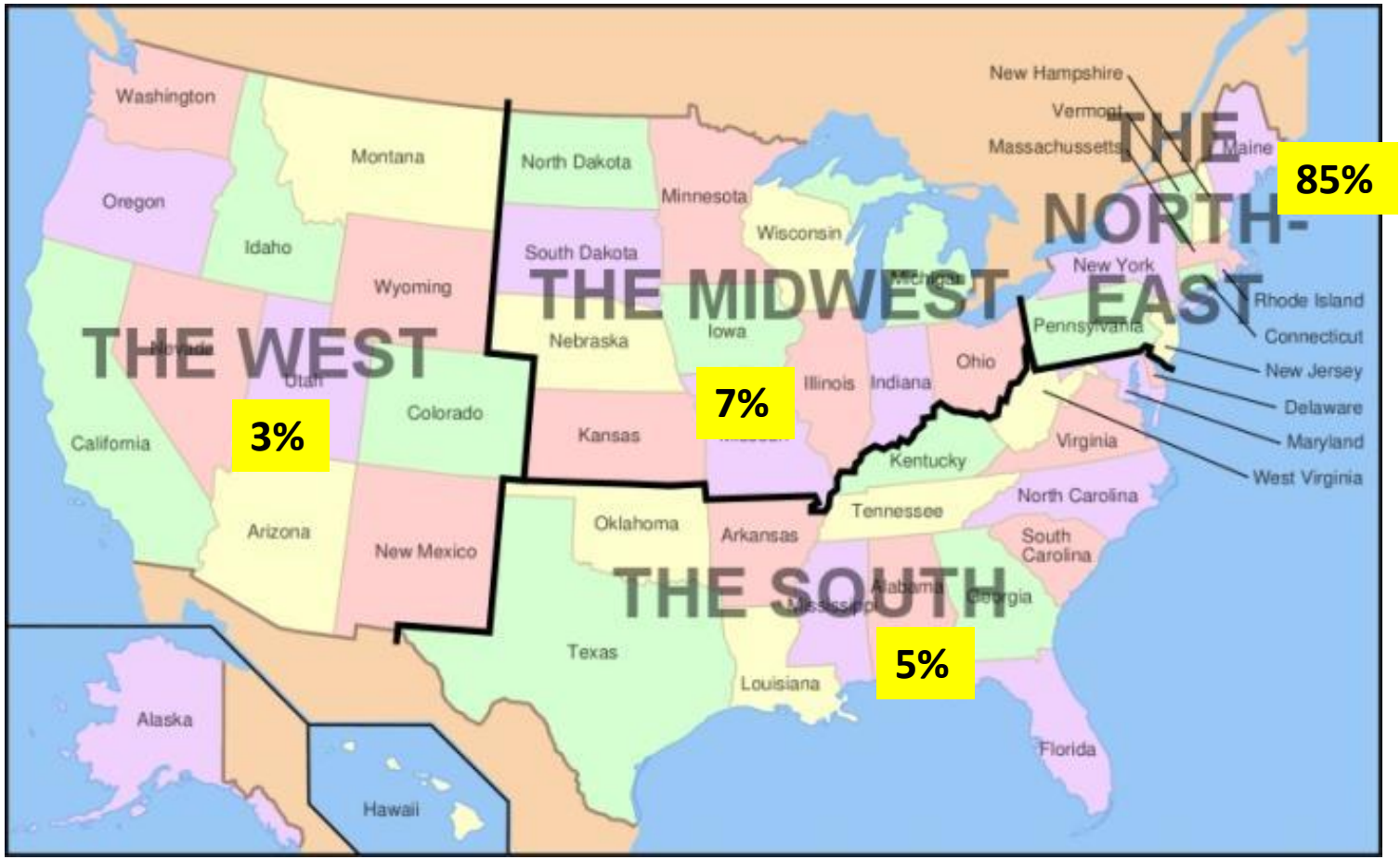
Oil Grades

- **Grades: #2, #4, #5, or #6**
  - #2 Oil (Heating Oil)
    - The lightest oil – used for residential, commercial and light industrial
    - Most popular grade used in Boilers predominately
    - Used in commercial market sector, retail, offices, etc.
  - #6 Oil
    - The heaviest and thickest oil – typically industrial fuel
    - Less expensive than #2 oil – has higher BTU content
    - Requires that it be kept hot during storage and additional heating before burning
    - Used in larger boilers or industrial applications, hospitals, etc.
  - Diesel
    - Used to power diesel engines
    - Same characteristics as #2 oil (difference being taxation of the different fuels and #2 oil is dyed a different color for government monitoring)
    - Used for back up generators and transportation fuel

Where is Heating Oil Being Used?

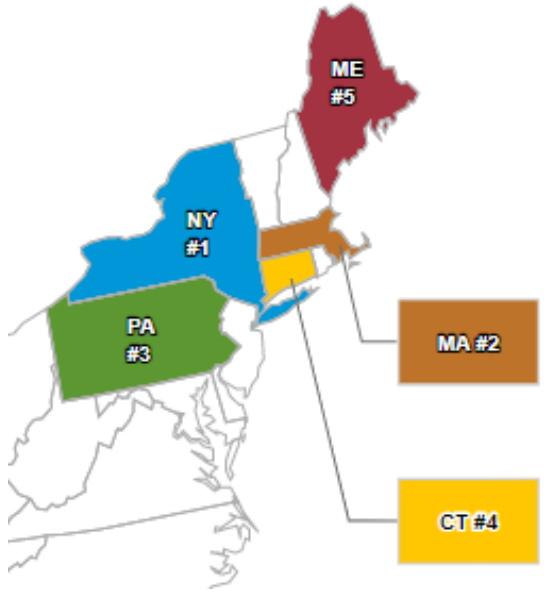


https://www.eia.gov/energyexplained/heating-oil/use-of-heating-oil.php

5.2 Million homes heated with oil during 2020/2021 heating Season

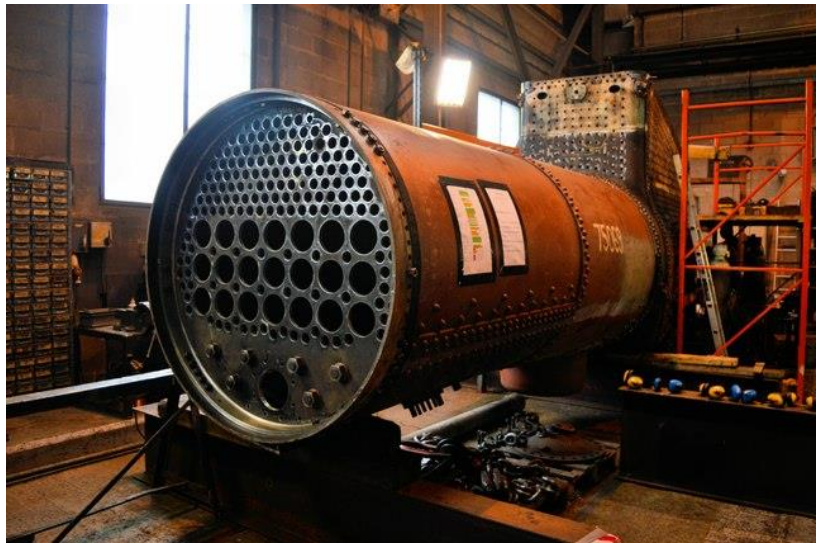
(Was 8.6 Million in 2008)

Top 5 states using heating oil:



Oil Operating & Maintenance Costs

- There are significant O&M cost associated with burning oil in comparison to natural gas:
  - Approximately 2.8% of cost for #2 oil
  - Approximately 6.6% of cost for #6 oil
- Efficiencies degrade when burning oil as soot builds up in boilers versus fairly constant efficiency with natural gas



Assumed Oil Operating Costs

Loss From	Description	#2 Oil	#6 Oil
Oil Pumping	Cost of electric required to pump oil from tank to boiler.	.32 %	.32%
Oil Inventory	Oil is paid for and stored before use compared to being billed after use	.6%	.6%
Atomization	The cost to atomize oil into small droplets & mix with combustion air	1.88%	1.88%
Oil Pre-Heating	Heating oil to 200 – 250 deg F so that it may be atomized		.78%
Storage Heating	Cost to heat and keep heavier grades of oil at 125 Deg F or more		2.0%
Make up Water	Water used for storage heating, soot blowing, etc.		.22%
Oil Additives	Additives to the heavier oils to boilers operate properly		.8%
	Total	2.8%	6.6%

Data taken from "An Analysis of the Losses and Costs Associated with Oil Versus natural gas Firing, an Update on a Nationwide Boiler program", 6/18/90

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Propane

- Propane is stored in liquid form, but burned in a gaseous form and has similar characteristics to that of Natural Gas when burned
- **L.P.**
  - Liquid Propane, One of the many byproducts that results in the cracking process of crude oil to turn it into Gasoline
- **Gallon**
  - Unit of measure that Propane is sold at
- Propane is often used when natural gas is not available
- **Air Blending**
  - A process where air is blended with propane
  - to give the characteristics of natural gas

