# Power Talk

*Electrical Energy Basics And Vocabulary For Understanding Electric Power And Climate Change*


Written by the
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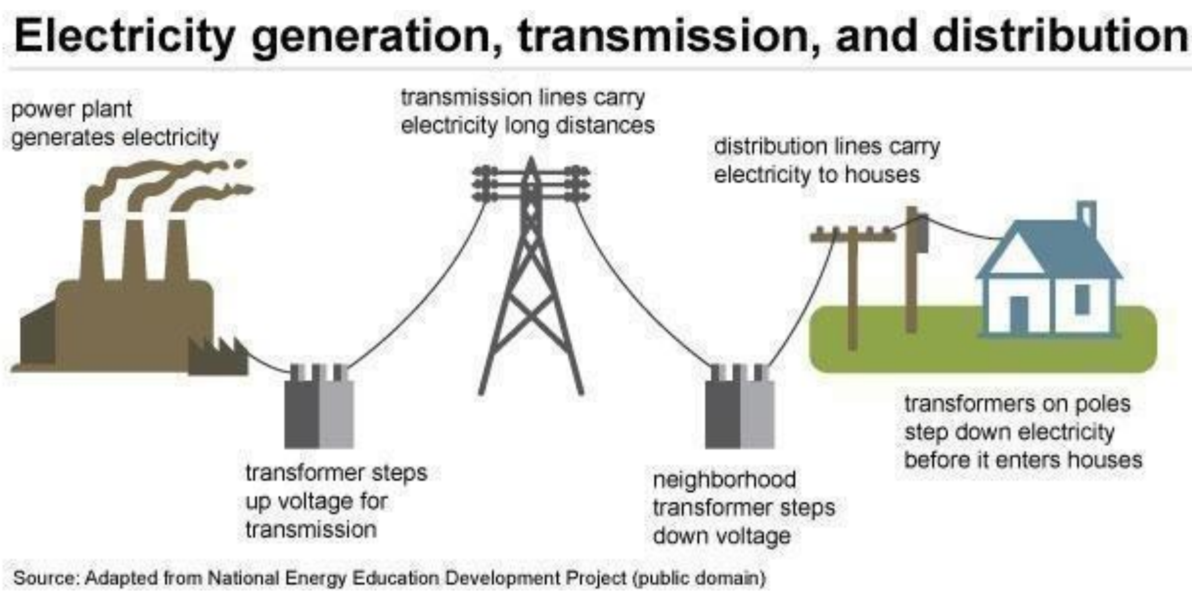
# Introduction: Why Power Talk?

Power Talk is designed for climate emergency community activists. Like many public policy issues, there are semi-technical terms that are particularly useful to know and understand in order to assess proposals and to hold officials accountable.

Important decisions are being made today in communities around the country about how to power our future. Electricity is a critical aspect of our lives, nearly as ubiquitous as the air we breathe, and many have taken it for granted. How is electricity produced, who produces it, and how does it get to our homes and businesses? In years past, consumers could be forgiven for not knowing the answers. Today we understand that electricity production causes greenhouse gasses and has a substantial impact on the climate. Not all forms of electricity are equal.

This Power Talk is divided into three sections. Sections 1-3 explain the process of generating, transmitting, and distributing electricity to homes and businesses, including new technologies and terminology.



