

# Energy Sources Overview

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IB PHYSICS | ENERGY PRODUCTION

# What is Energy Used For?

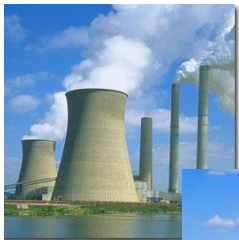
## Residential/Commercial



## Industrial



## Electric Power



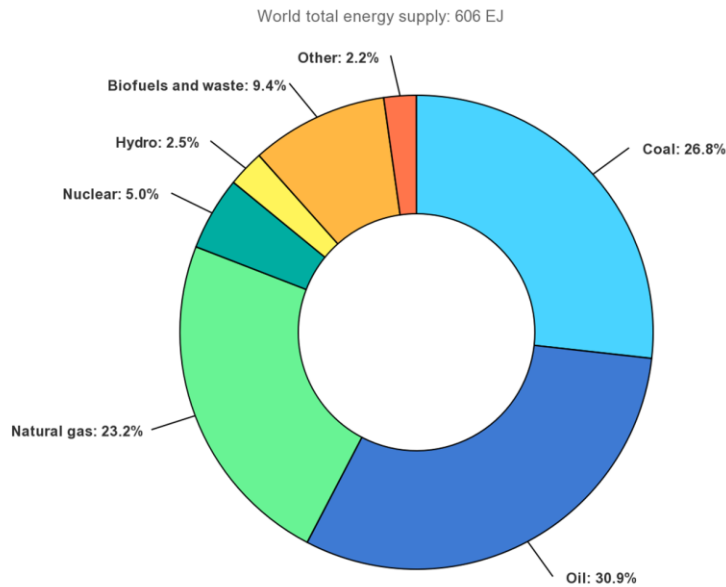
## Transportation



# Where does our Energy Come From?

## World Sources

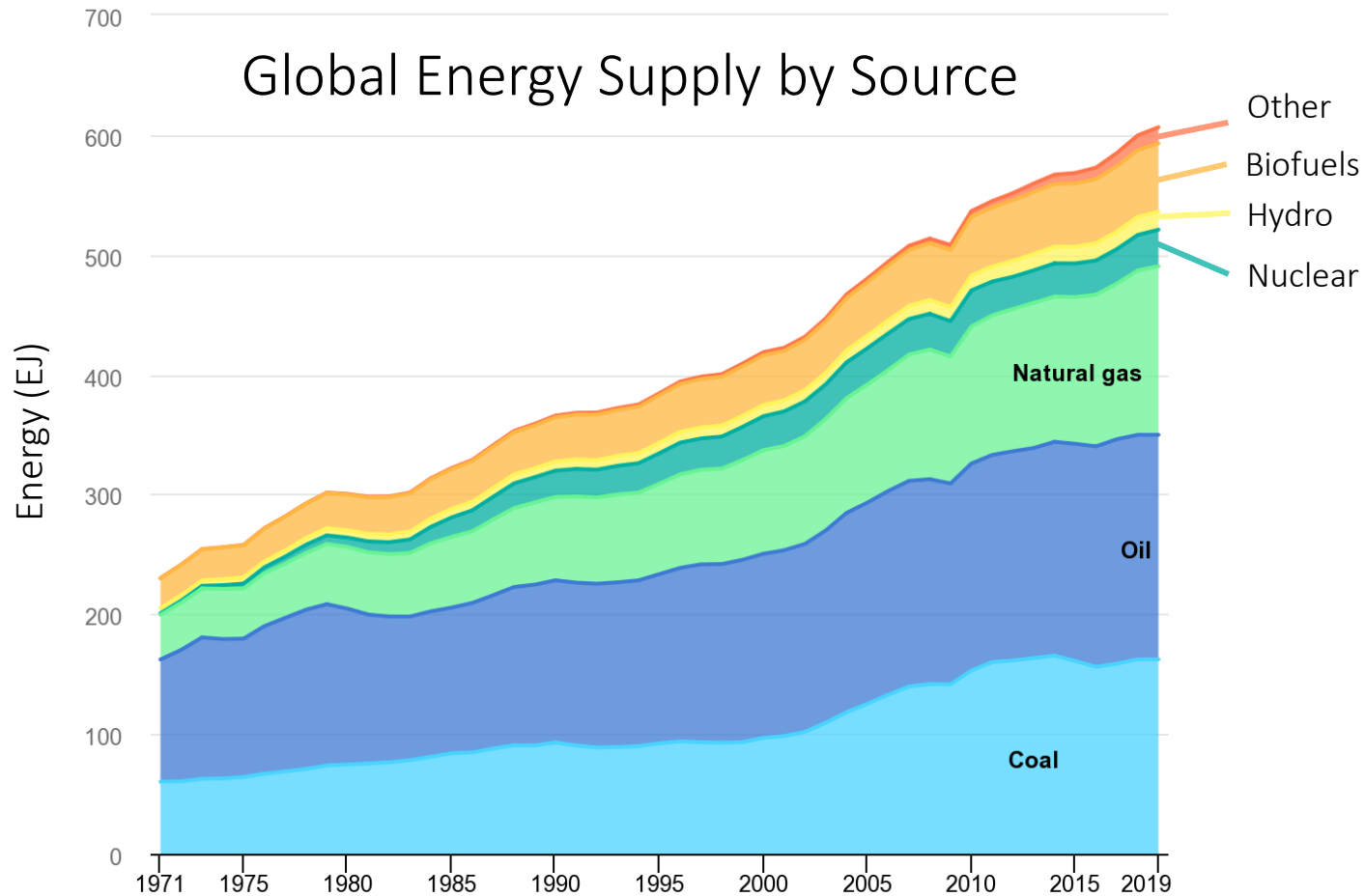
