Track: The Power Connection: Electric Generation for Gas Utilities

Unit #1: Introduction to Electric Generation

Presentation Outline

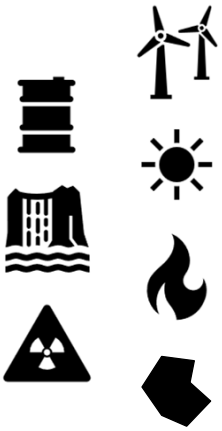
- Energy from Source to End-User
- Dispatchable vs. Non-Dispatchable Power
- Power Contracts, Trading, and Purchasing
- Interconnections
- eGRID Subregions vs. NERC Regions
- Electricity Producers
- Importance of Electricity Generation
- Comparing Natural Gas & Electric Infrastructure

Energy from Source to End-User

- Energy Sources
- Electric Generation
- Supply
- Transmission
- Distribution
- Consumption

Energy Sources

Energy – *"A fundamental entity of nature that is transferred between parts of a system in the production of physical change within the system and usually regarded as the capacity for doing work."* – Merriam-Webster



Often categorized by:

- Source (E.g., Coal vs. Natural Gas)
- Type (E.g., Fossil Fuel vs. Renewable)
- Sector (E.g., Transportation vs. Electrical Generation)
- End-Use (E.g., Heating vs. Lighting)

Source: https://www.merriam-webster.com/dictionary/energy
Source: U.S. Energy Information Administration: https://www.eia.gov/energyexplained/us-energy-facts/

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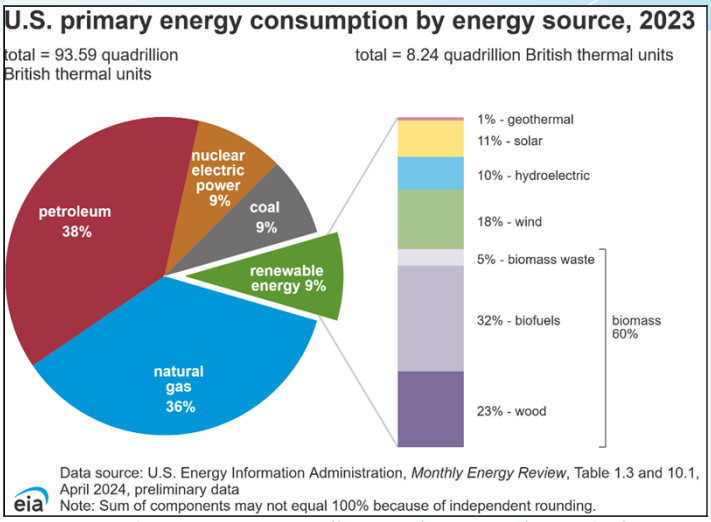
Energy Source Types

- **Fossil Fuels** – Fuels containing energy from plant or animal remains from antiquity.
- **Nuclear** – Energy produced through the splitting or combining of atoms.
- **Renewable** – Energy produced from naturally regenerative or comparatively limitless sources.



Source: U.S. Energy Information Administration: https://www.eia.gov/energyexplained/us-energy-facts/

Electricity is mostly a Secondary Source of Energy

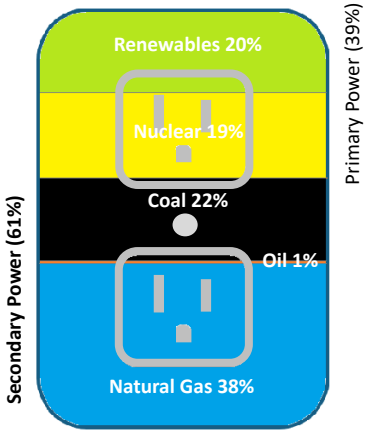
Secondary Generation Mix	% Mix
Coal	21.9%
Gas	38.4%
Oil	.6%
Other	.5%
Total Secondary	**61.4%**

Secondary electric produced with

Combustion Turbines

Engines

Fuel Cells



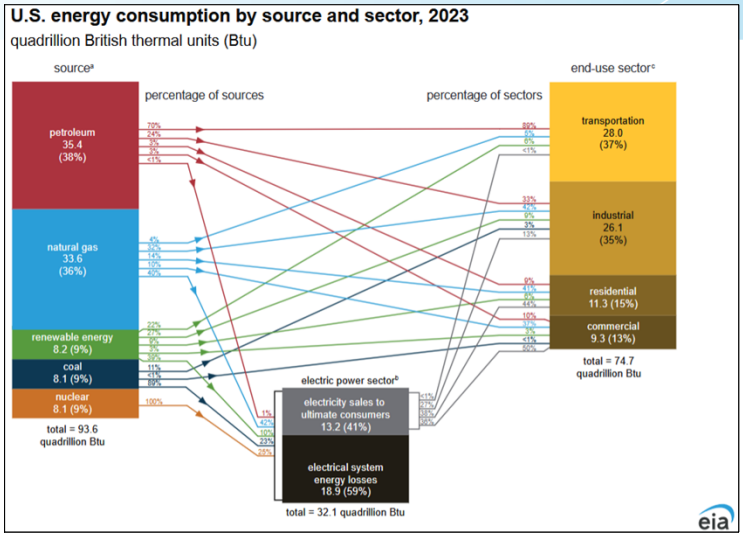
Primary Generation Mix	% Mix
Nuclear	18.9%
Hydro	6%
Wind	9.2%
Solar	2.8%
Biomass	1.3%
Geo-thermal	.4%
Total Primary	**38.6%**

Source: E-GRID 2023, using 2021 data, https://www.epa.gov/egrid/download-data
https://www.eia.gov/energyexplained/electricity/electricity-in-the-us.php

Energy Source Flows

Energy from each source is either delivered directly or indirectly to an end-use sector, often with losses along the way.

Approximately 34% of U.S. total energy consumption is dedicated to the electrical power sector, which is the primary energy source for both residential and commercial end-use sectors.



Source: U.S. Energy Information Administration: https://www.eia.gov/energyexplained/us-energy-facts/

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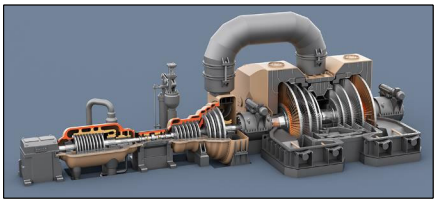
Electric Generation

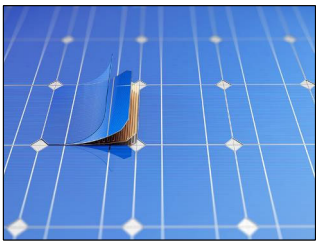
Electricity generation is the production of electricity, measured over time, and the method of generation is primarily determined by the energy source. The most common processes used at the utility scale are:

Electromechanical – The primary way to produce electricity is to use the movement of water, steam, or air to drive a turbine. Electricity is generated by the movement of magnets within a generator coupled with a turbine.