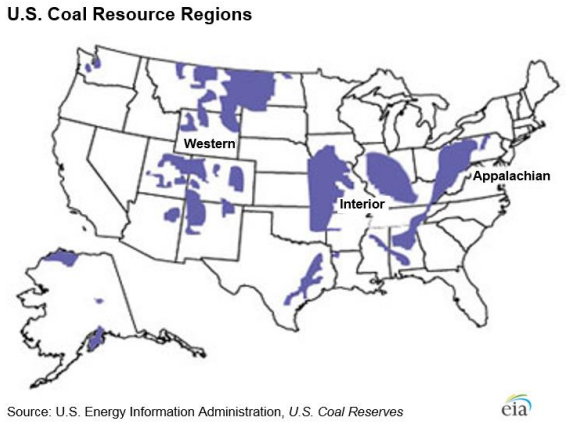
Coal

- Anthracite contains 86-98% carbon, and has a heating value of about 15,000 BTUs/lb.
- Bituminous Coal contains 45-86% carbon and is the most abundant form found in the U.S. although sulfur content tends to be high. Heating value: 15,500 BTUs/lb.
- Subbituminous Coal contains 35 to 45% carbon with a heating value of 8,300 – 13,000 BTUs/lb
- Lignite Coal contains 25-35% carbon, is generally high in ash and has a heating value of 4,000 – 8,300 BTUs/lb

Coal CO_2 Emissions are Twice that of Natural Gas

Coal Facts

- In the US, ~92 %* of the ~ 501 million short tons of coal consumed in 2021 was used for electricity generation
- Coal is environmentally challenged in terms of CO2, sulfur, mercury, particulates, and coal ash discharges
- 1 Short Ton = 2,000 Pounds
- 1 Tonne (metric ton) = 2205 pounds

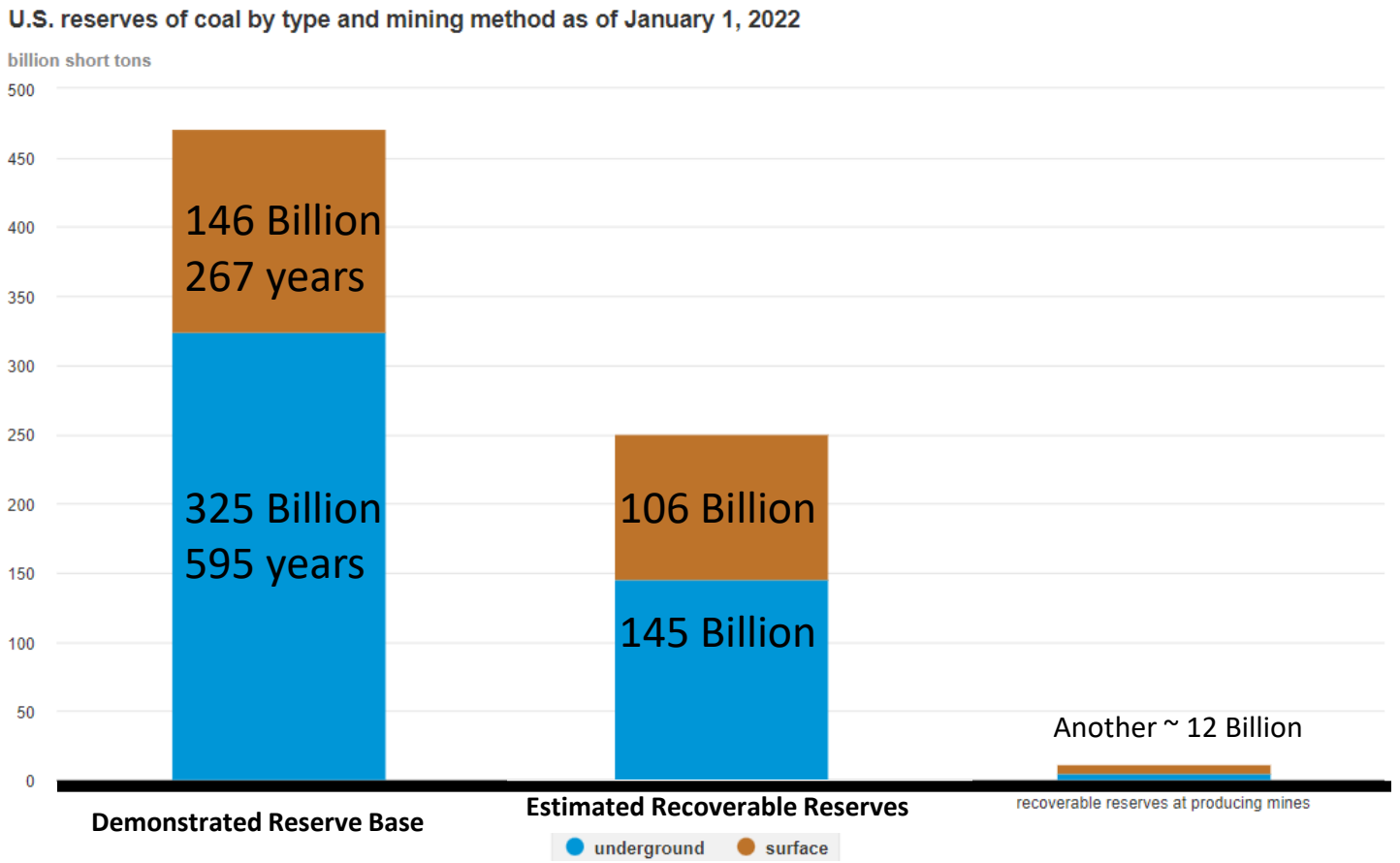


Six states had 77% of the *demonstrated reserve base* (DRB) of coal as of January 1, 2022:
•Montana—25%
•Illinois—22%
•Wyoming—12%
•West Virginia—6%
•Kentucky—6%
•Pennsylvania—5%
Twenty five other states had the remaining 23% of the DRB.

https://www.eia.gov/energyexplained/coal/how-much-coal-is-left.php

* EIA, https://www.eia.gov/coal/data.php#consumption, Table 26

Coal Reserves



Total 546 million short tons consumed in 2021.

Recoverable reserves alone have an estimated 435 years of coal at current usage.

https://www.eia.gov/energyexplained/coal/how-much-coal-is-left.php

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Electricity

Mostly A Secondary Source of Energy

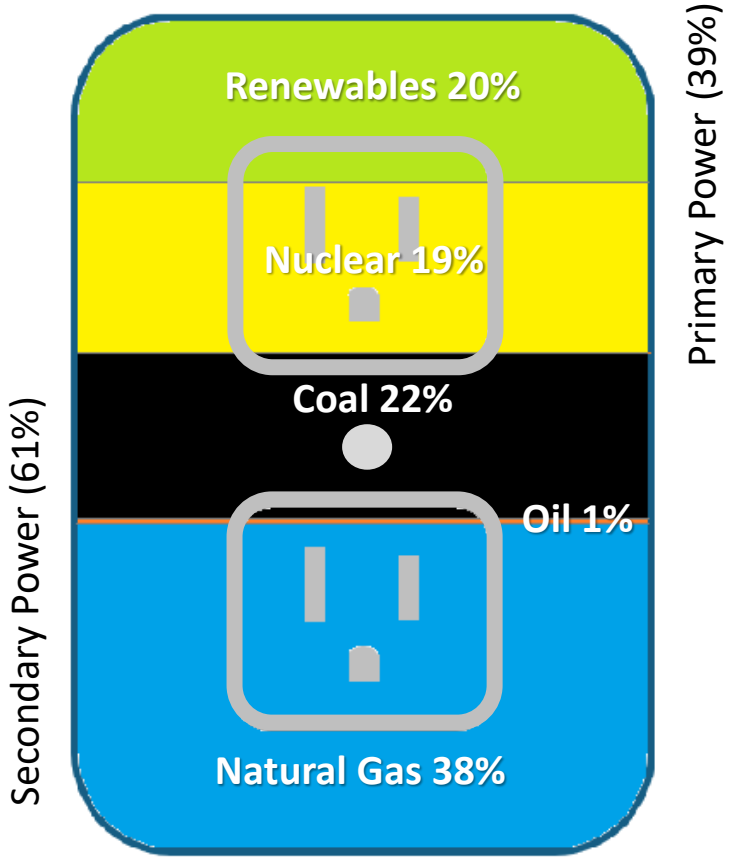
Secondary Generation Mix	% Mix
Coal	21.9%
Gas	38.4%
Oil	.6%
Other	.5%
Total Secondary	**61.4%**