### 2019 Global Energy Supply



## List Sources in Order:

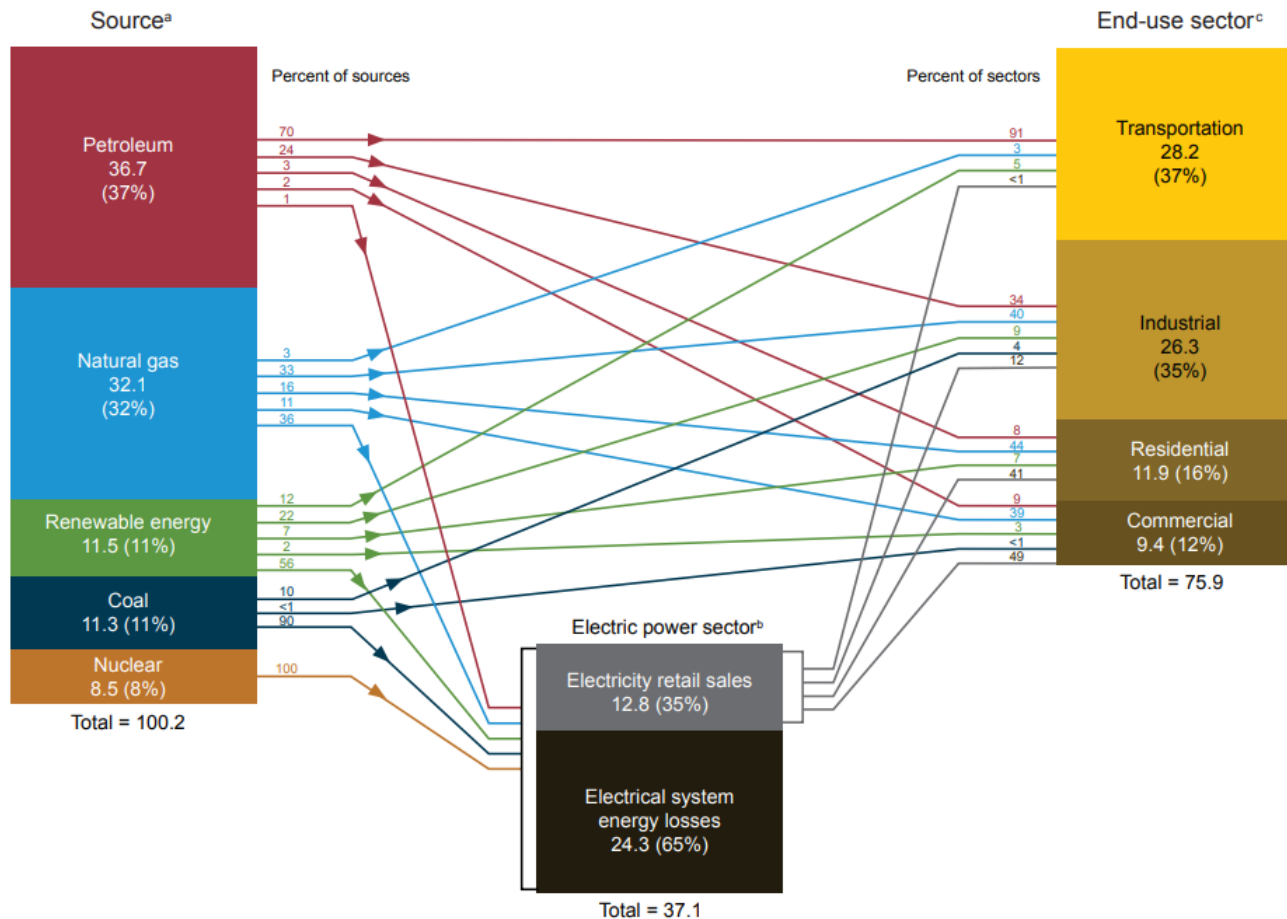
<b>Oil</b>	~31%
<b>Coal</b>	~27%
<b>Natural Gas</b>	~23%
<b>Biofuels</b>	~9%
<b>Nuclear</b>	~5%
<b>Hydropower</b>	~2.5%

# This changes over time



# Used in Many Ways...

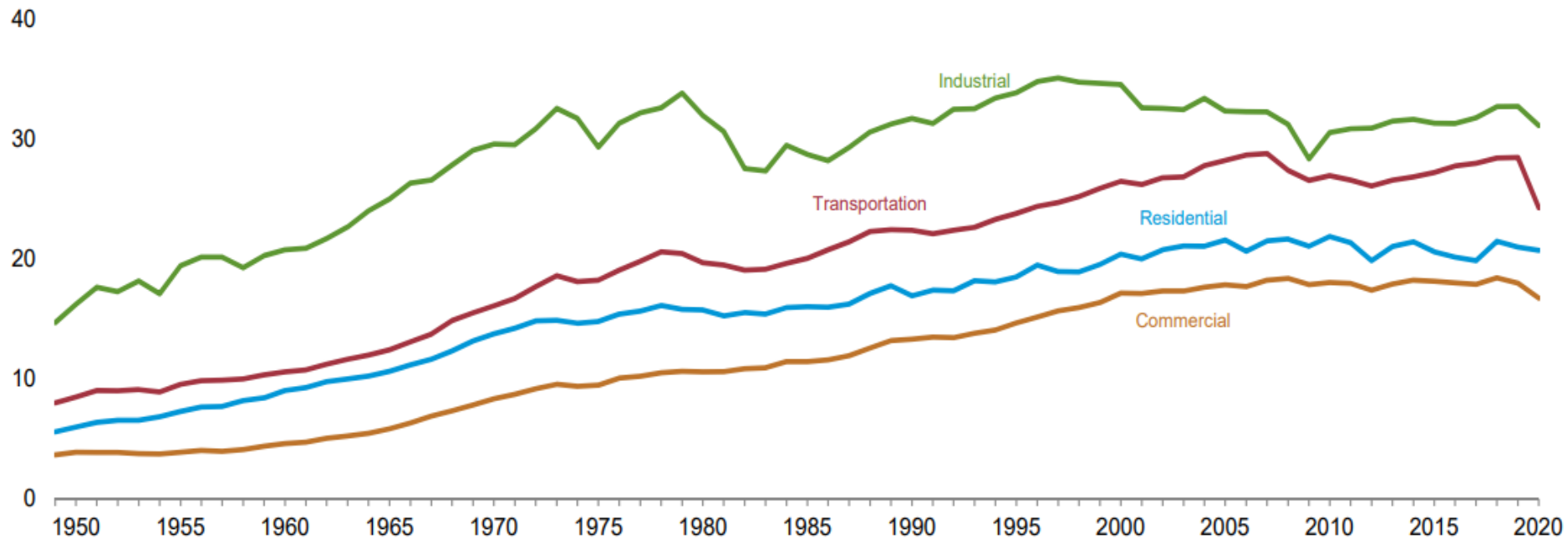
**U.S. energy consumption by source and sector, 2019**  
(Quadrillion Btu)