- Liquid and gas fuels, like natural gas, can directly drive a combustion turbine or internal combustion engine through the rapid expansion of air and fuel during combustion.
- Coal, natural gas, nuclear, and biofuels all can generate heat to drive a steam turbine.
- Hydroelectric and wind use the natural movement of water and air.

Photovoltaic – Solar energy uses a non-mechanical process called the photovoltaic effect to generate power from light.





Source: U.S. Energy Information Administration: https://www.eia.gov/tools/glossary/
Source: U.S. Energy Information Administration: https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php

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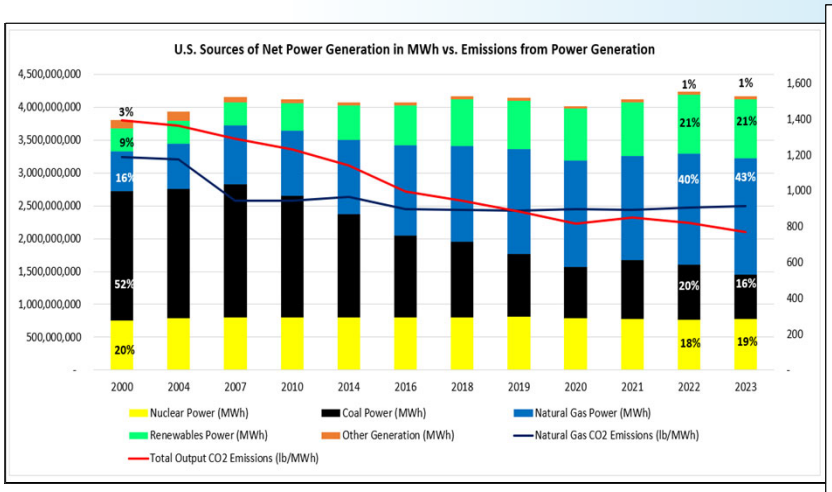
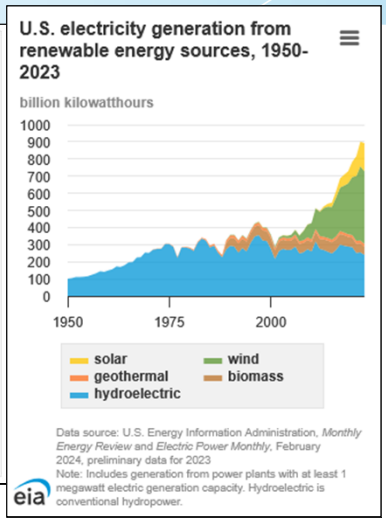
Electric Generation





Source: eGRID 2020
Source: U.S. Energy Information Administration:
https://www.eia.gov/energyexplained/electricity/data-and-statistics.php

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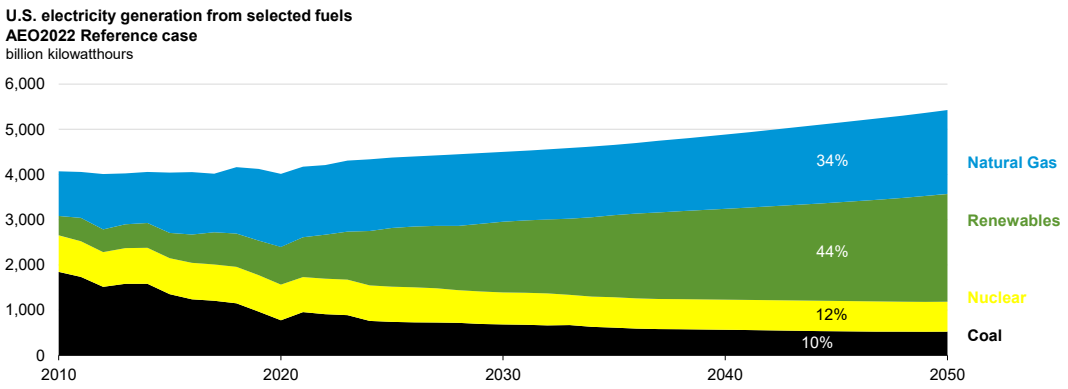
Expected Electric Generation Mix into the Future



Carbon emissions have dropped as natural gas and renewables replaced coal power. EIA is projecting 34% gas power generation in the future.

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Source: eGRID 2020

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Electric Supply

Each electrical generation source, or plant, can be characterized by how much it can generate and when. Most plants don't run at full capacity 24/7.

Common Units

Net generation – The amount of gross generation less the electrical energy consumed at the generating station(s) for station service or auxiliaries. **MWh**

Capacity – The maximum amount of electric power (electricity) that a power plant can supply at a specific point in time under specific conditions. **MW**

Net summer capacity – The maximum output, commonly expressed in megawatts (MW), that generating equipment can supply to system load, as demonstrated by a multi-hour test, at the time of summer peak demand (period of June 1 through September 30.) **Peak MW**

Source: U.S. Energy Information Administration: https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php
Source: U.S. Energy Information Administration: https://www.eia.gov/tools/glossary

Electric Transmission & Distribution

Transmission – Movement of electrical power over long distances. Electricity transmission networks consist of high-voltage transmission lines that interconnect various regions and demand centers.

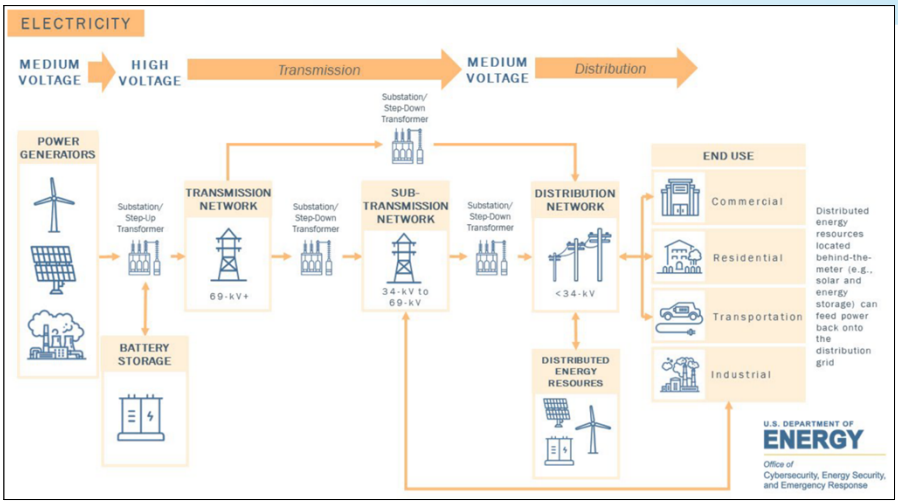
- Designed to minimize power loss over long distances.

Distribution – Delivery of electrical power to individual customers via a localized grid. Distribution networks convert high-voltage energy from transmission networks to lower voltages that can be more readily used.

- Designed to make customer connection and use easy.