Secondary electric produced with

Combustion Turbines

Engines

Fuel Cells



Primary Generation Mix	% Mix
Nuclear	18.9%
Hydro	6%
Wind	9.2%
Solar	2.8%
Biomass	1.3%
Geo-thermal	.4%
Total Primary	**38.6%**

E-GRID 2023, using 2021 data, https://www.epa.gov/egrid/download-data

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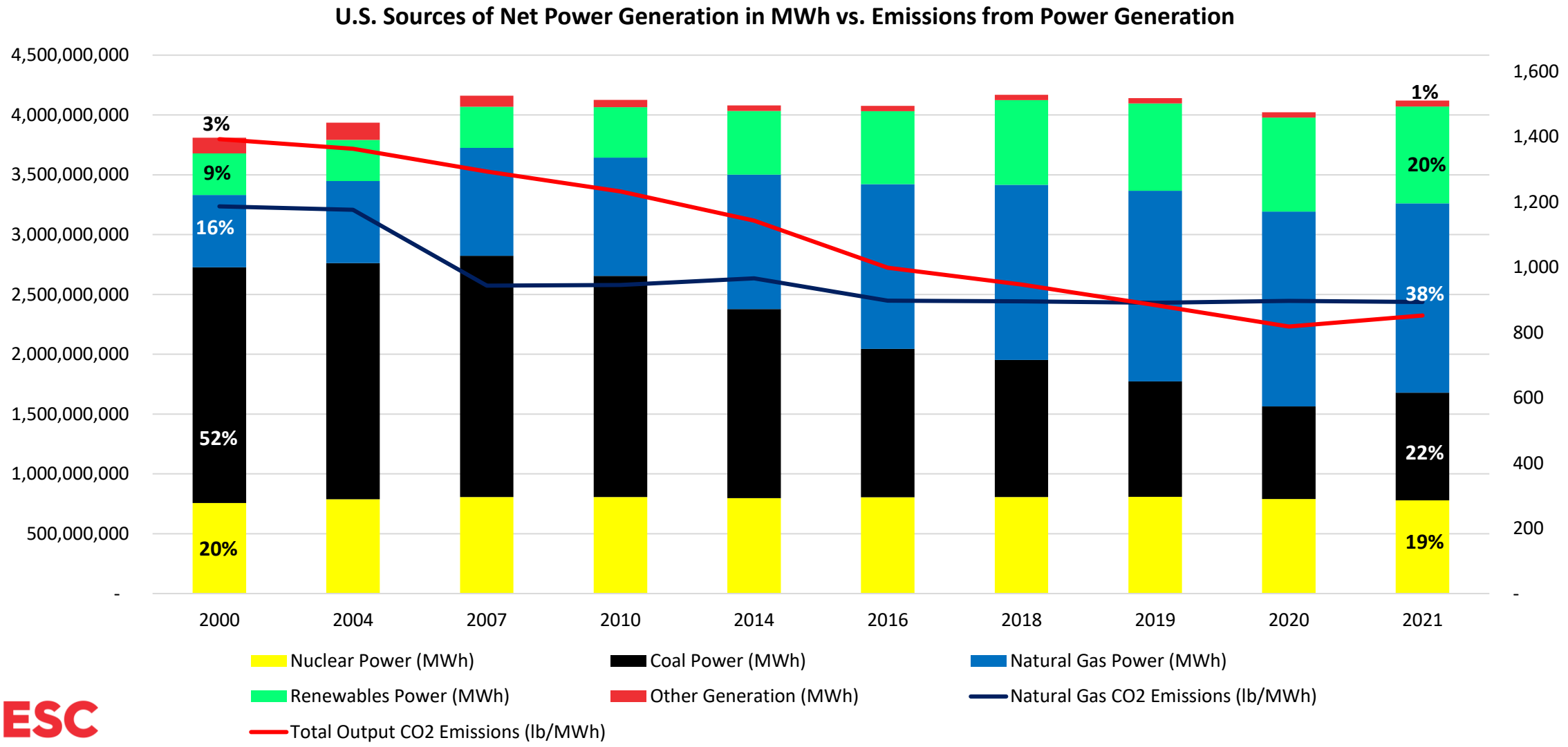
Historical Generation Mix vs. Emissions

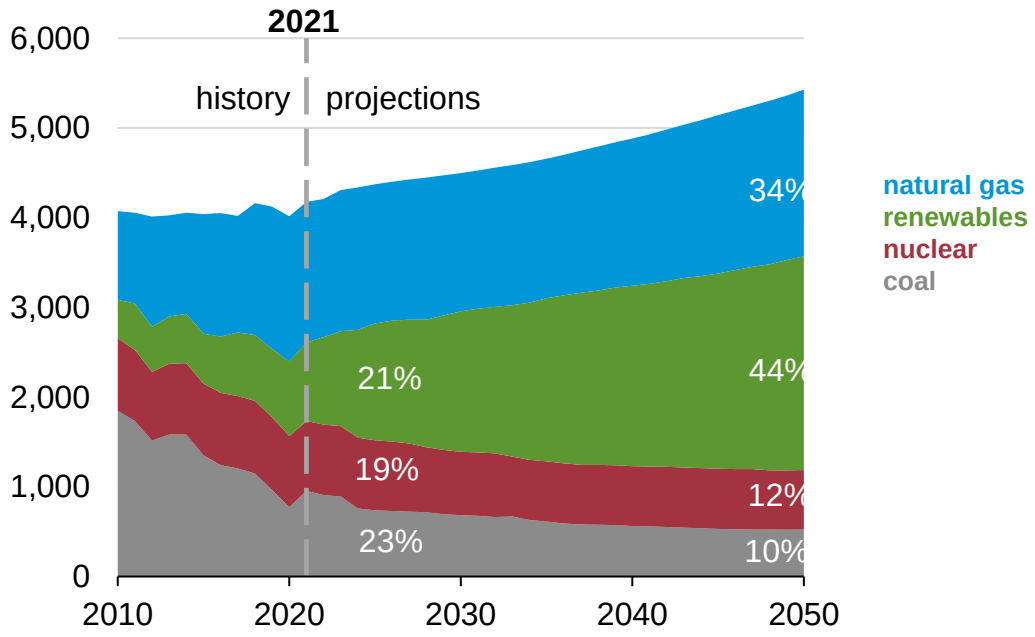


https://www.epa.gov/egrid/download-data

Future Electric Mix Outlook

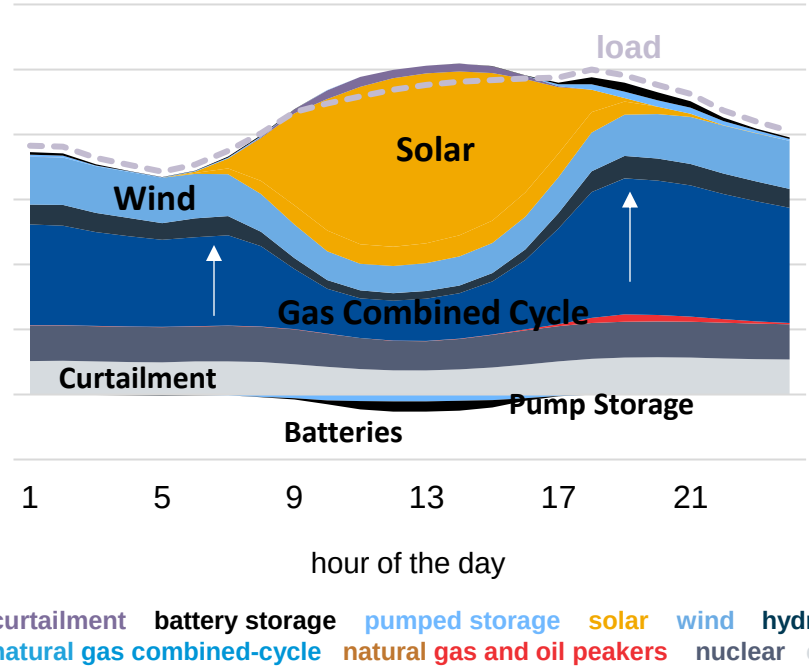
Natural Gas is expected to continue to play a significant role in power generation in the future.

U.S. electricity generation from selected fuels
AEO2022 Reference case
billion kilowatthours



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

Hourly U.S. electricity generation and load by fuel for selected cases and years
billion kilowatthours



Significant renewables growth leads to additional battery storage & Gas picks up much of this load in future.