# Used in Many Ways...

**Figure 2.1 Energy Consumption by Sector**  
(Quadrillion Btu)

Total Consumption by End-Use Sector, 1949–2020



# Primary vs. Secondary Sources

**Primary energy sources** are sources found in the natural environment



**Petroleum**



**Natural Gas**



**Coal**



**Propane**



**Uranium**



**Solar**



**Geothermal**



**Wind**



**Hydropower**



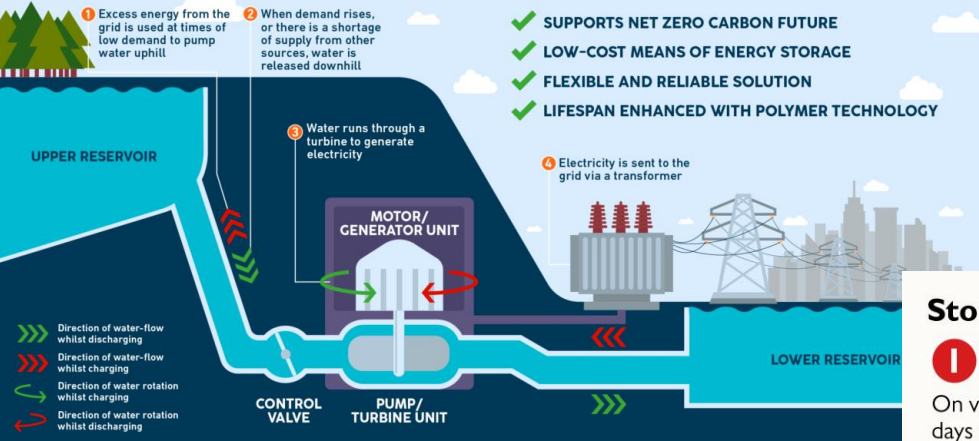
**Biomass**

**Secondary energy sources** are useful transformations of the primary sources. (typically used to **store** energy)

**Electricity – Batteries, Stored Hydropower**

# Other Secondary Sources...

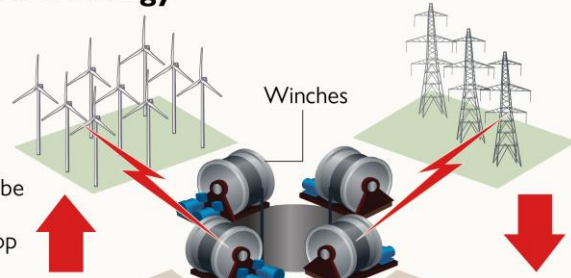
## PUMPED HYDROPOWER STORAGE GUIDE



## Storing excess energy

**1**

On very windy days excess electricity produced by turbines would be used to pull the weight to the top of the shaft



**2**

On still days when electricity is required the weight is lowered generating energy which is then passed back to the grid

Each unit can be configured to produce between 1 and 20MW peak power, with output duration from 15 minutes to 8 hours

Electrical power is absorbed or generated by raising or lowering the weight. The winch system can be accurately controlled through the electrical drives to keep the weight stable in the hole



What is the Ultimate Primary Source?

**The Sun**

# Which one is the best?

That's a hard question and depends on many factors

Some of the big ones are:

- Energy Density
- Cost
- Availability and Location
- Politics
- Safety
- Environmental

# U.S. Electricity Generation

**Figure 2.6 Electric Power Sector Energy Consumption**  
(Quadrillion Btu)

By Major Source, 1949–2020

24

20

16

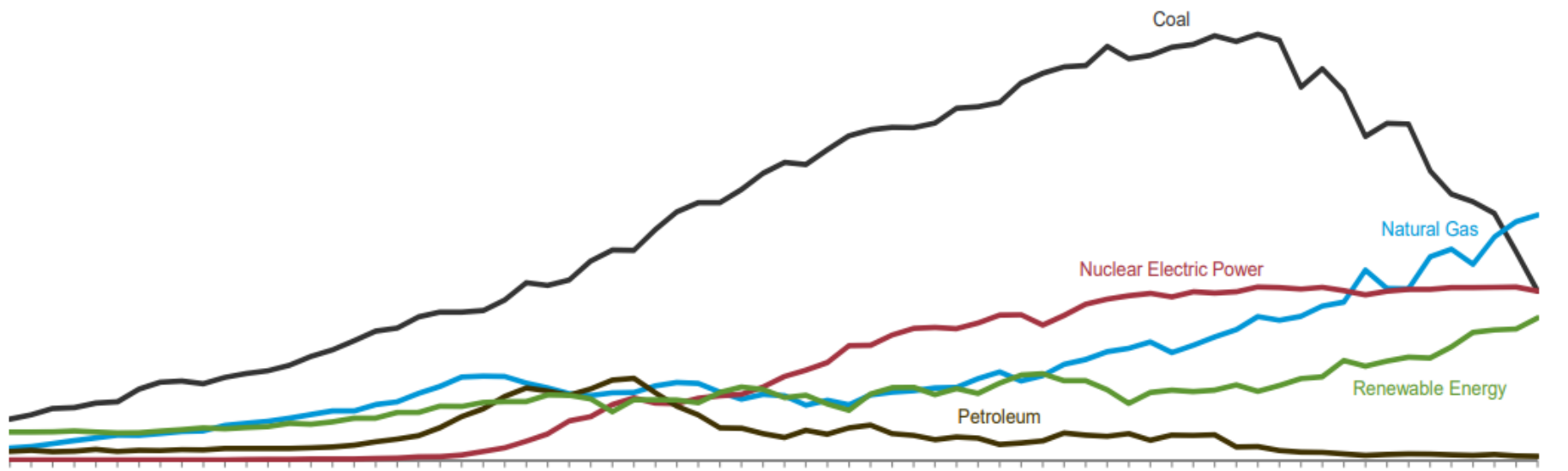
12

8

4

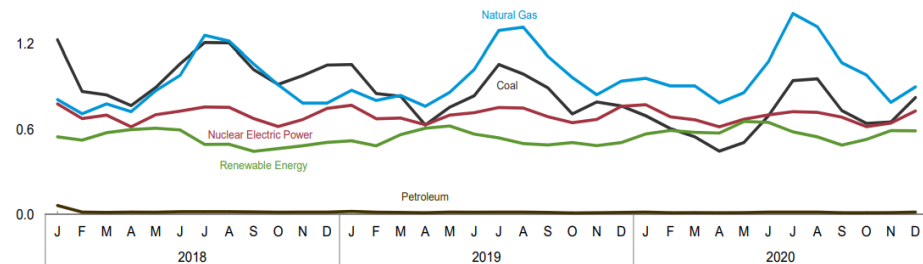
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1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020