Source: U.S. Department of Energy (Nov 2023): How It Works: Electric Transmission & Distribution and Protective Measures https://www.energy.gov/sites/default/files/2023-11/FINAL_CESER%20Electricity%20Grid%20Backgrounder_508.pdf

Electric Transmission & Distribution

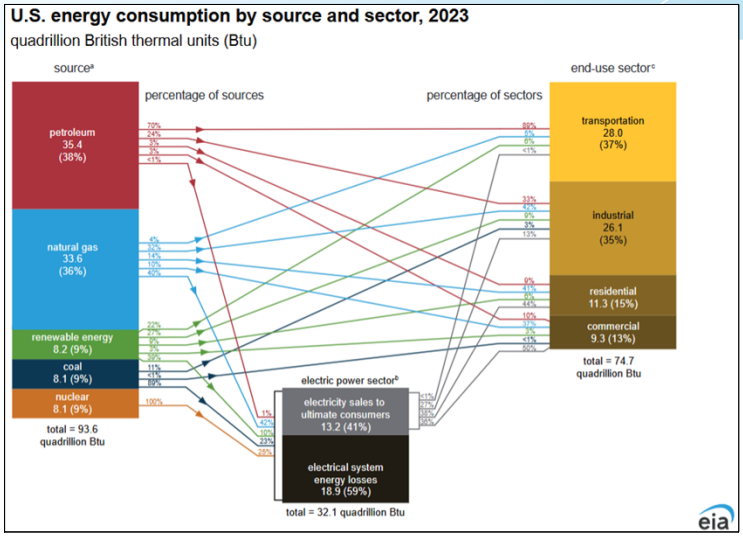


Source: U.S. Department of Energy: How It Works: Electric Transmission & Distribution and Protective Measures
https://www.energy.gov/sites/default/files/2023-11/FINAL_CESER%20Electricity%20Grid%20Backgrounder_508.pdf

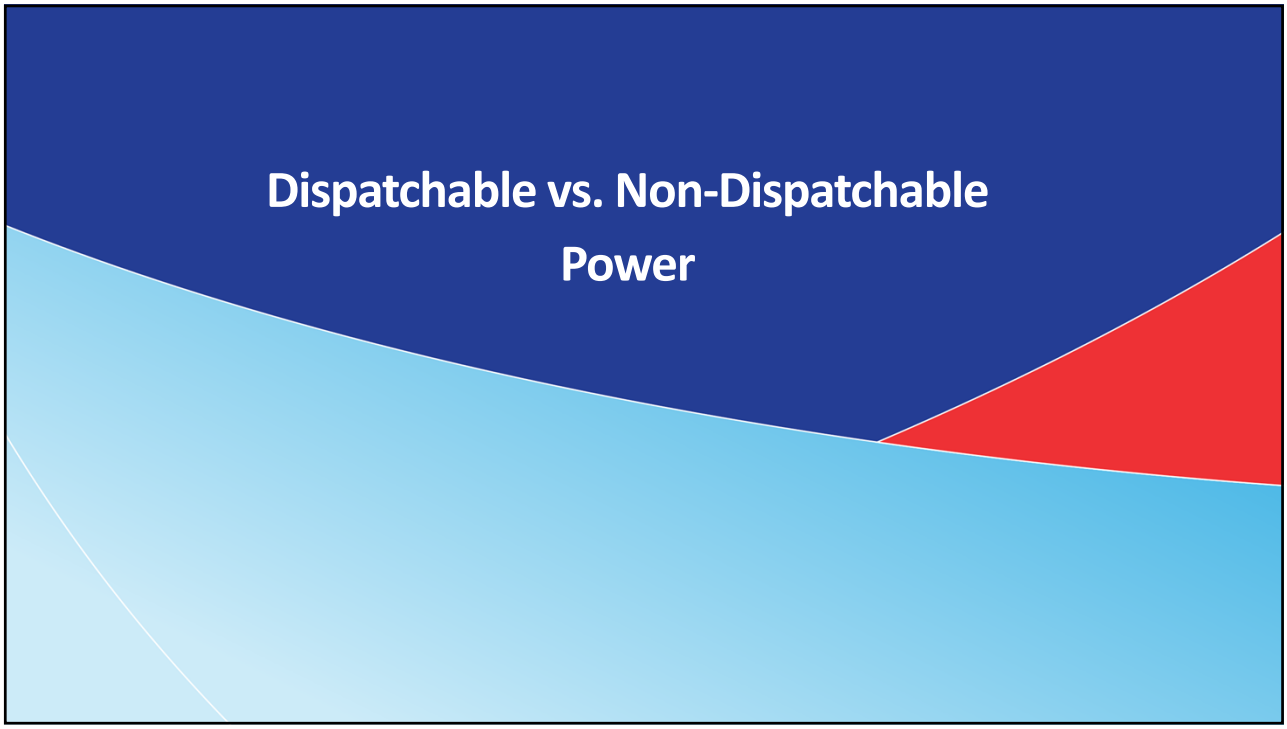
Electric Consumption

Electricity is used as an energy source across end use sectors, powering:

- Lighting
- HVAC
- Transportation
- Pumps & motors
- Process heating & cooling
- Various electronics



Source: U.S. Energy Information Administration: https://www.eia.gov/energyexplained/us-energy-facts/



Dispatchable vs. Non-Dispatchable Power

Demand for power from end-users is not constant. It increases and decreases based on time, day, season, weather, and other factors which can be predictable in some situations, and unpredictable in others. Power grids must plan for and quickly respond to variances in demand to ensure grid stability and prevent outages.

Dispatchable Power – Power that is available on demand, to match demand, or as a baseload for the grid. Depending on the source, dispatchable power may be available within seconds, minutes, or hours.

Non-Dispatchable Power – Power that cannot be ramped up or down as needed. This power has availability dependent on external factors.

Source: PCI Energy Solutions: Understanding the Differences Between Non-Dispatchable and Dispatchable Generation | PCI
Dispatchable source of electricity - Energy Education
Source: UNDERSTANDING THE TERM 'DISPATCHABLE' REGARDING ELECTRICITY GENERATION | NMPP Energy - Reliable, Cost-Based Energy

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Base Load vs. Marginal Load

Base Load Power – The electrical grid has a minimum load from customers that is always present. This base load can be serviced by base load power plants which are always able to satisfy this demand.

Marginal Power – Load on the electrical grid from customers that is not base load, varying over time, is satisfied with marginal power. Marginal power sources are able to ramp up and down more quickly than base load sources.

Base Load Power – Able to satisfy grid's 24/7 needs.

Marginal Power – Able to satisfy grid's varying power needs above base load.

Non-Dispatchable Power – Unable to ramp up or down quickly.

Dispatchable Power – Able to ramp up and down quickly.