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Electric Factors

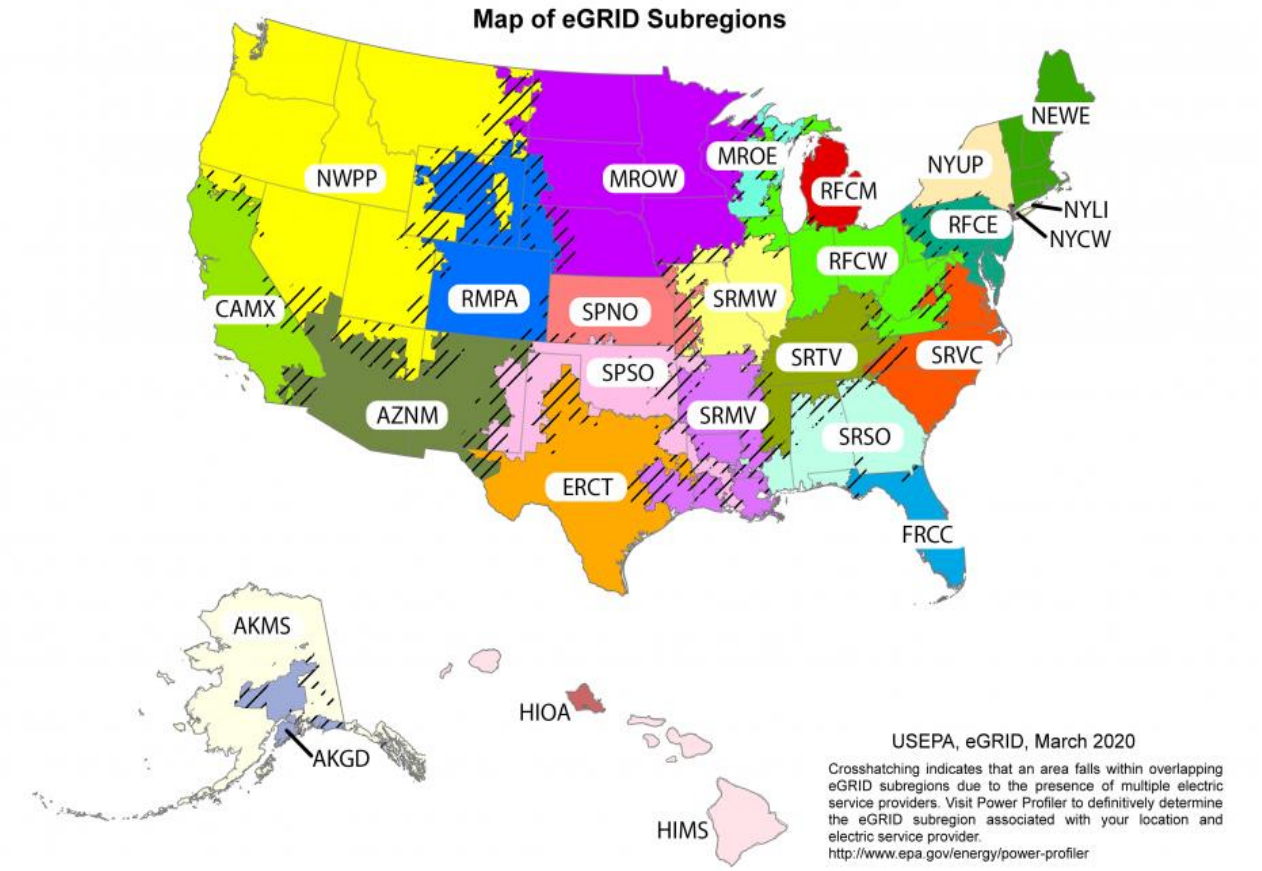
- **kW** - Kilo Watt, 1,000 Watts, Demand Component
  - 1 kW is equivalent to 3,412 BTUs
- **kWh** - Kilo Watt Hour, Usage Component
- **MW** - Mega Watts, 1,000,000 Watts
- **Peak** - Time of day when electric usage is at highest level, hours determined by local electric utility
- **Load Factor** - Relationship of one's usage to their demand
- **Power Factor** - calculation related to 'spikes' caused by end user motors etc. These may require a tremendous draw until up to speed, and the cure is typically to add capacitors

Terms: Electric Generation

- **Spark Spread**
  - The difference between the price of power & the cost to produce it at a given facility
- **Simple Cycle**
  - One pass generation, where waste heat is not recovered to generate additional power
- **Combined Cycle**
  - Producing additional electricity from otherwise lost waste heat exiting from gas turbines. This process increases the total efficiency.
- **Capacity** - the maximum load that a generating station can carry under specific conditions for a given period of time

Terms: Electric Generation

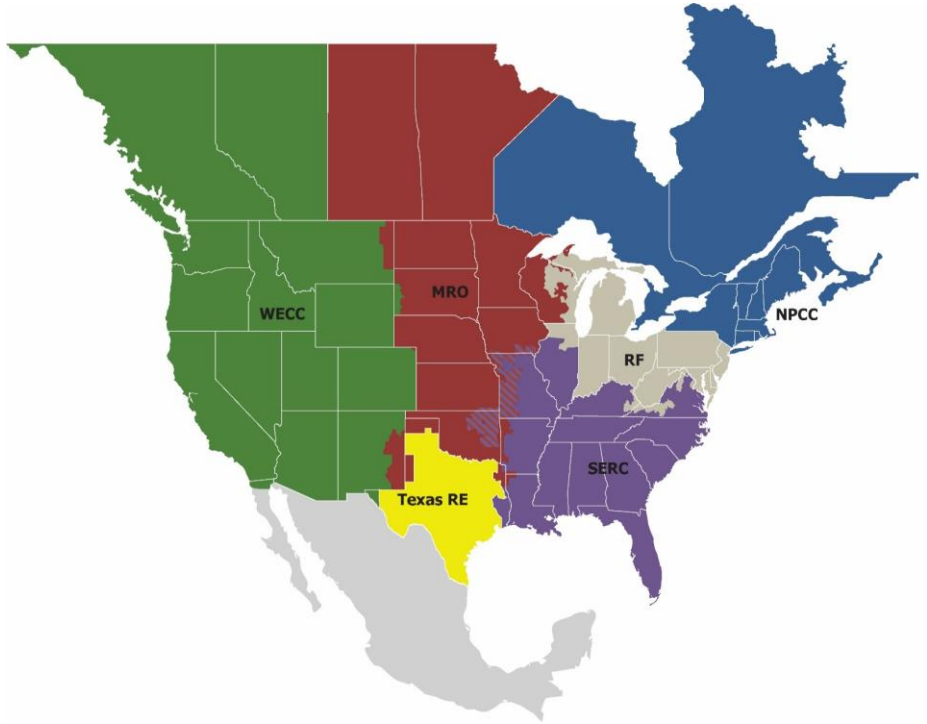
- **Synchronous / Parallel**
  - Generated power must synchronize with the grid power if the customer wants to work in tandem with grid power
- **RTP**
  - Real Time Pricing - Buying electric on hourly basis the day before it is expected to be used



Misc. Electric Terms

- **ISO -** Independent System Operator
  - Coordinates, controls and monitors the operation of the electric power system
- **RTO -** Regional Transmission Organization
  - Local grid who controls all power flow for a given region
- **Stranded Costs**
  - Those costs prior to de-regulation that may not be able to be recovered after de-regulation
- **CTC**
  - Competitive Transition Charges, way to recover of stranded costs

NERC Regions



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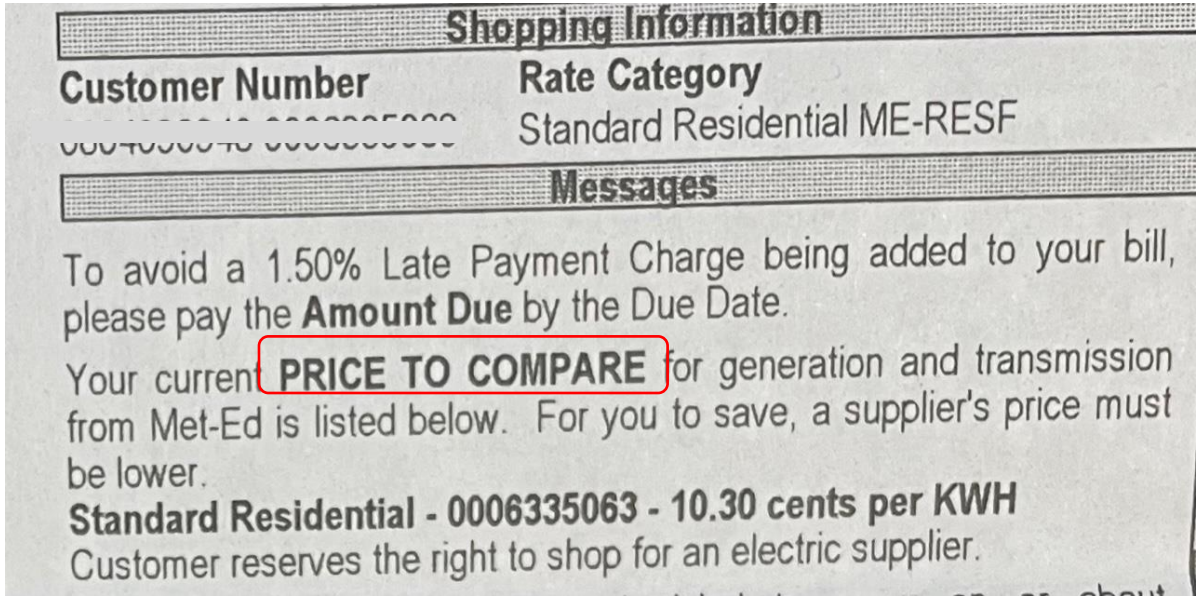
Terms: Buying Deregulated Electric

- **EGS** - Energy Generation Supplier
  - where to buy de-regulated power
- **Price to Compare**
  - Utility price for energy and capacity if customer decided to remain with Utility – what is shopped against
- **Default Provider of Last Resort**
  - Local electric utility will supply power if customer does not wish to participated in de-regulated electric or is dropped by their EGS

Terms: De-regulated Electric Bill Components

- **Energy and Capacity**
  - Charge for generated electric
  - This is the piece that is bought separately from the utility in the de-regulated market
- **T&D**
  - Transmission and Distribution
- **Variable Distribution Charges**
  - Cost to deliver power to end user



Shopping Information

Customer Number [redacted]

Rate Category
Standard Residential ME-RESF

Messages

To avoid a 1.50% Late Payment Charge being added to your bill, please pay the **Amount Due** by the Due Date.