By Major Source, Monthly

1.8



# Renewable vs. Non Renewable

Highlight the primary energy sources that are considered **renewable**



**Petroleum**



**Geothermal**



**Coal**



**Hydropower**



**Uranium**



**Solar**



**Natural Gas**



**Wind**



**Propane**

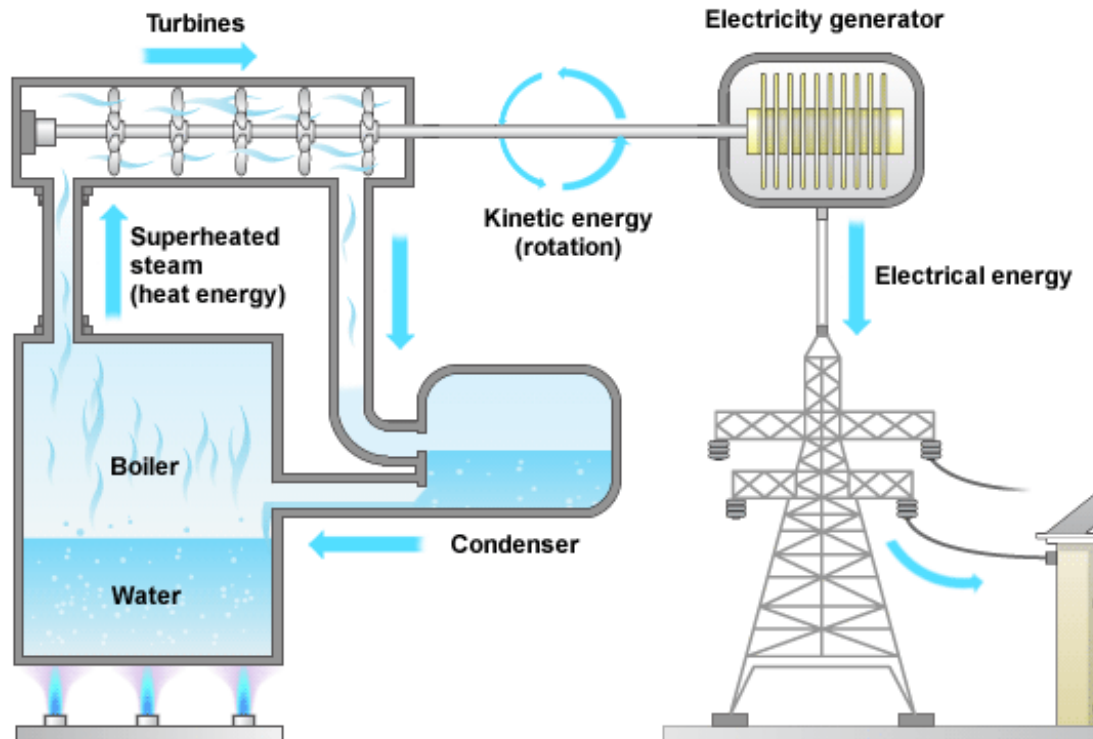


**Biomass**

\*Note: this doesn't mean that it cannot ever be replaced, just that it won't happen in any sort of useful time frame...

# Efficiency

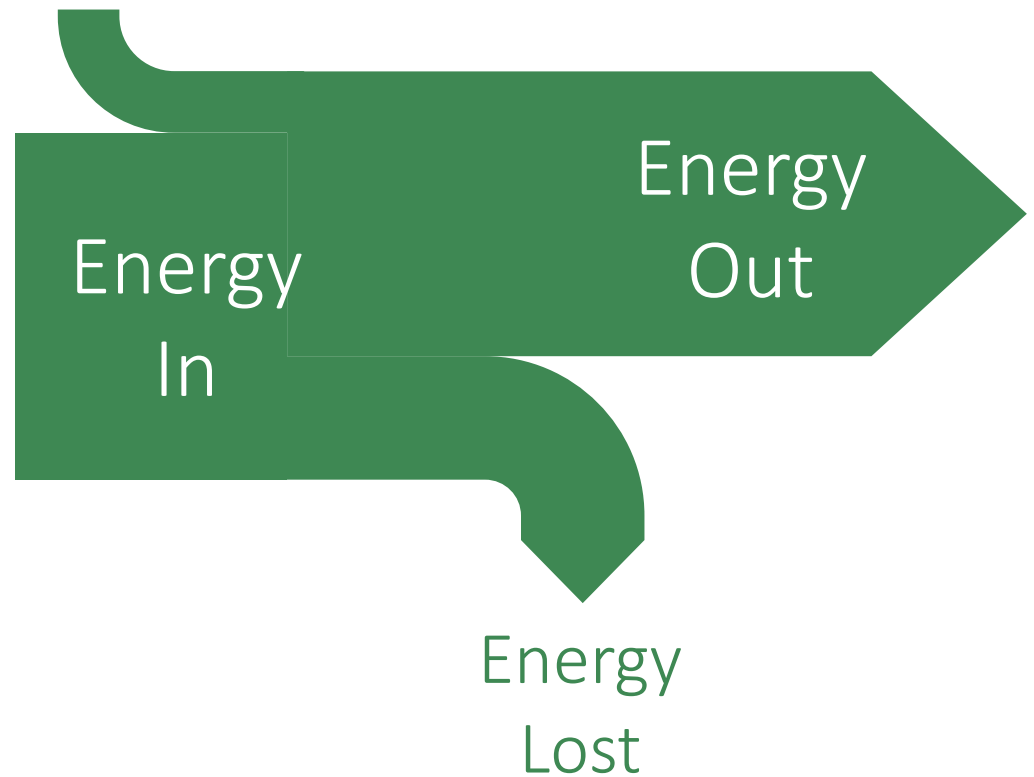
Almost every energy source has the same general path