Source: PCI Energy Solutions: Understanding the Differences Between Non-Dispatchable and Dispatchable Generation | PCI
Dispatchable source of electricity - Energy Education
Source: UNDERSTANDING THE TERM 'DISPATCHABLE' REGARDING ELECTRICITY GENERATION | NMPP Energy - Reliable, Cost-Based Energy

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Power Source Examples

Dispatchable Power Examples:

- Natural Gas
- Coal
- Petroleum
- Nuclear
- Some Hydroelectric

Non-Dispatchable Power Examples:

- Wind
- Solar

Base Load Power Examples:

- Nuclear
- Coal
- Hydroelectric (without reservoirs)

Marginal Load Power Examples:

- Natural Gas
- Hydroelectric (with reservoirs)
- Wind (as is available/predicable)
- Solar (as is available/predicable)

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Source: U.S. Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=7590

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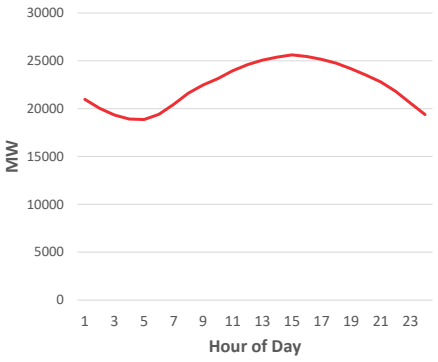
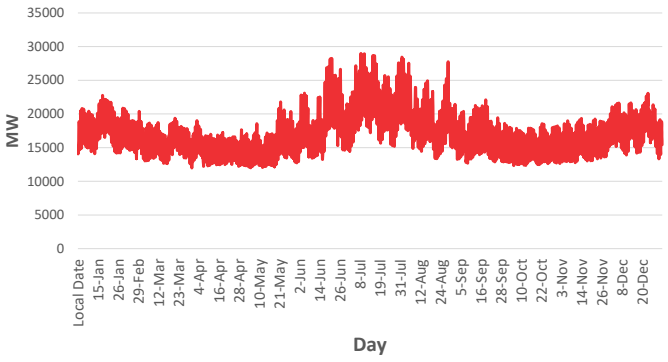
Grid Load Patterns

NY ISO Load (MW): One Day
8/6/2024



NY ISO Load (MW): One Year
2024



Source: U.S. Energy Information Administration (Feb 2025): https://www.eia.gov/electricity/wholesalemarkets/data.php?rto=nyiso

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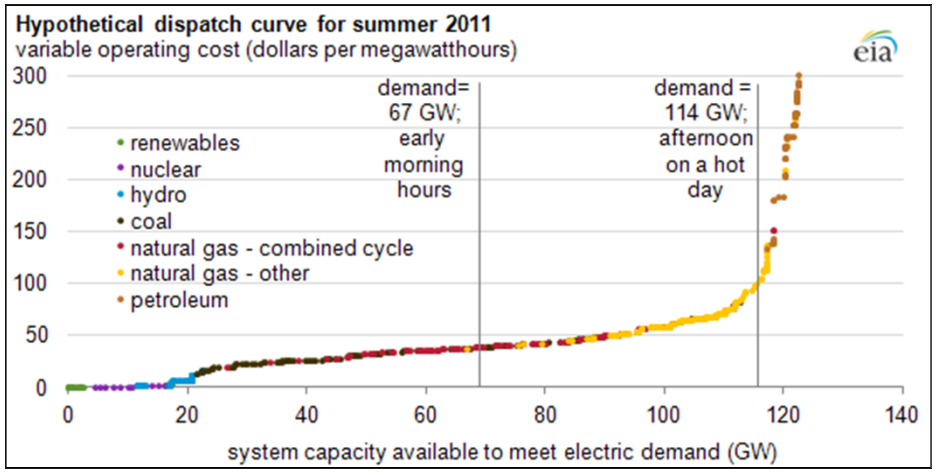
Dispatchable vs. Non-Dispatchable Power



Source: U.S. Energy Information Administration (Aug 2012): https://www.eia.gov/todayinenergy/detail.php?id=7590

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Dispatchable vs. Non-Dispatchable Power

Grid-scale power storage is able to help bridge the gap, converting energy from non-dispatchable sources into dispatchable energy. Grid-scale power storage has been around for decades but been relatively limited in scale and capacity. There have significant advances and large developments in this area in recent years. Examples are:

- Pumped-storage hydropower
- Chemical storage / Battery storage
- Flywheels
- Capacitors
- Compressed air (CAES)

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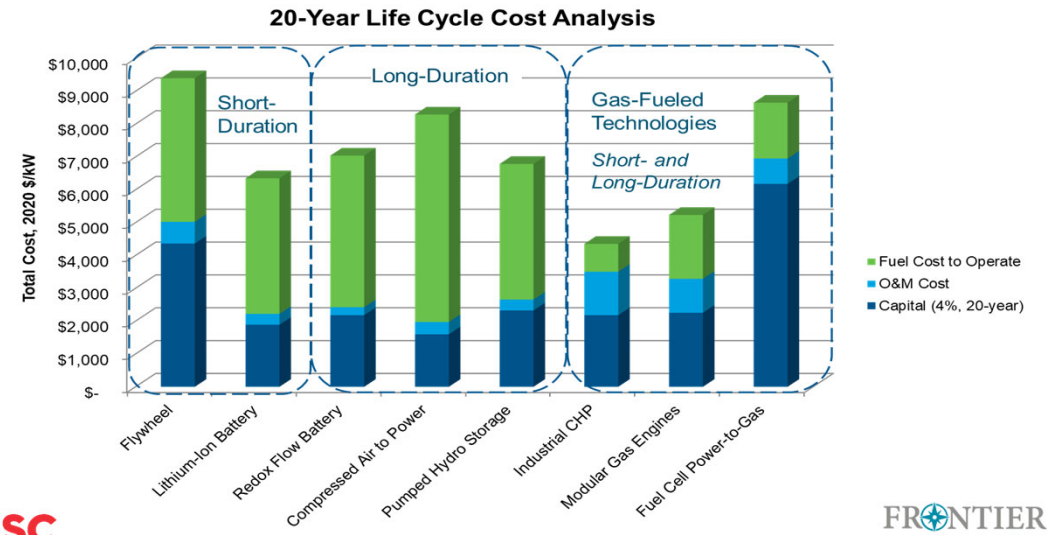
Electric Storage Options



Source: Energy Storage Comparison Analysis with Gas-Fueled Technologies, ICF, September 2020

Power Contracts, Trading, and Purchasing

- Contract Terms
- Trading
- Fuel Supply Agreements
- Additional Terms

Electric Industry Contract Terms

Engineering, Procurement, and Construction (EPC) Contracts – A short-term agreement where a contractor is responsible for an operational project from design to completion. These are used in the construction of power plants and can include performance guarantees.

Power Purchase Agreements (PPAs) – The long-term contracts between an electricity producer and a purchaser. These enable separate entities to generate and distribute power, taking on independent risks in each area. These can include a capacity charge for availability and a usage charge for generation.

- For instance, a private entity owning and operating a power plant would have a PPA with a utility to generate power for their distribution network.

Fuel Supply Agreements – An agreement between a fuel supplier and electricity generator to ensure fuel for operation is supplied on a schedule in sufficient quantities and with sufficient quality.