Your current **PRICE TO COMPARE** for generation and transmission from Met-Ed is listed below. For you to save, a supplier's price must be lower.

Standard Residential - 0006335063 - 10.30 cents per KWH

Customer reserves the right to shop for an electric supplier.

Generation Pros & Cons

	Pro	Con
Nuclear	▪ No site Greenhouse gas emissions ▪ Domestic Fuel supply	▪ Radioactive waste ▪ Uranium mining ▪ Transportation
Coal	▪ Domestic supply	▪ Highest greenhouse gas emissions ▪ Coal mining
Wind	▪ No emissions ▪ No fuel or water consumed	▪ Intermittent supply ▪ Can be far from customers
Natural Gas	▪ Least land required, mostly domestic supply	▪ Greenhouse gas emissions ▪ Drilling

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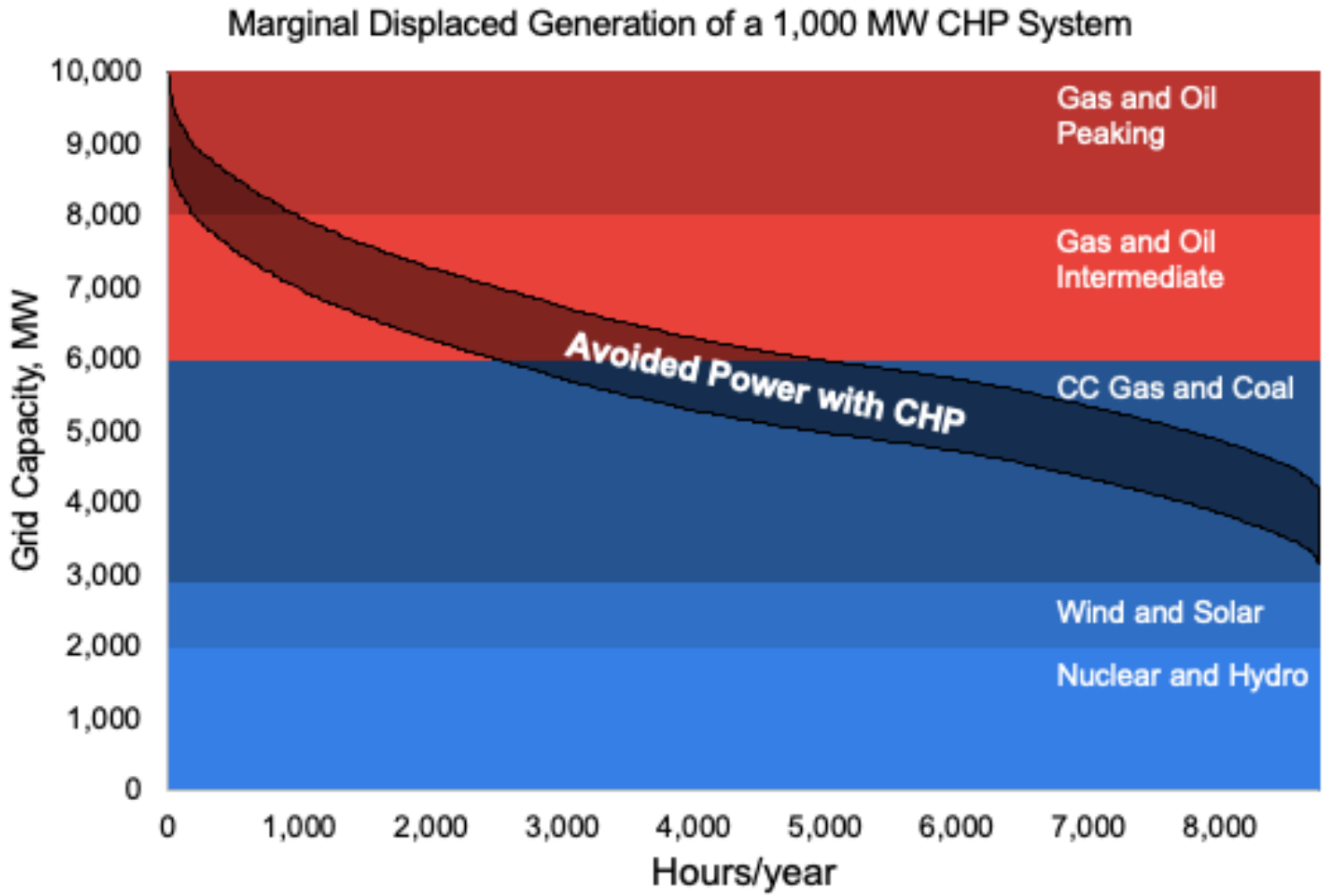

Marginal Load. Gas fills peak demand swings and meets intermittent power loads.

Base Load, On when available

Source: Combined Heat and Power Potential for Carbon Emission Reductions, National Assessment, 2020-2050. ICF, July 2020

Heating Values/BTUs

Oil Factors

- Heating oil BTU values vary by quality & grade of fuel
- Oil today likely has less BTU's per gallon than years ago primarily due to additives and government requirements of lower sulfur/gallon
  - Distillate Fuel (#2 oil) = 5.817 MMBtu per barrel = 138,500 BTU/Gallon
  - Residual Fuel (#6 oil) = 6.287 MMBtu per barrel = 149,690 BTU/Gallon
- Natural Gas averages 1,037 BTU/Cubic Foot

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Gas Factors

- 1 Gallon Propane = 91,600 BTU's on average
- 1 Pound Propane = 21,500 BTU

- Natural Gas = 1,037,000 BTU/MCF

Coal Factors

- 1 Ton Coal (Anthracite) = 27,000,000 BTU
- 1 Ton Coal (Bituminous) = 26,000,000 BTU

Electric Factors

- **1 KWH** = 3,412 BTU
- **Monthly Load Factor =**

$$\frac{\{\text{Total Usage kWh / Registered Demand kW}\}}{\{\#\text{days/month X 24hrs/day}\}}$$

- **1 kW** = 1.341 horsepower
- **1 Horsepower-hour** = 2,545 BTU
- To generate 1 kilowatt-hour (kWh) requires 10,000 BTU of fuel burned by the average electric utility

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Converting Gas to $ Equivalent

- **Natural Gas to #2 Oil**
  - $/MCF Gas X 138,500 BTU/Gal#2 / 1,037,000 BTU/MCF = $/Gallon equivalent
  - #2 Oil = 7.41 gallon per MCF
- **Natural Gas to #6 Oil**
  - $/MCF Gas X 149,690 BTU/Gal#6 / 1,037,000 BTU/MCF = $/Gallon equivalent
  - #6 Oil = 6.86 gallon per MCF
- **Propane**
  - $/MCF Gas X 91,700 BTU/Gal LP / 1,037,000 BTU/MCF = $/Gallon equivalent