# Sankey Diagram

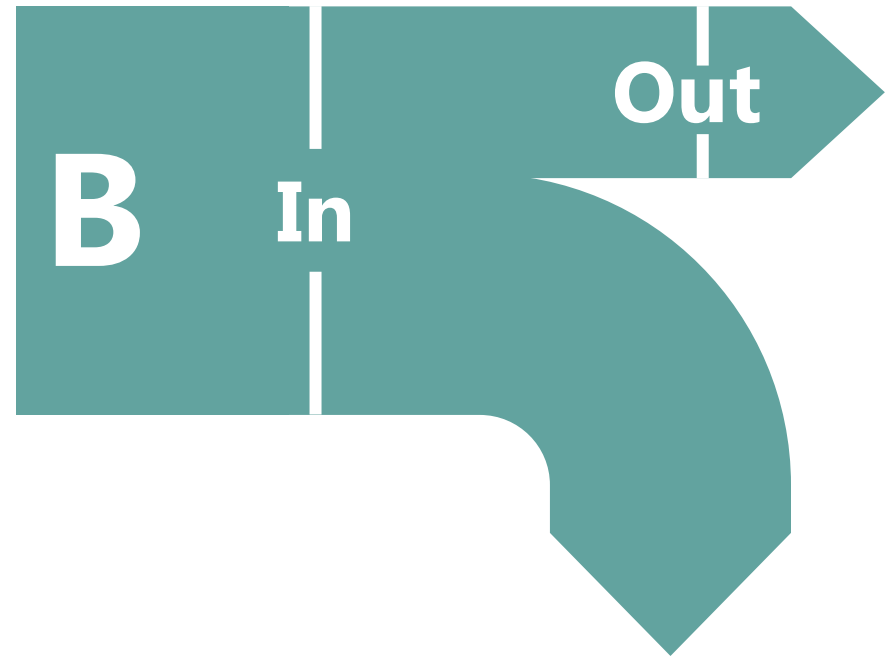
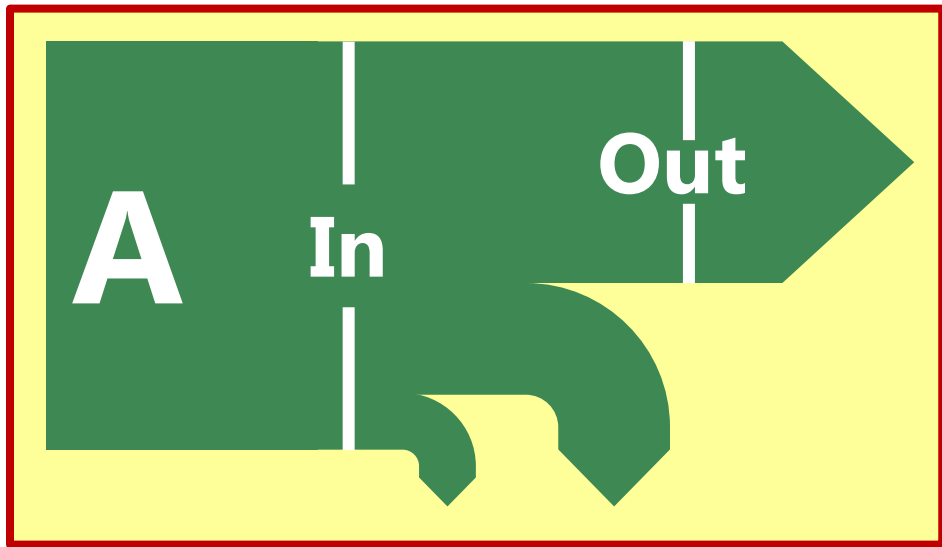
Sometimes it's easiest to represent energy flow in a picture.

In these diagrams the width of the arrow represents the amount of energy

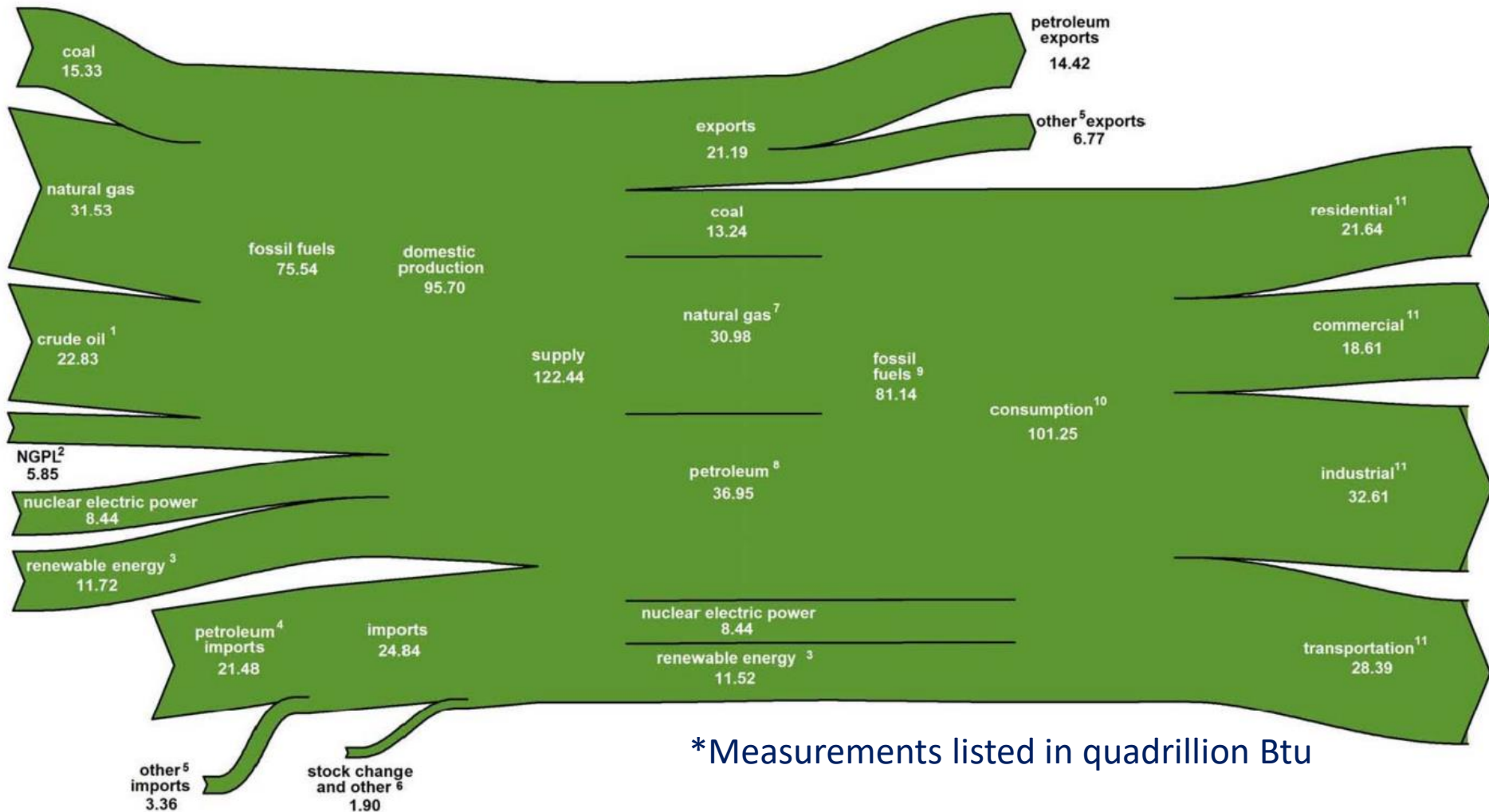


# Sankey Diagrams

Which process is more efficient?