Source: The World Bank: https://ppp.worldbank.org/public-private-partnership/sector/energy/energy-power-agreements/power-purchase-agreements
Source: Mastt: https://www.mastt.com/glossary/epc

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Electric Industry Trading

Spot Market – Transactions for immediate or day-ahead energy delivery are made here on an auction or exchange basis with real-time pricing dependent on supply and demand.

- These are a tool for grid operators to manage short-term grid stability during peak periods, but pricing is volatile.

Forward Market – Transactions for future delivery at predetermined pricing are negotiated here through futures contracts which can themselves be traded between parties.

- These are a tool for grid operators to ensure long-term electricity availability and price stability using forecasted electricity demand.

Source: Diversegy: https://diversegy.com/spot-vs-forward-markets/

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Fuel Supply Agreements

Firm Contracts – Obligate a fuel producer to supply and deliver fuel when requested. These provide power plant operators stability and priority in delivery of fuel.

Interruptible (Non-Firm) Contracts – Allow a fuel producer to interrupt the fuel supply or delivery for predetermined conditions. These are generally less expensive than firm contracts, but at the risk of fuel delivery stops or curtailments if fuel is limited, or needed by higher-priority or higher-paying customers.

Source: U.S. Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=35112

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Additional Terms

Synchronous / Parallel – Generated power must synchronize with the grid power if the customer wants to work in tandem with grid power.

Real Time Pricing (RTP) – Buying electric on hourly basis the day before it is expected to be used.

Stranded Costs – These are costs that a utility has invested in infrastructure that could become redundant due to regulation or market changes. These costs may or may not be recovered as a result of future changes.

Competitive Transition Charges (CTC) – A way to distribute the utility burden of stranded costs caused by regulatory or market transitions to customers through an additional charge on bills.

ESC Source: U.S. Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=35112

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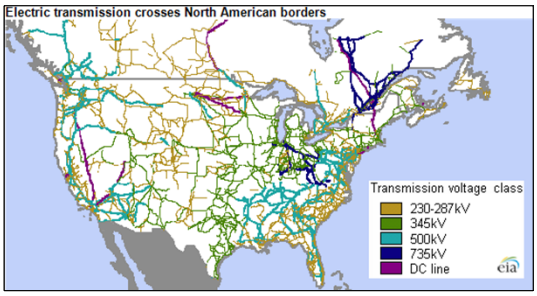
Interconnections

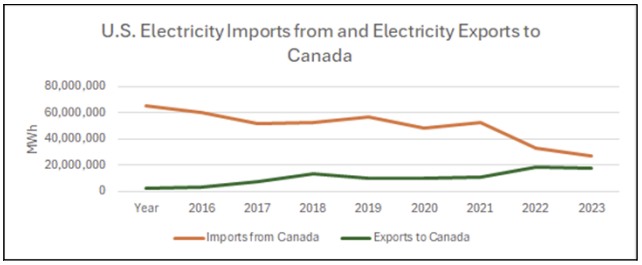
- U.S. and Canada
- ISOs and RTOs
- Consumer Interconnections
- PURPA Qualifying Facilities
- Regulated vs. Deregulated Utilities

US & Canadian Electrical Interconnections

The U.S. and Canadian electric power grids are connected through 37 major transmission lines.

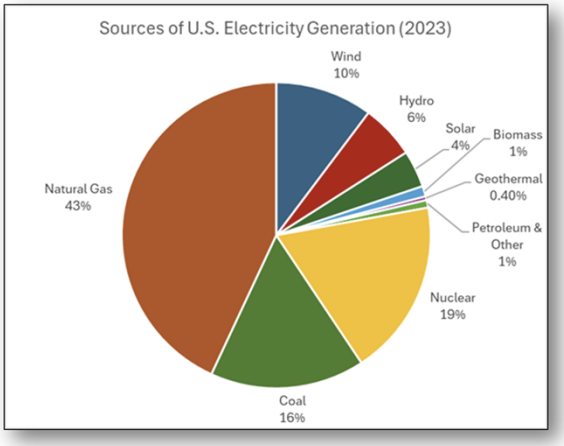
Canada is a net exporter of electricity to the US and has a comparatively cleaner electricity mix.

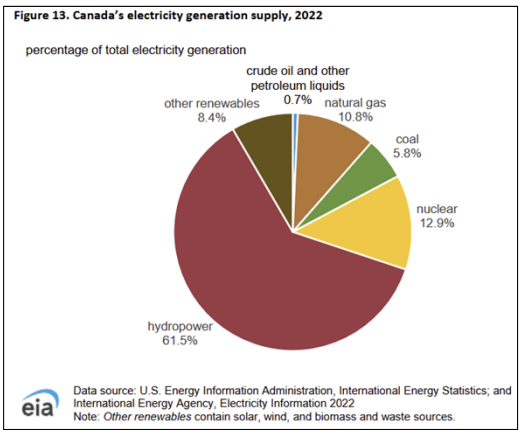




U.S. Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=8930
U.S. Energy Information Administration: https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=table_7_01

US & Canadian Electrical Interconnections



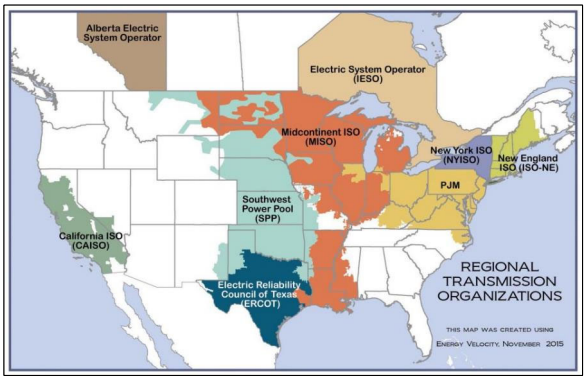


U.S. Energy Information Administration: https://www.eia.gov/energyexplained/electricity/electricity-in-the-us.php
U.S. Energy Information Administration: https://www.eia.gov/international/content/analysis/countries_long/Canada/pdf/Canada_FY2024.pdf

ISO Regions

Traditional Markets – Wholesale physical power trade typically occurs through bilateral transactions.

ISO & RTO Markets – Independent system operators (ISOs) and **regional transmission organizations (RTOs)** are independent organizations that oversee the generation and delivery of electricity to consumers. These have competitive energy and ancillary services markets in which buyers and sellers can bid for or offer generation. The ISOs and RTOs use bid-based markets to determine economic dispatch. RTOs and ISOs also operate portions of the electric transmission system.



ISOs & RTOs are intended to foster competition and guard against market manipulation among power suppliers; facilitate grid planning and operations to ensure reliability; and guarantee that all types of power suppliers have access to the electricity grid.