Energy Storage & Reliability

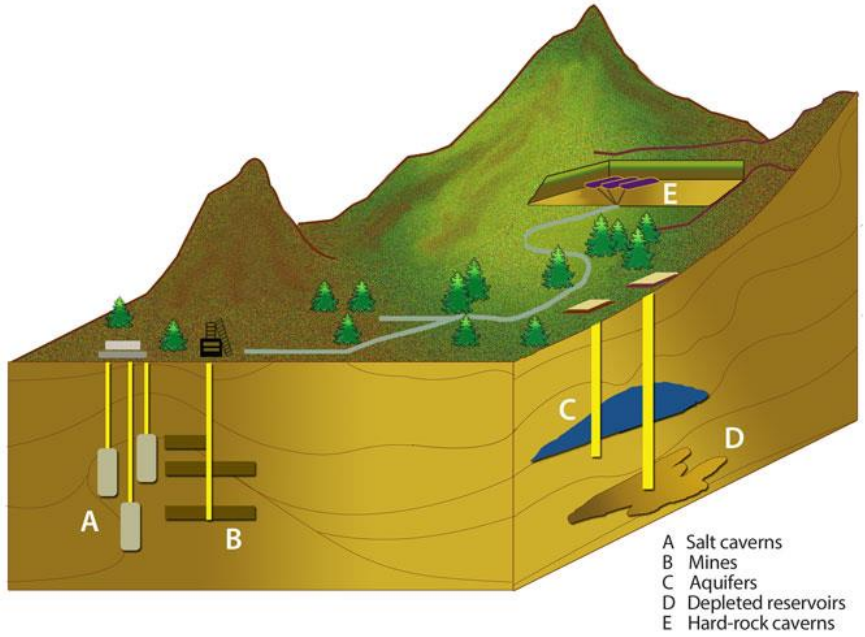
Natural Gas Storage

- **Natural Gas**
  - Can be stored in its natural gaseous state, compressed at high pressures or stored in large quantities in liquid form
  - Natural Gas is not typically stored at a customer's premises
  - Stored gas is injected to the local utility's system to balance out demand issues

LNG

Gaseous form

Figure 1. Types of underground natural gas storage facilities



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

Energy Storage

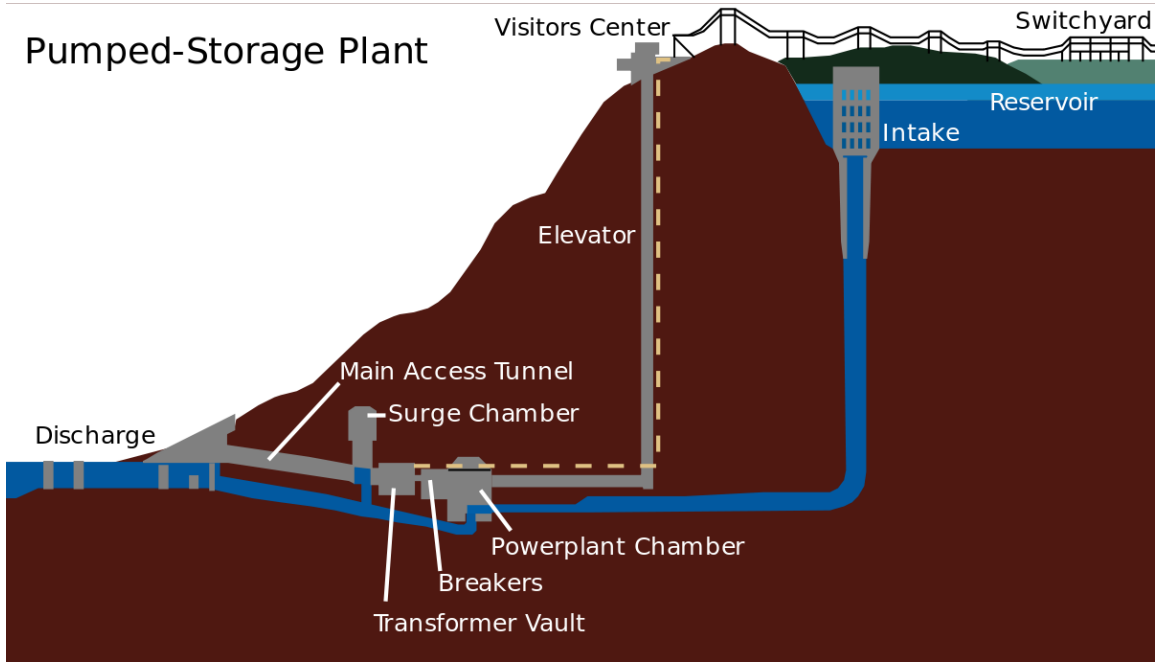
- **Oil/Propane**
  - Typically stored by dealers in large tank farms, and smaller quantities are stored locally at the customer facility

Oil

Propane

Energy Storage

- **Electric Storage**
  - Grid generated power must be used instantaneously by end users.
  - Some storage methods include
    - Batteries
    - Pump Storage
    - Gas Generator



Costs of Various Storage Systems

Technology	Primary Application	Capital Costs ($/kW)	O&M Costs ($/kW-year)	Fuel Cost to Operate ($/kWh)
Short-Duration Technologies				
Flywheel Energy Storage	Small-scale frequency and voltage stabilization	$2,000 – 4,000	$10 – 20	$0.08 – 0.10
Lithium-Ion Battery 2020	Small-to-large demand response, ancillary services, frequency/ voltage stabilization	$900 – 1,700	$10 – 20	$0.08 – 0.09
Lithium-Ion Battery 2030		$450 – 900	$5 – 10	$0.08 – 0.09
Long-Duration Technologies				
Redox Flow Battery	Industrial-scale peak shaving, frequency/ voltage stabilization	$1,400 – 1,600	$10 – 12	$0.08 – 0.11
Compressed Air to Power	Utility-scale baseload generation and peak shaving	$1,000 – 1,200	$16 – 18	$0.09 – 0.17
Pumped Hydro-electric Storage	Utility-scale baseload generation and peak shaving	$1,500 – 1,700	$13 – 17	$0.08 – 0.09
Gas-Fueled Technologies				
Industrial CHP	Industrial-scale demand response, spinning reserve	$1,200 – 1,800	$30-$45/kW-year (FOM), ~$10/MWh (VOM)	$0.015 – 0.020
Modular Gas Engines	Demand response, spinning reserve, balancing renewables	$1,300 – 1,800	$35/kW-year (FOM), ~$6/MWh (VOM)	$0.03 – 0.05
Power-to-Gas Fuel Cell	Convert excess electricity to hydrogen for time shifting	$2,900 – 5,600	$30 – 40/kW-year, plus stack replacement	$0.03 – 0.04

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ESC study: Energy Storage Options to Assist with High Renewable Penetration in a Decarbonized Future, ICF, 9/1/20

Energy Reliability

Efficient and Affordable Natural Gas Heat Pumps, Dec 2021

Energy Pricing

Energy Pricing

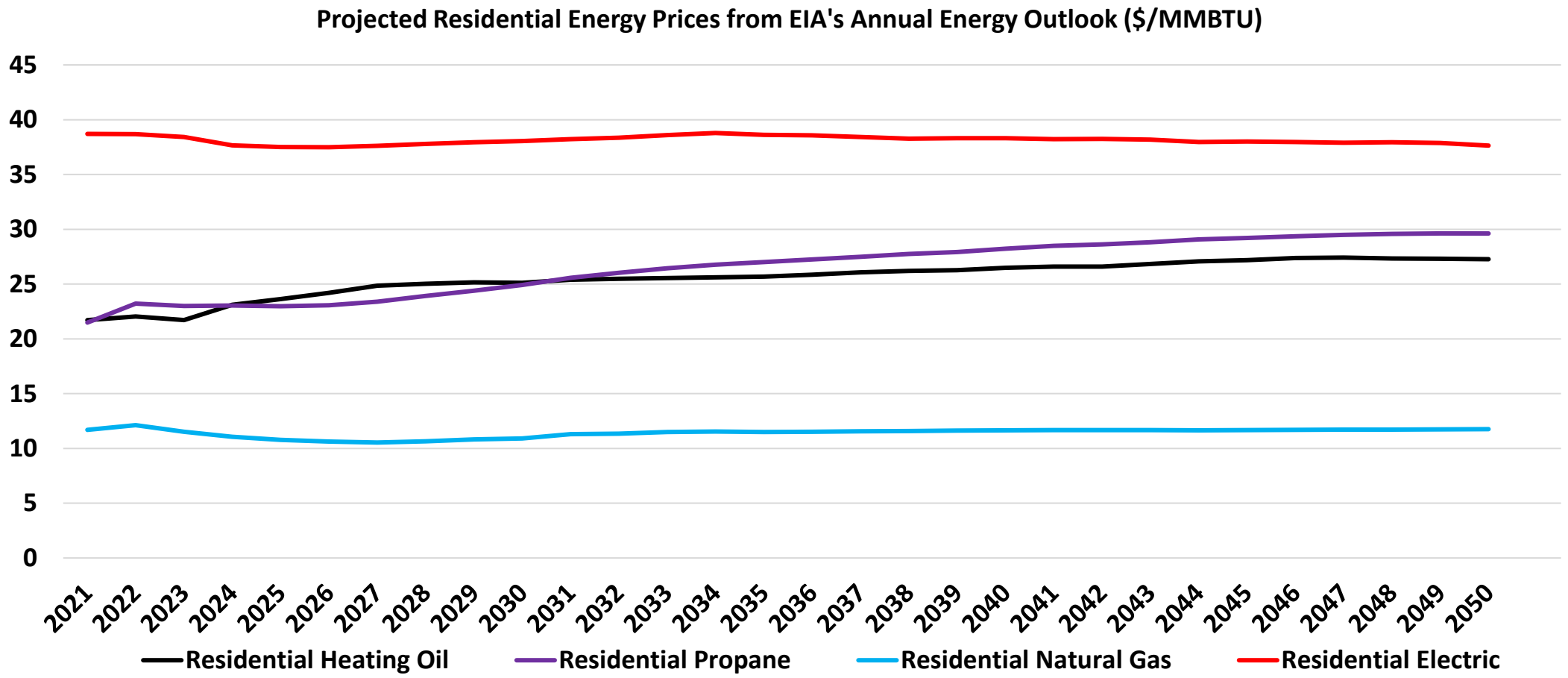
- Typical pricing from highest cost to lowest cost/BTU is:

Most Expensive

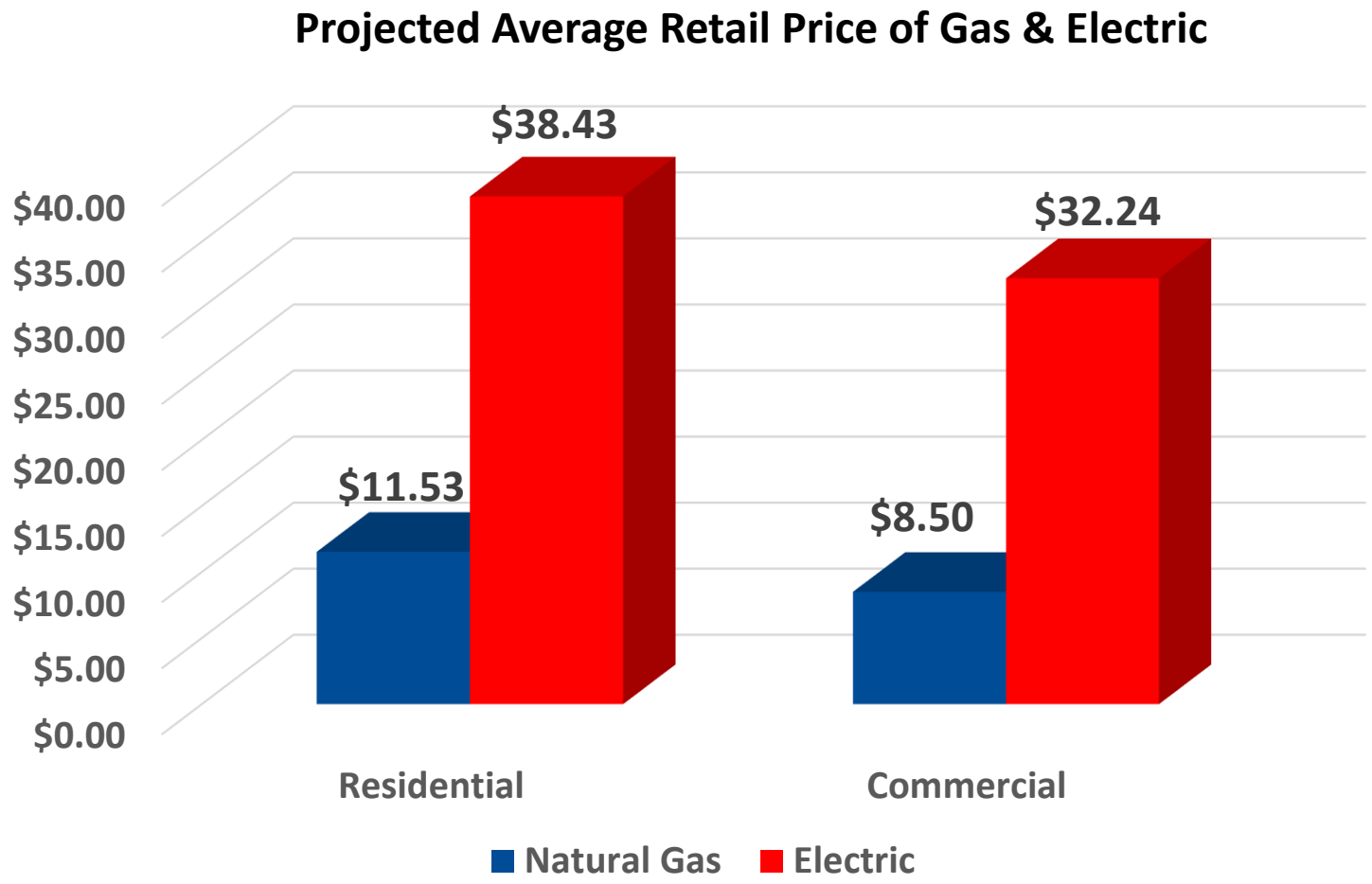
- **Electric**
- Propane
- Kerosene
- Diesel
- #2 Oil
- #4 Oil
- #6 Oil
- **Natural Gas**
- Coal

Least Expensive

Future Residential Energy Pricing



Current Average Retail Energy Prices ($/MMBTU)



Source: EIA AEO 2022, projected 2023 retail pricing, https://www.eia.gov/outlooks/aeo/

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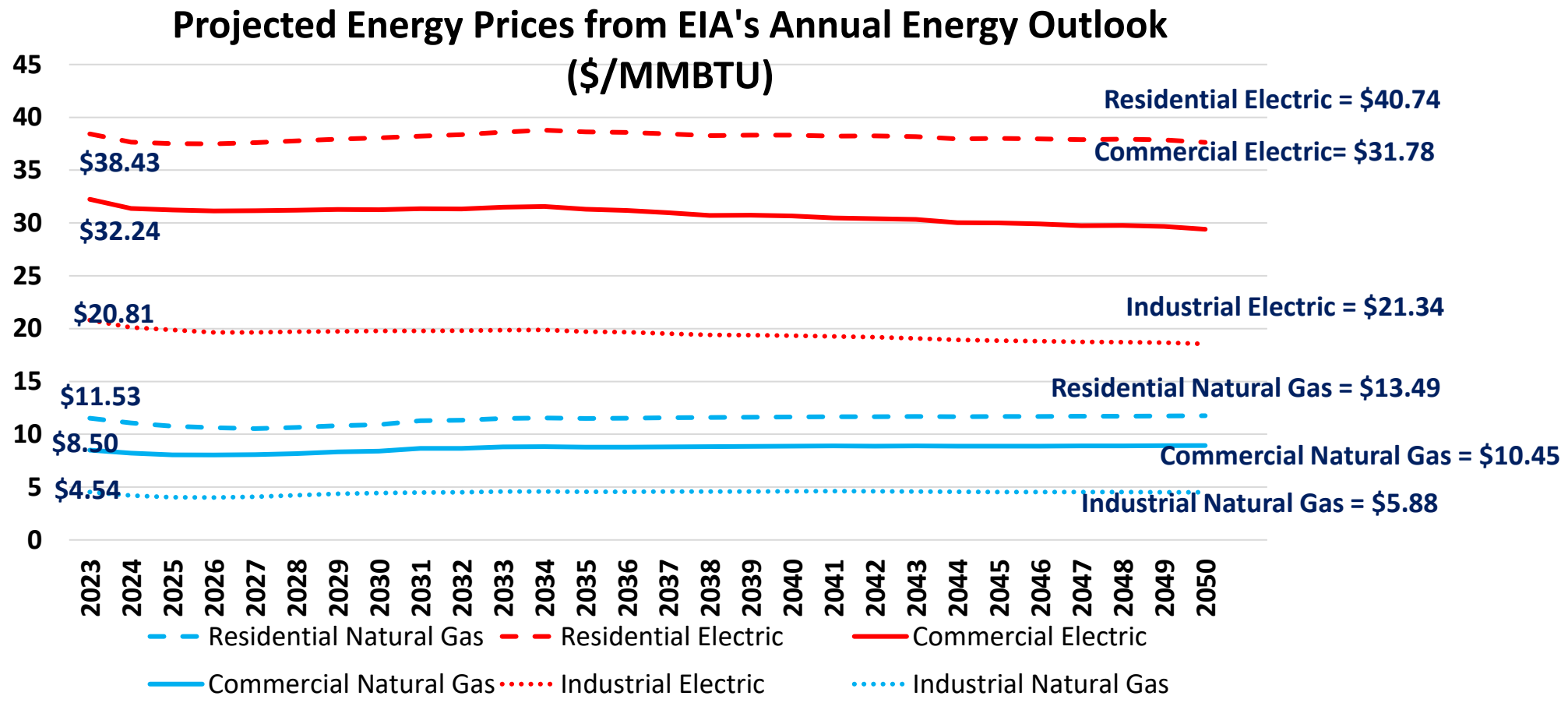
Current Average Retail Energy Prices ($/MMBTU)