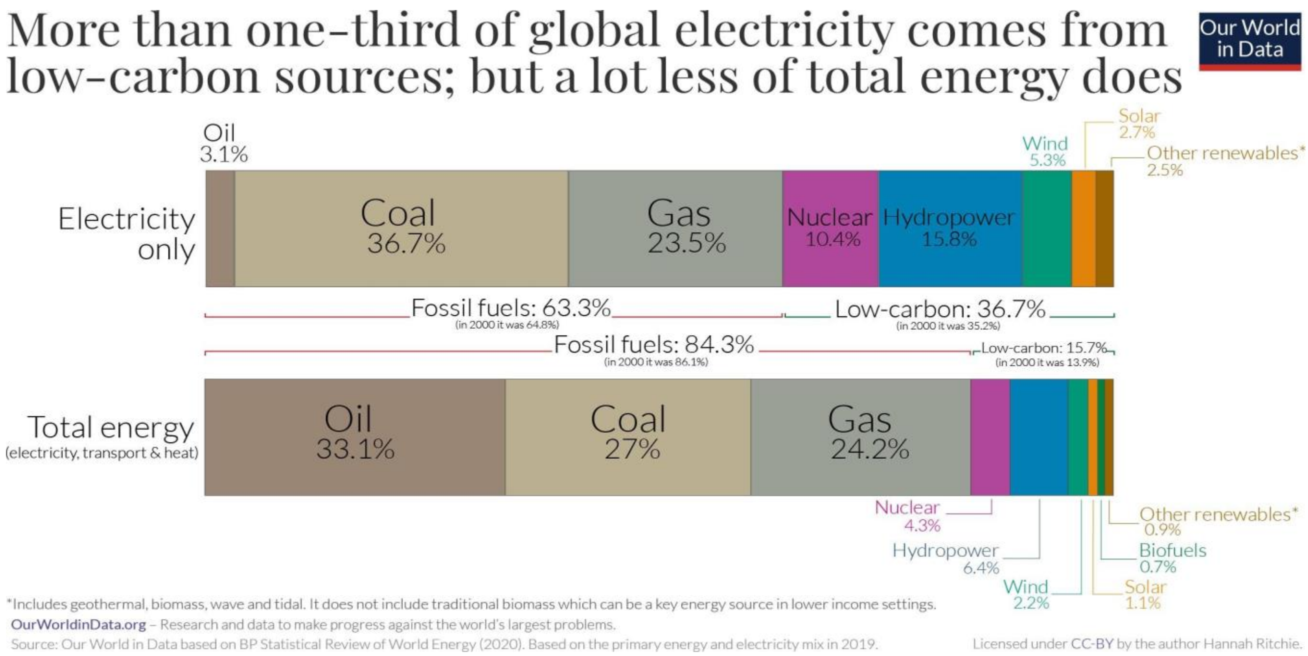

Energy storage, as explained in Section 4, is becoming a top priority to enhance the reliability and effective utilization of renewable energy. Section 5 clarifies the accountability of public and private entities that regulate and manage the electricity network called the **Grid** (See Section 2.1). Section 6 serves as a guide to leadership in the transition to clean energy.

1. Generation of energy
2. Transmission of energy
3. Distribution / delivery of energy
4. Energy storage
5. Regulation and management of Energye
6. Planning for the energy transition
7. Recommended resources

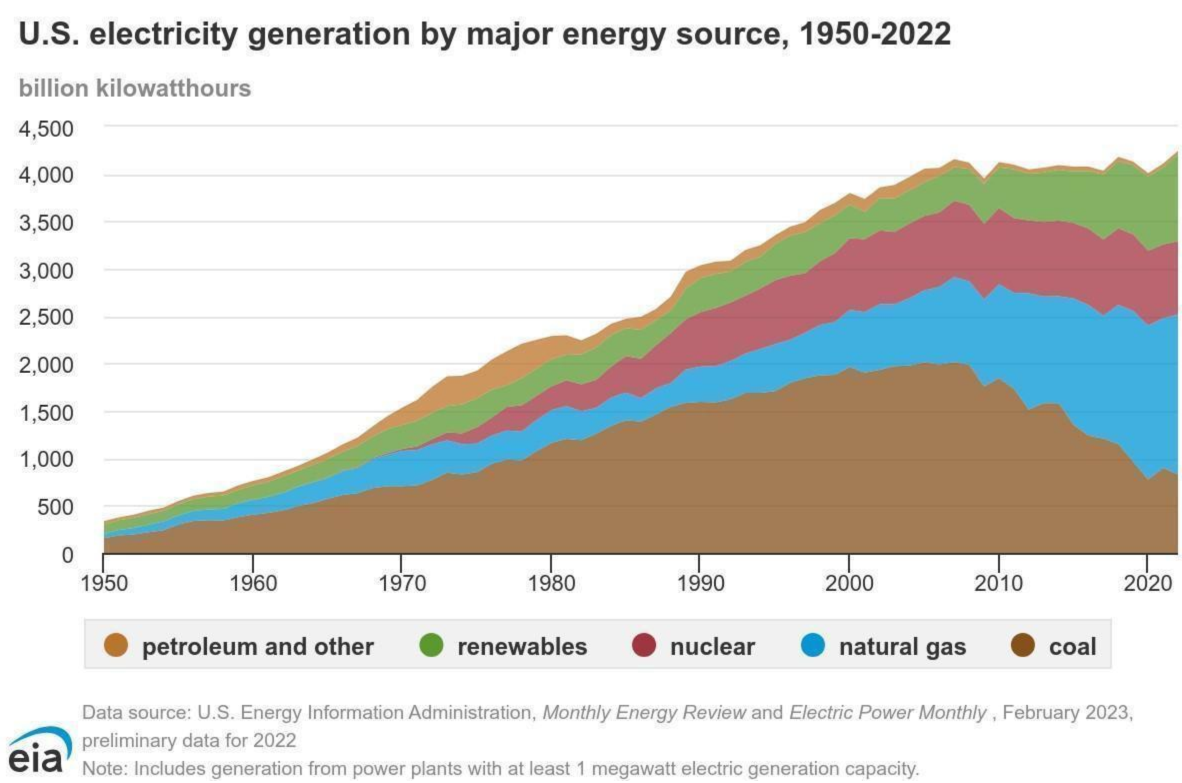
Power Talk introduces the basic concepts and vocabulary used in discussions about energy so we can each be informed and engaged in the decision-making process about our energy future. The ability to "power talk" is essential to energy democracy.