Source: Federal Energy Regulatory Commission: https://www.ferc.gov/electric-power-markets
Source: U.S. Environmental Protection Agency: https://www.epa.gov/green-power-markets/power-market-structure

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ISOs & RTOs

ISOs and RTOs grew out of separate government orders. However, ***"Both ISOs and RTOs share the same general mandates:***

- *They must operate as a nonprofit.*
- *They must ensure non-discriminatory access to the transmission grid by both customers and suppliers.*
- *They operate the bulk power transmission system within their footprint and do so independently of the wholesale market (meaning they don't sell electricity to end users).*
- *They cannot own any equipment (generators, power lines, and the like).*
- *They must obtain electricity from generation suppliers to maintain system reliability and meet market demand.*

The only difference between an ISO and an RTO in today's market is the size of its footprint and the way it prices services."

- PCI Energy Solutions

Source: Federal Energy Regulatory Commission: https://www.ferc.gov/electric-power-markets
Source: PCI Energy Solutions: https://www.pcienergysolutions.com/2022/11/29/whats-the-difference-between-iso-and-rto/

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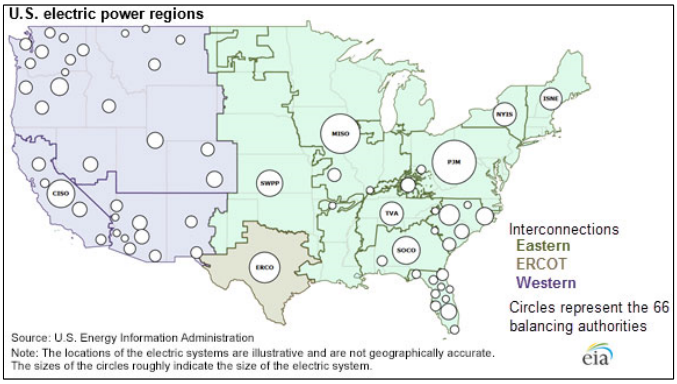
Electrical System Interconnections

The U.S. power system (Lower 48 states) consists of three main interconnections, which operate largely independently from each other with limited transfers of electricity between them.

- **Eastern Interconnection**
- **Western Interconnection**
- **Electric Reliability Council of Texas (ERCOT)**

The network structure of the interconnections helps:

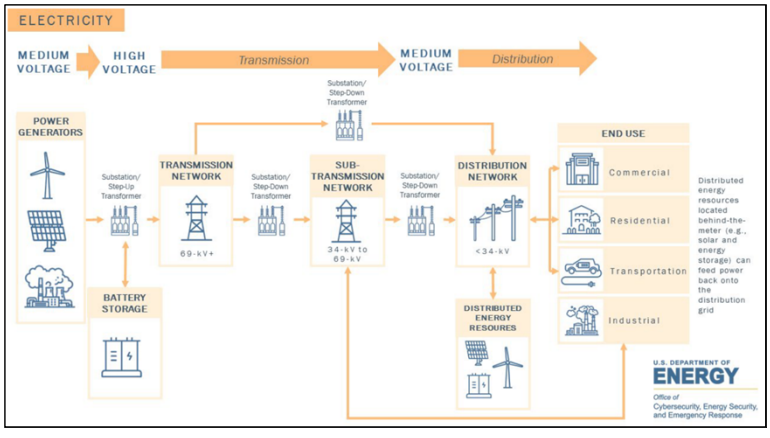
- Maintain the reliability of the grid
- Allows generators to supply electricity to many load centers
- Provides redundancy



Source: U.S. Energy Information Administration: https://www.eia.gov/energyexplained/electricity/delivery-to-consumers.php

Consumer Interconnection

Utility-Consumer Interconnection – A path for power to be delivered to an end user. As power transmission occurs at high voltages to reduce energy loss over long distances, transformers are used to step down the voltage for local distribution, and delivery. End-users are connected via a meter to measure and appropriately bill usage.



Source: Electrical Engineering Portal: https://electrical-engineering-portal.com/utility-consumer-interconnection-configurations
Source: U.S. Department of Energy: How It Works: Electric Transmission & Distribution and Protective Measures https://www.energy.gov/sites/default/files/2023-11/FINAL_CESER%20Electricity%20Grid%20Backgrounder_508.pdf

PURPA Qualifying Facilities

The **Public Utility Regulatory Policies Act of 1978 (PURPA)** encourages:

- The conservation of electric energy.
- Increased efficiency in the use of facilities and resources by electric utilities.
- Equitable retail rates for electric consumers.
- Expeditious development of hydroelectric potential at existing small dams.
- Conservation of natural gas while ensuring that rates to natural gas consumers are equitable.

PURPA established a new of a new class of generating facilities **(Qualifying Facilities or QFs)** that would receive special rate and regulatory treatment.

- The right to sell energy or capacity to a utility.
- The right to purchase certain services from utilities.
- Relief from certain regulatory burdens.

PURPA also requires electric utilities to allow interconnection of Combined Heat and Power qualified facilities to their grids.

Source: Federal Energy Regulatory Commission: https://www.ferc.gov/qf

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Regulated vs. Deregulated Utilities

Utilities in **deregulated** markets are prohibited from generation and transmission ownership and are only responsible for distribution, operations, maintenance from the point of grid interconnection to the meter, and billing ratepayers.

- Generating entities in these regions typically sell the electricity they generate through competitive power markets (ISOs & RTOs).

Regulated markets feature vertically integrated utilities that own or control the total flow of electricity from generation to meter.

- In these markets, utilities determine the mix of resources that they use to generate electricity, with approval from state public utility commissions.
- The electric system in much of the South and West is managed using these traditional wholesale electricity markets.

Source: U.S. Environmental Protection Agency: https://www.epa.gov/greenpower/understanding-electricity-market-frameworks-policies
Source: U.S. Environmental Protection Agency: https://www.epa.gov/green-power-markets/power-market-structure

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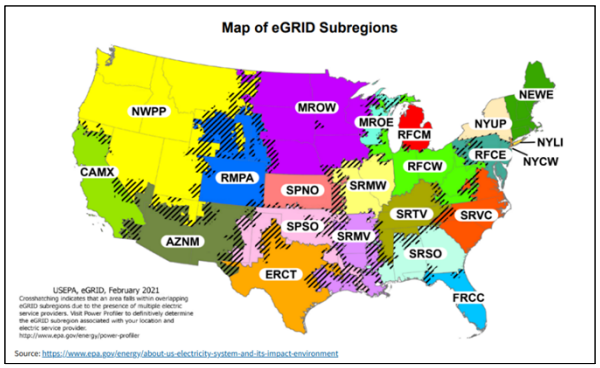
eGRID Subregions vs. NERC Regions

eGRID

eGRID – Emissions & Generation Resource Integrated Database

This is a comprehensive source of data from EPA's Clean Air Power Sector Programs on the environmental characteristics of almost all electric power generated in the United States. Data includes:

- Emissions
- Emission rates
- Generation
- Heat input
- Resource mix
- Other attributes.



eGRID is typically used for greenhouse gas registries and inventories, carbon footprints for electricity purchases, consumer information disclosure, emission inventories and standards, power market changes, and avoided emission estimates.