# U.S. Energy Flow 2018



\*Measurements listed in quadrillion Btu



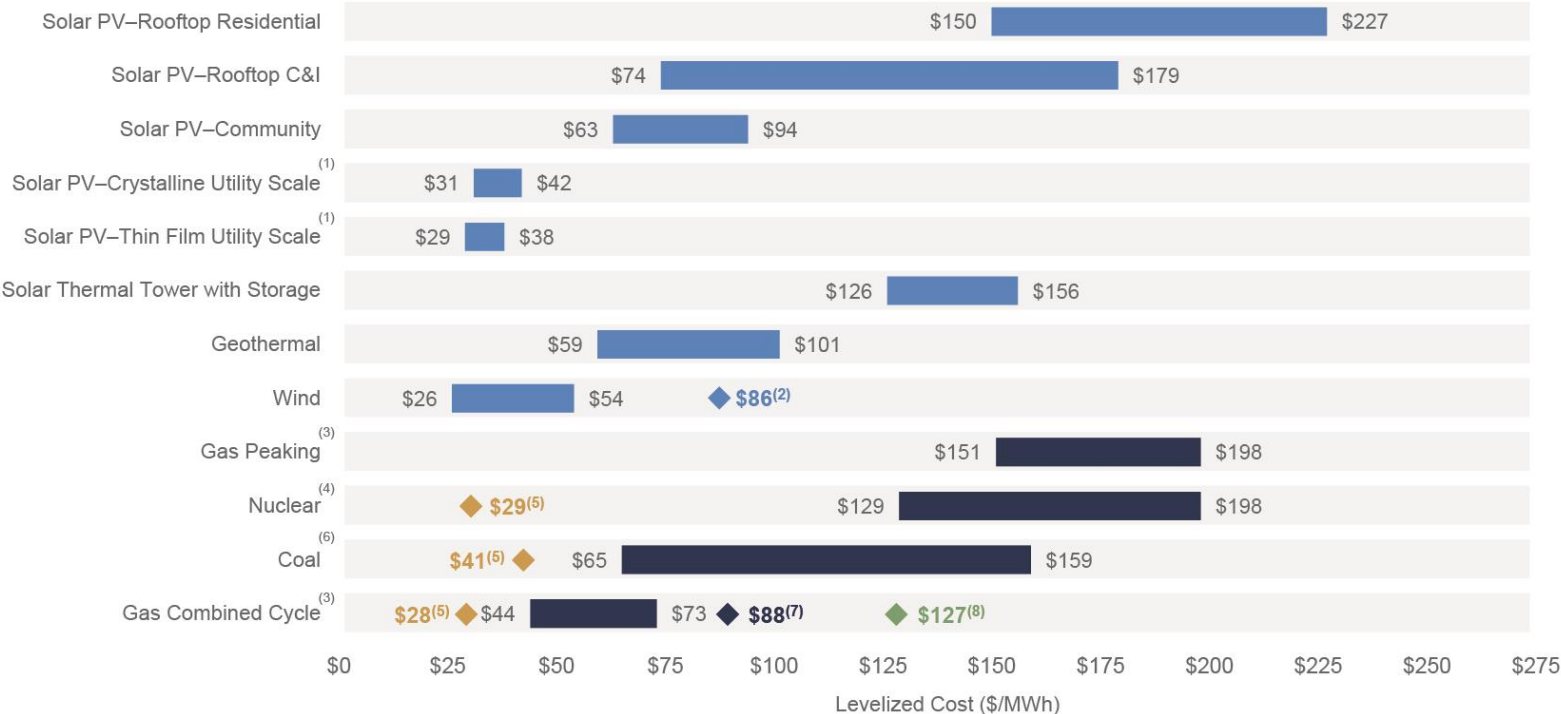
# Cost

## Levelized Cost of Energy Comparison—Unsubsidized Analysis

Selected renewable energy generation technologies are cost-competitive with conventional generation technologies under certain circumstances

Renewable Energy

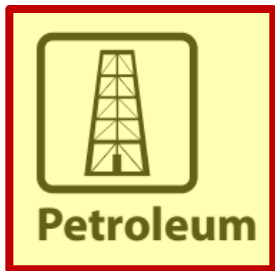
Conventional



Source: Lazard estimates.

# CO<sub>2</sub> Emissions

Highlight the primary energy sources that are produce Carbon Dioxide



**Geothermal**



**Hydropower**



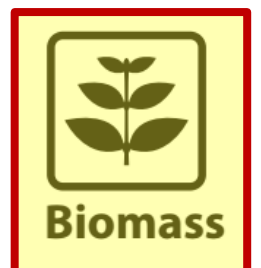
**Uranium**



**Solar**



**Wind**



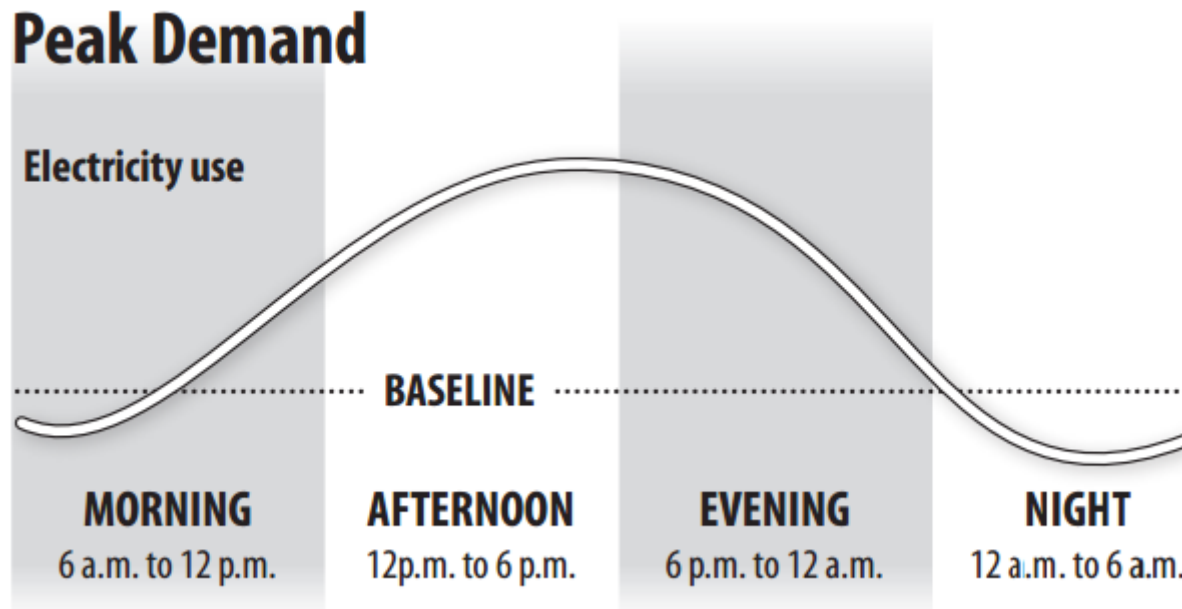
\*Note: this is just one of several greenhouse gases. We'll discuss this.