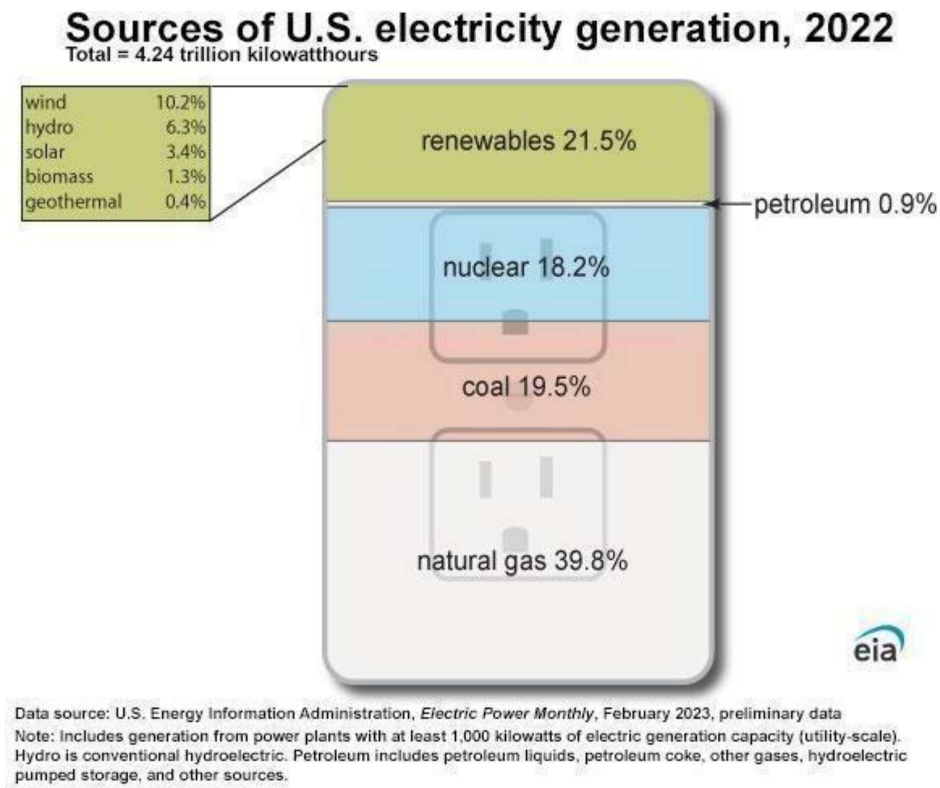
# 1. Generation of Electrical Energy

Electricity is one of four components that make up total energy use. The others are transportation, heating, and industry. The bar chart below (from 2019) shows that coal, followed by gas, is the largest source of electricity production globally, with about 63% of total fossil fuel. [1]




The charts below show that despite the replacement of coal by natural gas as a primary source of electricity production in the U.S., fossil fuels still account for around 60% of the country's utility-scale electricity generation. (2022 data). [2]






## 1.1 What is electrical generation?

**Electrical generation** is the production of electricity from an energy **source**. These sources can include thermal energy (burning fossil fuels like coal and gas, nuclear), chemical energy (batteries), gravitational energy (dams), kinetic energy (wind, tides), and electromagnetic energy (sunlight – conversion by solar panels or thermal plants).