Source: EIA AEO 2022, projected 2023 retail pricing, https://www.eia.gov/outlooks/aeo/

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Efficiencies and Environmental Issues

Typical Efficiency

- **Efficiency**
  - The related energy output or effect as a result of energy input
- **Heating**
  - With Natural Gas, Oil or Propane the standard efficiency today is around 80-82%
  - Higher efficiency models are also available > 90 %
  - Gas Heat Pumps are approx. 140% efficient
- **Electric Resistance Heating or Gas Infra Red**
  - There is no energy lost in the form of waste heat and is typically 99% efficient
- **Electric Heat pumps** work differently and have efficiencies well over 100%. Electric heat pumps are typically rated in Heating Seasonal Performance Factors (HSPF)

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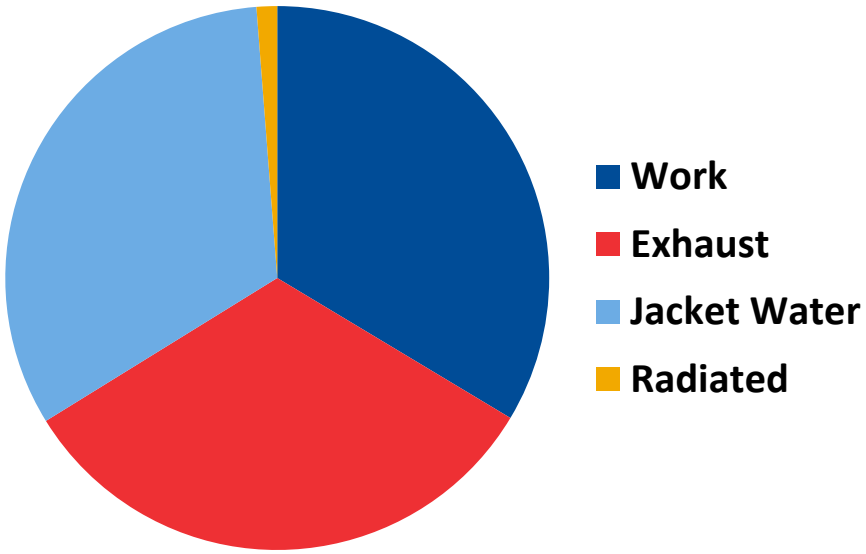
Typical Engine Efficiency

- **Engines**
  - Natural Gas & Diesel engines are typically only around 30% efficient, but have tremendous amounts of waste heat which can be re-captured and utilized



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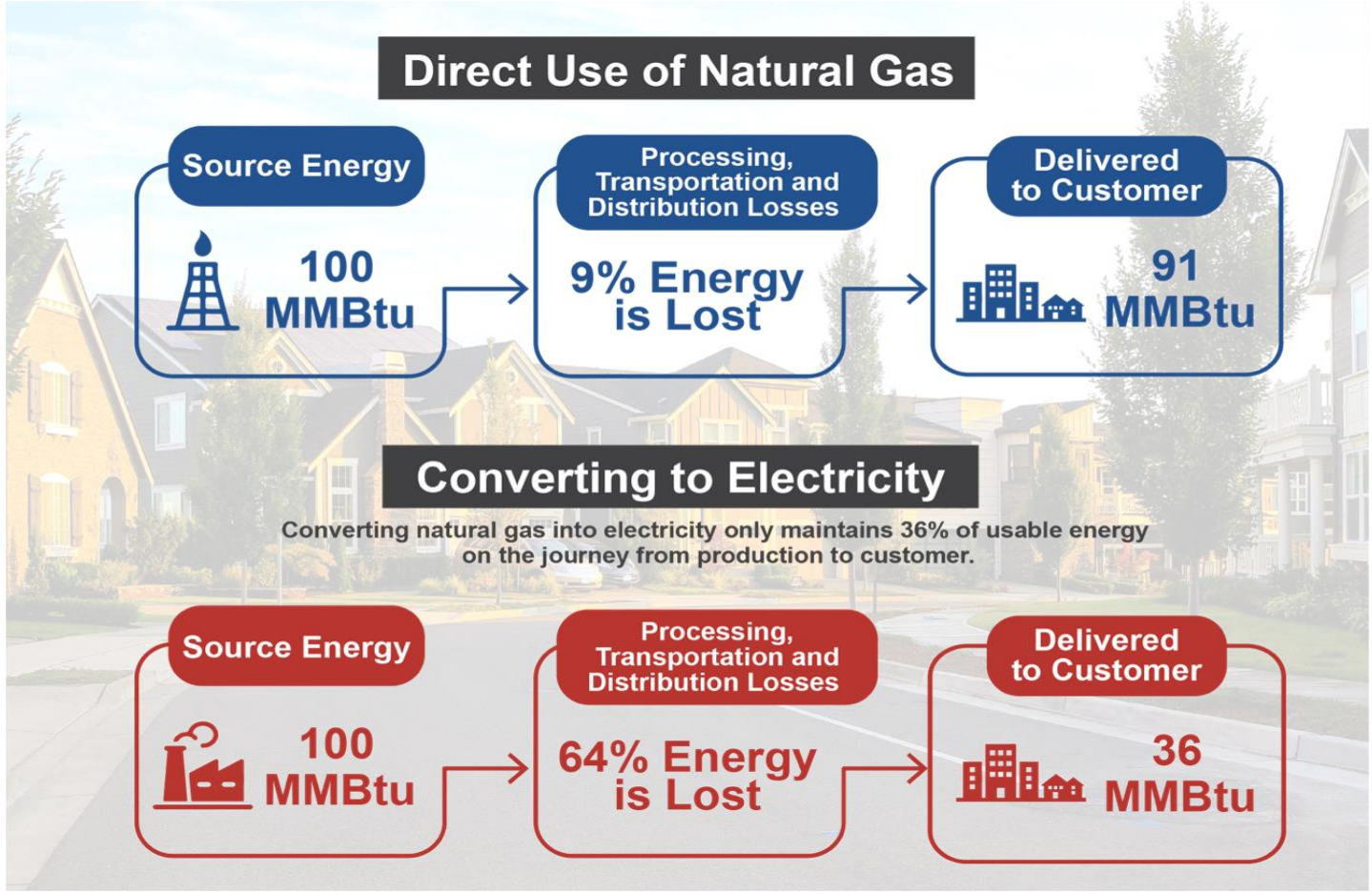
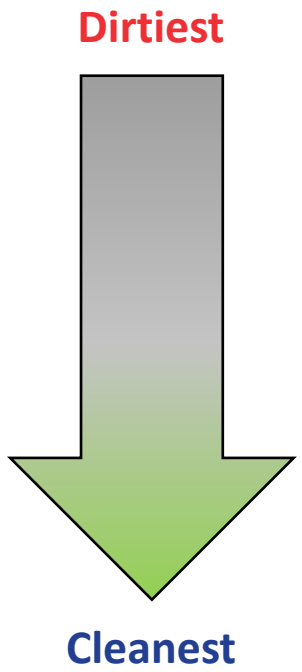
Source to Site Efficiency



Source of data: 2020 AGA Playbook

Environmental Cleanliness

- Typical air emissions that are created by utilizing various fuels and contribute to Global Warming and Acid Rain :
  - **Electric** (Generation Source)
  - Coal
  - #6 Oil
  - #4 Oil
  - #2 Oil / Diesel / Kerosene
  - **Natural Gas** / Propane
  - Electric **(Site)**



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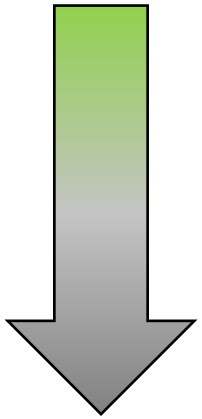
Carbon Dioxide Emissions From Combustion of Fossil Fuels

Cleanest



Dirtiest

Carbon dioxide emitted per quantity of energy for various fuels

Fuel Type	CO_2 Emitted (lbs/10^6 Btu)	CO_2 Emitted (kg/10^6 Btu)
Natural Gas	117.00	53.07
Propane	139.05	63.07
Automobile Gasoline	157.20	71.30
Kerosene	159.40	72.30
Fuel Oil	161.30	73.16
Coal (bituminous)	205.70	93.30

EIA CO2 Emissions Coefficients

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Other Fossil Fuel Emissions

	Pounds per Billion Btu's of Energy Input		
Pollutant	**Natural Gas**	**Oil**	**Coal**
Carbon Dioxide	**117,000**	**161,300***	**205,700***
Carbon Monoxide	40	33	208
Nitrogen Oxides	**82**	**448**	**457**
Sulfur Dioxide	**1**	**1,122**	**2,591**
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

The amount of CO_2 produced far exceeds any other harmful pollutant

Natural Gas has much lower emissions of greenhouse gases than oil or coal

http://www.climate.org/topics/clean-energy/natural-gas.html

* Adjusted to more current data available

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Thank You

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