# Location Dependency and Politics



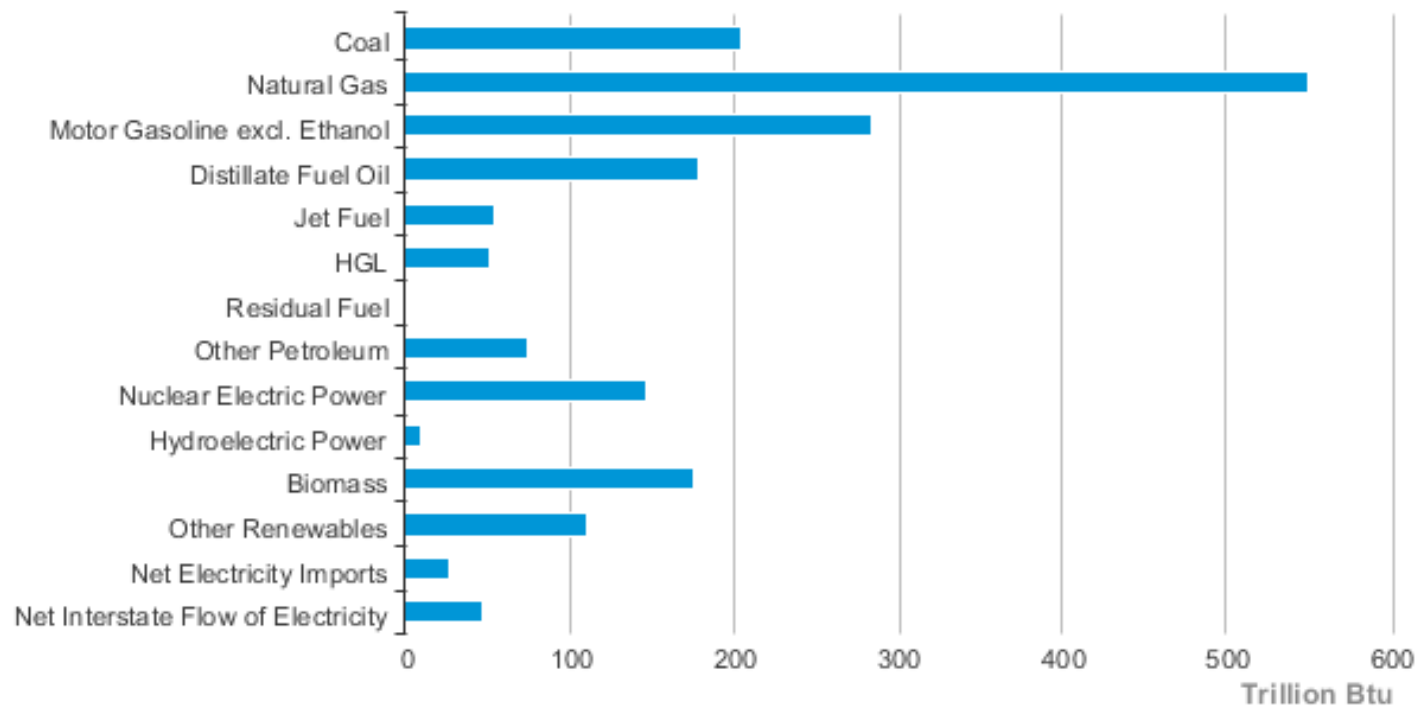
# Energy Load Requirements

Energy needs to be available when electricity is most needed but should also be available other times as well.



# Where does our Energy Come From?

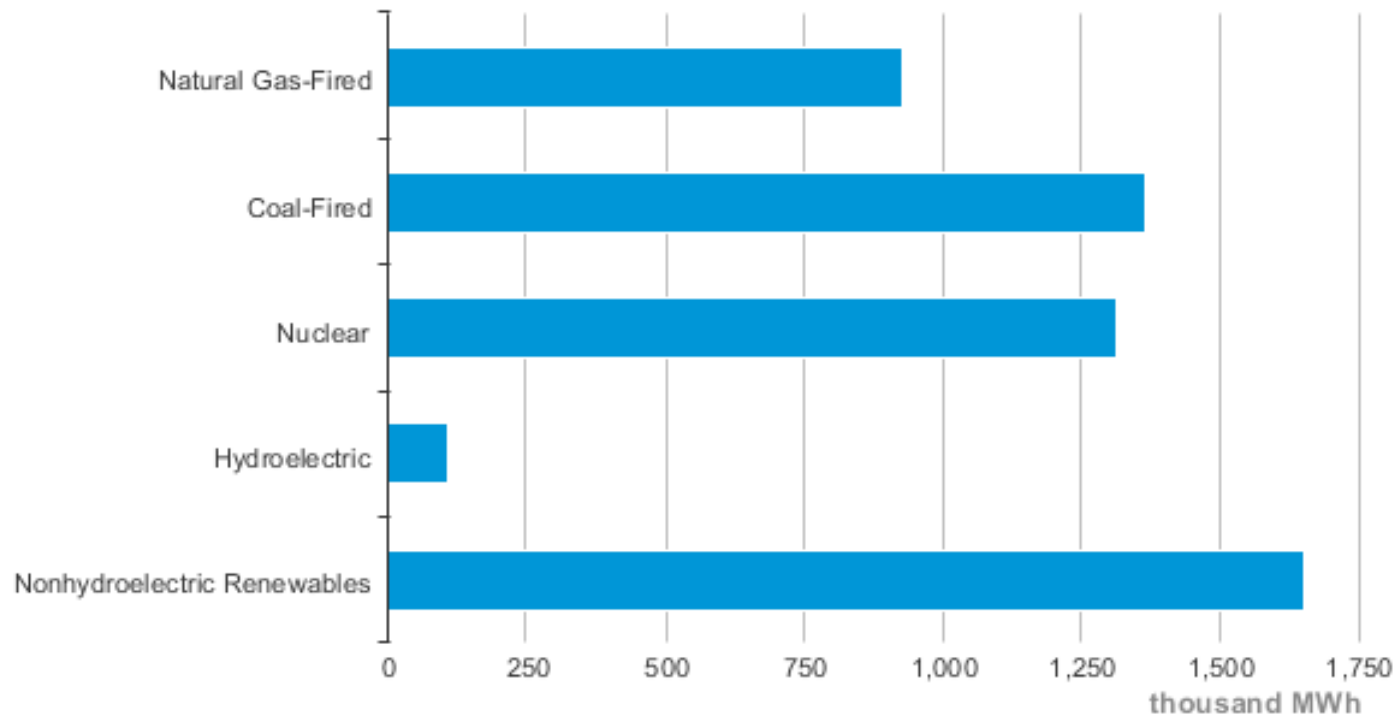
Minnesota Energy Consumption Estimates, 2019