**Electricity** is energy of the motion of charge (electrons or ions) due to an electric field (**voltage**). Electric **current** is a measure of the flow of electric charge through a circuit per unit of time. The unit of current is the **ampere.** Water is often used as an analogy for electricity: Water pressure is analogous to voltage and the volume of water flowing per second is analogous to electrical current.

The international standard metric for **energy** is the **joule**. Lifting a pound weight up one foot requires 1.36 joules of energy. Electrical energy is the voltage times the amount of charge moved by that voltage. **Energy** is the ability to do work and **power** is defined as the amount of energy transferred per unit of time. Electrical power is the voltage times the current.

The term for units of power is **watts.** Watts are like the "miles per hour measurement" showing how fast energy is speeding down a highway. [3]

One watt is the energy of electrons flowing at one joule per second. A **kilowatt (kW)** is 1,000 watts. A **megawatt (MW)** is 1,000 kilowatts. Your hair dryer draws about 1800 watts max; your LED light draws about 10 watts.

The **capacity** of an electrical system to provide electricity at any given moment is usually measured in **megawatts** (**MW**). [4]

**A watt hour** (**Wh**) is how much electrical energy a system delivers in one hour. A kilowatt hour (kWh) is 1000 watt hours and a megawatt hour (MWh) is one million watt hours. Your hair dryer which might be rated at 1800 watts would consume about 1800 watt hours (1.8kWh) if used on the high heat setting for an hour. A solar array that generates 1 MW for one hour delivers 1 MWh of electricity. The average US home consumes about 29kWh per day or about 10,500kWh per year, but this varies by large amounts depending on your climate and appliances. [5] Large scale operations are usually rated in MWh, such as a 400 MWh battery storage project.

To transfer electrical energy, you must have a closed conducting path, known as a **circuit**. Wires are conductors used to accomplish this. Energy is lost in conductors when current flows through them. This loss of energy results in a drop in voltage (known as voltage drop). Resistance in conductors is the major energy loss mechanism in electrical transmission. The average US electricity transmission and distribution (T&D) loss is 5%, but varies between 3% and 13%. [6]

# 1.2 Different ways to generate electricity: electrical energy resources

## 1.2.1 Fossil fuel

Fossil fuel electric plants generate electricity from burning fossil fuels (mainly *coal* and *natural gas*— a.k.a. **methane**).

Fossil fuel plants produce the **greenhouse gasses (GHGs)** carbon dioxide, nitrogen oxides, and sulfur dioxide when they generate electricity. In addition, coal-fired plants produce and spread airborne mercury and fly ash, which have many harmful chemicals such as mercury, cadmium, and arsenic. The extraction and transportation of fossil fuels can release methane and harmful hydrocarbons such as benzene and particulate matter into the atmosphere. [7] Electricity from fossil fuels is generated in power plants.

- Coal power plants burn pulverized coal to boil water, which makes superheated steam, which drives a steam turbine coupled to a generator.
- Natural gas (methane) plants use gas turbines which are much like turbojet engines but are powered by natural gas. The turbine is coupled to a generator to produce electricity. A **single cycle or simple cycle gas plant** uses only a gas turbine. A **combined cycle** gas plant uses a gas turbine but the waste heat from the gas turbine is routed to a heat recovery system to generate steam, which drives a steam turbine to generate more electricity. Single cycle plants are often used as "peaker plants" because they can be fired up quickly to meet a specific need for electricity. Combined cycle plants are more expensive but more efficient.

## 1.2.2 Nuclear

Nuclear power plants use the heat generated from nuclear reactions to produce steam to drive a turbine and generator. Nuclear power can be obtained from **nuclear fission**, nuclear decay, and nuclear fusion reactions. Presently, the vast majority of electricity from nuclear power is produced by nuclear fission of uranium and plutonium in nuclear power plants.

A nuclear plant is similar in concept to a coal plant except that radioactive elements like uranium and thorium are used as the primary fuels instead of coal. These radioactive fuels undergo fission reactions, which propagate a controlled chain reaction that produces energy in the form of heat. This happens in a nuclear reactor and heat exchanger tubes (whereas in a coal plant heat is generated in a boiler).