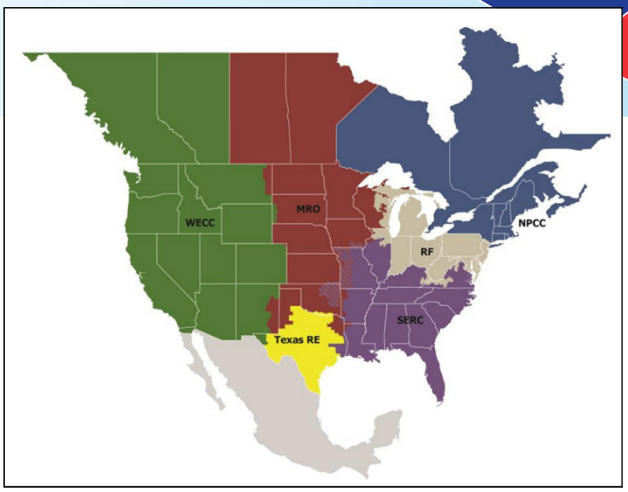
Source: U.S. Environmental Protection Agency: https://www.epa.gov/egrid
Source: U.S. Environmental Protection Agency: https://www.epa.gov/green-power-markets/us-grid-regions

NERC

NERC – North American Electric Reliability Corporation

This is a not-for-profit international regulatory authority whose mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid.

NERC develops and enforces Reliability Standards; annually assesses seasonal and long-term reliability; monitors the bulk power system through system awareness; and educates, trains, and certifies industry personnel.



By User:DevonJade - A commons file NERC-map.jpg updated to the 2021 state of affairs per the NERC document "Balancing and Frequency Control" (May 11, 2021), CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=125050144

NERC oversees six regional reliability entities and encompasses all the interconnected power systems of Canada and the contiguous United States, as well as a portion of Mexico.

Source: https://www.epa.gov/green-power-markets/us-grid-regions
https://www.nerc.com/AboutNERC/Pages/default.aspx
North American Electric Reliability Corporation – Wikipedia

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Electricity Producers

- Commercial
- Industrial
- IPP
- Electric Utilities
- Franchise Agreements

Commercial & Industrial Power Producers

Commercial Producers – Businesses can generate energy for their own use and sell excess generation to the grid.

- For example, these might include offices, shopping centers, or warehouses with solar installations.

Industrial Producers – Industrial sites, such as manufacturing plants, may also generate energy for their own use while simultaneously being connected to the grid.

- Combined heat and power (CHP) is an example where a site needing both heat and power for processes can obtain both from electricity generation, improving efficiency.

Source: U.S. Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=64504

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IPPs & Electric Utilities

Independent Power Producers (IPPs) – Also known as merchant plants, IPPs are entities that own and operate facilities that generate power for bulk sale and use by others. IPPs are not utilities.

- Facilities owned by IPPs mostly have been built in regions that support competitive wholesale markets.

Electric Utilities – Electric utilities are entities responsible for the distribution and delivery of electricity for public use. These may also produce power in some areas.

- These can be investor-owned, municipal, State, Federal, and rural cooperatives.

Source: U.S. Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=64504
Source: U.S. Energy Information Administration: https://www.eia.gov/tools/glossary/index.php?id=Electric%20utility

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Franchise Agreements

A **franchise agreement** is a negotiated contract between a municipality and an electric service provider that grants the utility the right to serve customers in the city's jurisdiction. The contract often specifies the period of service, and a fee remitted back to the municipality. These agreements commonly include stipulations regarding a utility's right of way to install and maintain electrical infrastructure.

Source: National Renewable Energy Laboratory: https://www.nrel.gov/solar/market-research-analysis/municipal-franchise-agreements.html

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Importance of Electricity Generation

- Historical Generation
- Diverse Fuel Sources

Electricity is Critical

Reliable access to electricity is critical for supporting the tools of modern society. US infrastructure and the economy rely on electricity to provide essential jobs and services.

While some energy end-uses can be powered by different fuels, others can not.

- Technology with potential for fuel switching: cars, space heating, water heating, motors…
- Electricity-dependent technology: lighting, computers, motors, communications equipment, healthcare equipment…

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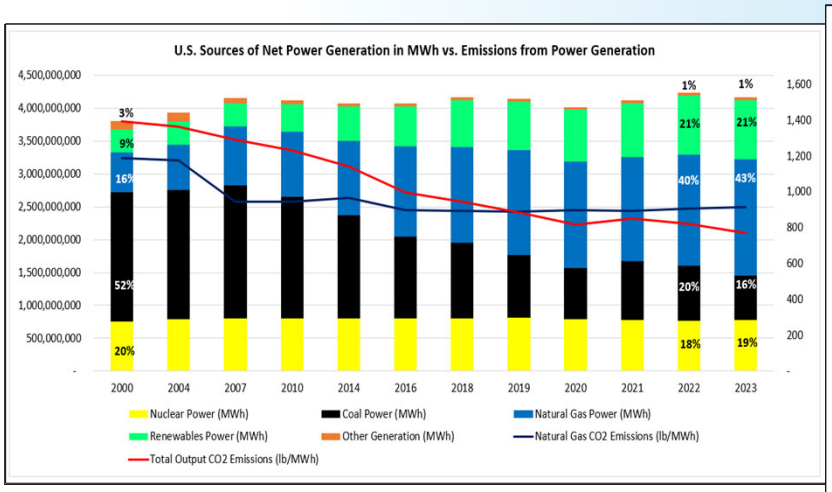
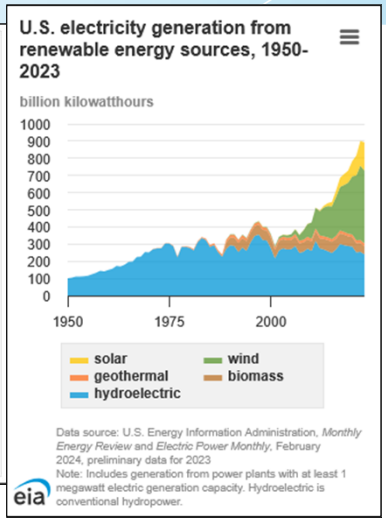
Electric Generation History





Source: eGRID 2020
Source: U.S. Energy Information Administration: https://www.eia.gov/energyexplained/electricity/data-and-statistics.php

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Diverse Fuel Sources

Diverse fuel sources for the electric grid are essential in ensuring:

- **Reliability** – Dispatchable and non-dispatchable sources compliment each other in ensuring power is available as needed.
- **Affordability** – Fluctuations in the price of one fuel can be tempered by other fuels.
- **Resilience** – Disruptions from supply chain limitations or natural disasters can be mitigated with a diverse grid.
- **Energy Security** – Domestic fuels and diversity in trade partners and fuels ensure more stability in energy supply.
- **Environmental & Safety** – Fuels have differing environmental impacts, including emissions, pollution, and safety.

Source: U.S. Energy Information Administration: https://www.eia.gov/energyexplained/electricity/electricity-in-the-us.php

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Comparing Natural Gas & Electric Infrastructure

Similarities Between Natural Gas & Electric Infrastructure

Natural gas and electricity, as fuels, compliment each other in the support they provide to modern society. They are also interdependent.