Source: Energy Information Administration, State Energy Data System

# Where does our Energy Come From?

Minnesota Net Electricity Generation by Source, Dec. 2021



Source: Energy Information Administration, Electric Power Monthly

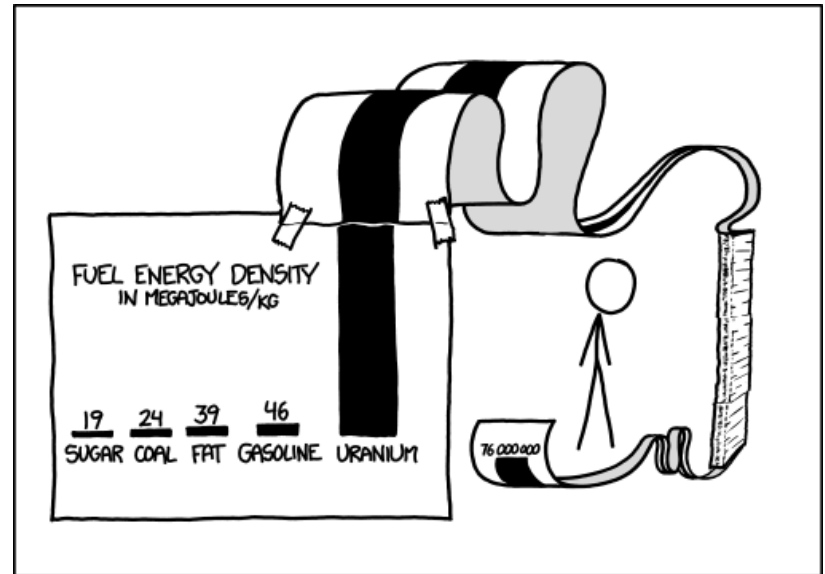
# Energy Density

Specific Energy = Energy per Unit Mass [ $\text{J kg}^{-1}$ ]

Energy Density = Energy per Unit Volume [ $\text{J m}^{-3}$ ]

$$E_S = \frac{E}{m}$$

$$E_D = \frac{E}{V}$$



SCIENCE TIP: LOG SCALES ARE FOR QUITTERS WHO CAN'T FIND ENOUGH PAPER TO MAKE THEIR POINT PROPERLY.

# Energy Density

Material	Specific Energy / MJ kg <sup>-1</sup>	Energy Density / MJ m <sup>-3</sup>
Uranium – (Nuclear Fission)	83,000,000	15,000,000,000,000
Natural Gas (Methane)	54	37
Gasoline/Petrol	46	34,000
Crude Oil	42	36,500
Coal	32	23,000
Ethanol	30	21,000
Wood	17	Varies
Average Food	17	Varies

Why are **Specific Energy** and **Energy Density** important?

**Higher energy density lowers transportation and storage costs**



# Power and Energy

**Energy**

Joules [J]

**Power**

Watts [W]

How are these quantities related?

$$1 \text{ W} = 1 \frac{\text{J}}{\text{s}}$$

# Energy Density

How much coal must be supplied per day to run a 500 MW power plant at 30% efficiency? (Specific Energy of coal is 32 MJ kg<sup>-1</sup>)

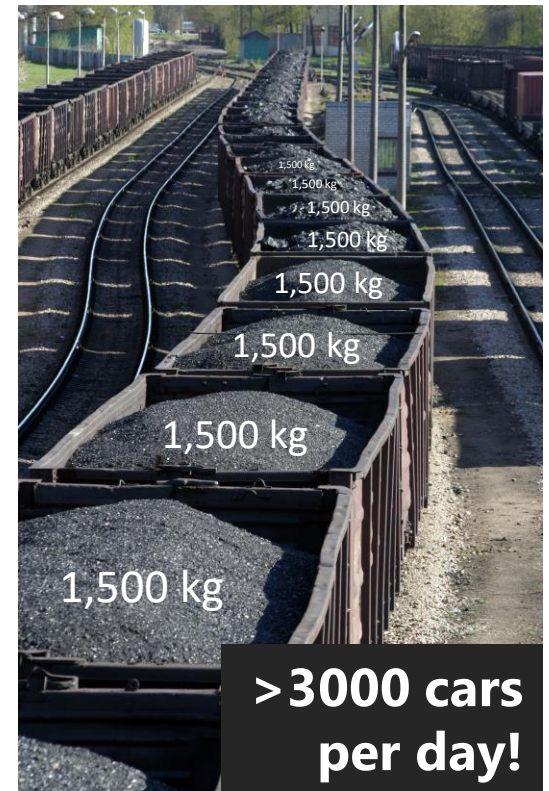
$$E_{in} \times 0.3 = 500 \frac{\text{MJ}}{\text{s}}$$

$$E_{in} = 1,700 \frac{\text{MJ}}{\text{s}}$$

$$\frac{1,700 \text{ MJ}}{1 \text{ s}} \times \frac{1 \text{ kg}}{32 \text{ MJ}} = 53.1 \frac{\text{kg}}{\text{s}}$$



$$\sim 4,600,000 \frac{\text{kg}}{\text{day}}$$



How many train cars per day?

# Energy Density

If a nuclear power plant powered by uranium-235 ( $83,000,000 \text{ MJ kg}^{-1}$ ) has the same output (500 MW) and the same efficiency (30%) as the coal-fired plant of the previous example, how many kg of nuclear fuel will it burn per day? Per year?

30% efficient

$$E_{in} \times 0.3 = 500 \frac{\text{MJ}}{\text{s}}$$

$$E_{in} = 1,700 \frac{\text{MJ}}{\text{s}}$$

$$\frac{1,700 \text{ MJ}}{1 \text{ s}} \times \frac{1 \text{ kg}}{83,000,000 \text{ MJ}} = 0.00002 \frac{\text{kg}}{\text{s}}$$

$$\sim 646 \frac{\text{kg}}{\text{year}}$$

$$\sim 1.77 \frac{\text{kg}}{\text{day}}$$