A primary environmental concern related to nuclear power is the creation of **radioactive waste** such as uranium mill tailings, spent (used) reactor fuel, and other radioactive wastes. These materials can remain radioactive and dangerous to human health for thousands of years. Other concerns include damage to the environment due to the extraction of nuclear fuels and the waste heat generated by nuclear plants affecting local ecosystems.

The International Atomic Energy Agency issued a report in 2022 outlining some possible vulnerabilities of nuclear power due to climate change, including high temperatures, flooding, sandstorms, droughts and wildfires. "Shutdowns [of nuclear power plants] are reported more frequently across all geographies and climatic zones, with river-cooled power plants particularly affected during summer months." [8]

### 1.2.3 Hydropower

People have been using the movement of water to generate power for centuries, originating with water wheels. **Hydropower,** or **hydro energy**, is a form of renewable energy that uses the water stored in dams and flows in rivers or through pipes, which then push against and turn blades in a turbine that spin to power a generator to produce electricity.

Although hydropower is a sustainable method of energy production, it can negatively affect wildlife habitat, water quality, and fish migration and diminish the recreational benefits of rivers.

The most common type of hydroelectric power plant is an **impoundment facility**. An impoundment facility uses a dam to store river water in a reservoir. Water released from the reservoir flows through a turbine, spinning it, activating a generator to produce electricity.

### 1.2.4 Wind

Electricity is generated by wind turning the propeller-like blades of a turbine around a **rotor,** which spins a generator, creating electricity.

Wind farms have a lower environmental impact than traditional power plants. They have a small land footprint and are often located on farms. Their manufacture has a relatively low environmental impact. However, wildlife can be impacted by the noise from the construction and operation of wind farms. Birds and bats can be injured or killed if turbine blades hit them. [9]

A **wind farm** or wind park, also called a wind power station or wind power plant, is a group of wind turbines in the exact location used to produce electricity. Wind farms vary in size from a small number of turbines to several hundred wind turbines covering an extensive area. Wind farms can be either onshore or offshore." [10]

### 1.2.5 Solar

Solar power uses solar radiation from the sun to generate electricity. The ability to harness sunlight to generate electricity is primarily achieved through **photovoltaic (PV)** and **solar thermal** power plants.

- Photovoltaic (PV) solar generates electricity by converting sunlight directly into electricity using photovoltaic cells. Photovoltaic cells use a semiconducting material that, when struck by sunlight, generates a current due to the photovoltaic effect. Unlike some power plants that require steam, solar power using PV cells is created directly by transforming energy from the sun into electricity. The majority of photovoltaic cells are composed of silicon semiconductors, which interact with incoming photons of light to generate an electric current. A **solar farm** is a "large collection of photovoltaic (PV) solar panels that absorb energy from the sun, convert it into electricity, and send that electricity to the power grid for distribution and consumption by customers. Sometimes called solar parks or photovoltaic power stations — they are usually mounted to the ground instead of rooftops and come in all shapes and sizes." [11]

- Solar thermal power plants use energy from the sun to heat a fluid or molten salts to a high temperature. This fluid then transfers its heat to water, becoming superheated steam. This steam is then used to turn turbines in a power plant, and a generator converts this mechanical energy into electricity. This type of generation is essentially the same as electricity generation which uses fossil fuels but heats steam using sunlight instead of combustion of fossil fuels. These systems use solar collectors to concentrate the sun's rays on one point to achieve appropriately high temperatures. [12] Concentrated solar power (CSP) systems generate solar power by using mirrors or lenses to concentrate a large area of sunlight into a receiver. [13]

The primary environmental impact of solar plants is in the manufacturing and mining of the metals and other minerals required, and recycling and reclamation. [14] There can also be an impact due to land use for the solar panels and transmission lines; rooftop solar avoids these impacts.