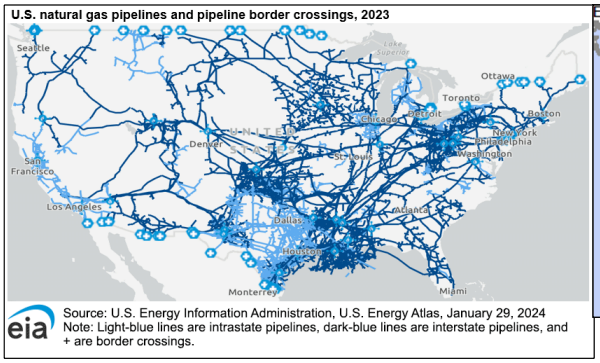
Natural Gas Grid: Production sources, pipelines, storage facilities, compressor stations, meters.

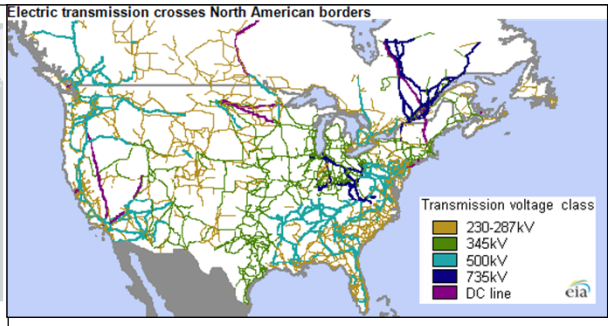
- Gas grid infrastructure relies on electricity to operate.

Electric Grid: Production sources, electrical lines, energy storage, transformers & substations, meters.

- Electric generation is largely dependent on natural gas for generation.

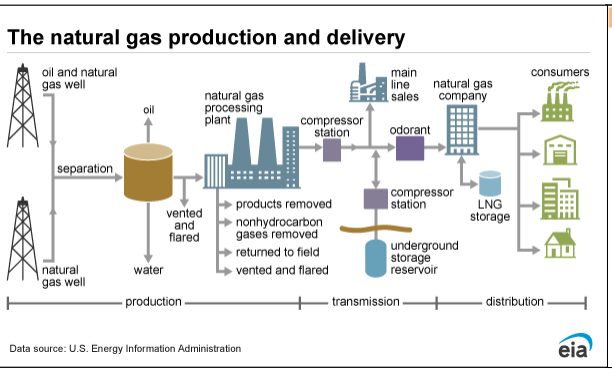
Natural Gas & Electric Grids

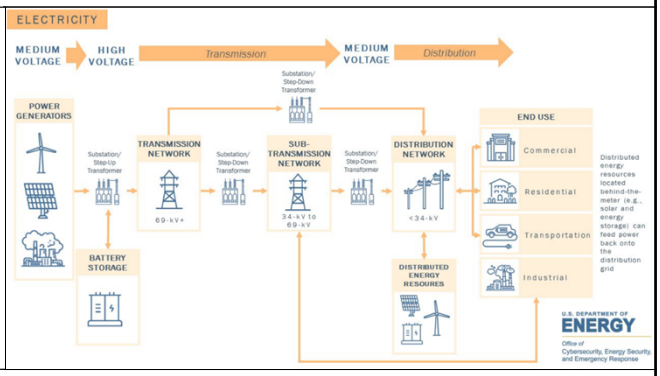




Source: U.S. Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=8930
Source: U.S. Energy Information Administration: https://www.eia.gov/energyexplained/natural-gas/natural-gas-pipelines.php

Natural Gas & Electric Grids





Source: U.S. Energy Information Administration: https://www.eia.gov/energyexplained/natural-gas/delivery-and-storage.php
Source: U.S. Department of Energy: How It Works: Electric Transmission & Distribution and Protective Measures https://www.energy.gov/sites/default/files/2023-11/FINAL_CESER%20Electricity%20Grid%20Backgrounder_508.pdf

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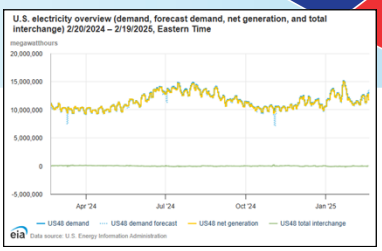
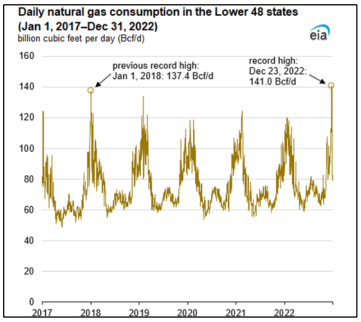
Similarities Between Natural Gas & Electric Infrastructure

Both natural gas and electric grids experience seasonal peak demand patterns.



Natural Gas: Annual peak demand periods generally are winter heating demand and summer peak loads assisting peaks in electrical generation.

Electric: Annual peak demand periods generally are summer cooling demand and winter electric heating demand.



Source: U.S. Energy Information Administration: https://www.eia.gov/naturalgas/weekly/archivenew_ngwu/2023/01_19/#itn-tabs-1
Source: U.S. Energy Information Administration: https://www.eia.gov/electricity/gridmonitor/expanded-view/electric_overview/US48/US48/ElectricityOverview-2/edit

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Differences Between Natural Gas & Electric Infrastructure

Sources differ:

- Natural gas is primarily sourced from underground reservoirs. Other sources are possible, such as biogas and waste stream collection, but these remain a small portion.
- Electricity can be produced through a wide range of sources and processes.

Distribution differs:

- Natural gas is a physical product that must be transported from source to end use. While distribution is complex, it can be physically moved, compressed, stored, and metered. This gives it flexibility to be delivered when needed, but also physical limitations, such as large equipment and the ability to be lost through leaks in infrastructure.
- Electricity is the movement of electric charge, and not a physical product like natural gas. Distribution relies on a real-time supply and demand. Electricity can be modified to different characteristics for different transport or end uses (AC vs. DC, voltage, etc.). This gives it certain flexibilities in transport to minimize losses, but limitations in the ability to be stored without conversion.

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Differences Between Natural Gas & Electric Infrastructure

Gas pressure vs. electric voltage: Both natural gas and electricity can be modified to aid in transport.

- **Pressure:** Natural gas can be pressurized to move from one location to another. Gas will move from an area of high pressure to an area of low pressure through pipelines, and pressure can be maintained by adding gas to one end of the line. Only one line is needed, and higher pressures move gas faster. Pressure is impacted by things like friction along the pipeline and changes in elevation. Pressure is measured in psi, atm, or Pa.
- **Voltage:** Electric voltage is the measure electric potential energy per unit charge between two points. Maintaining a voltage across an electrical wire moves electrons along the wire, delivering electricity. A power source, such as a power plant, maintains this voltage on the grid. Distribution requires a circuit, or two wires for electrons to move along. Higher voltages reduce resistance along a wire, reducing energy losses over long distances. Voltage is measured in volts or (V).

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