### 1.2.6 Geothermal

Geothermal generation uses the heat in the layers below the Earth's crust to make electricity. Deep holes are drilled into the Earth to bring steam or hot water to the surface, which drives a turbine/generator. [15]

Geothermal is widely appreciated as a **firm (non-intermittent) energy** resource (see Section 1.3.2 for explanation of "firm"). A criticism is that contamination of aquifers and release of gases such as carbon dioxide, hydrogen sulfide, methane, and ammonia can occur as the water is brought to the surface. Also, minerals in the water often contain mercury, boron, arsenic, and antimony. [16] [17] However, other minerals in the water, such as lithium, could be extracted for economic benefit. [18]

There are three types of geothermal power plants: [19]

1. **Flash steam plants** take high-pressure hot water from deep inside the earth and convert it to steam to drive generator turbines. When the steam cools, it condenses into water and is injected back into the ground for use. This is the most common type of geothermal power plant.
2. **Binary cycle power** plants transfer the heat from geothermal hot water to another liquid with a lower boiling point. Then, the heat causes the second liquid to turn to steam, and this steam drives a generator turbine. This kind of two-step (binary) geothermal generation has the advantage that it works when the underground water is only medium hot (<400F), and most of the world's available geothermal resources are at this temperature. Also, it is environmentally advantageous because it is a closed-loop system, and nothing except some water vapor goes into the atmosphere.
3. **Dry steam plants** use steam directly from a geothermal reservoir to turn generator turbines. The first geothermal power plant was built in 1904 in Tuscany, Italy, where natural steam erupted from the earth and it used this method.

### 1.2.7 Ocean power (tidal, thermal)

Ocean power includes energy generated from the movement of tides and waves. **Tidal energy** comes from the rise and fall of ocean tides and gives a predictable output due to the accurate prediction of tides. The movement of water through a turbine makes mechanical energy, which is then converted to electricity.

**Ocean Thermal Generation** uses temperature differences in the ocean layers to generate electricity. The warm surface water is used to vaporize a working fluid and drive a generator, and then the cool water is used to condense the fluid.

Tidal power can damage marine life, as tidal turbines with rotating blades may lead to the deaths of living creatures in the sea. Noise from the rotation of the turbines may also impact fish habitations in tidal power locations. Tidal energy can also affect the quality of water and sediment processes. With thermal generation, there could be environmental effects with the warming of previously cool ocean water.

There are three ways to get tidal energy:

1. **Tidal stream**: Place a turbine in a fast stream created by a tide; the turbine moves with the water's movement.
2. **Tidal barrage:** Build a dam across a tidal stream so water spills through turbines in the dam.
3. **Lagoon:** Place a turbine in ocean water partly enclosed by a natural or artificial barrier, filling and emptying the lagoon.

### 1.2.8 Biomass Waste

Biomass energy is generated by burning waste (e.g. wood, food waste, parts of plants that are not used for food, animal, and human waste). Woody biomass such as wood chips, pellets and sawdust are typically combusted or gasified to generate electricity. Biomass is burned in a boiler to produce high-pressure steam. This steam drives a turbine/generator producing electricity. [20]

Although considered a carbon-neutral energy source, burning biomass is inefficient and, like fossil fuels, it releases greenhouse gasses and other pollutants. Soil disturbance, nutrient depletion, and impaired water quality are potential environmental effects of biomass feedstock production and utilization of agricultural and forest residues for energy. The severity of these impacts is highly site-dependent and must be assessed.

### 1.2.9 Hydrogen

Because hydrogen typically does not exist freely in nature and is produced from other energy sources, it is known as an energy carrier or type of energy storage, not a resource for generating electricity. Some envision a future "hydrogen economy," where hydrogen is made from various energy sources, stored for later use, piped to where it is needed, and converted cleanly into heat and electricity. However, the technology for large-scale electricity production using hydrogen is still under development. [21] (See Section 4 for further discussion of hydrogen as a storage means).

## 1.3 Terminology associated with the generation of electricity

### 1.3.1 Distributed vs. centralized generation

These terms refer to two ways of generating electricity, but the terms are counterintuitive. **Distributed generation** is when electricity is generated near the point of use, usually from renewable energy sources. [22] Distributed energy resources (**DER**—pronounced D-E-R) is the term used to describe the sources used to generate electricity near the point of use, such as rooftop solar. **Centralized generation** refers to the large-scale generation of electricity at facilities often far from the point of use that are connected to a network of high-voltage transmission lines. [23] This is sometimes called remote generation or utility-scale generation. This could be renewable generation (e.g. a solar farm) or nonrenewable (e.g. a gas plant).

The debate about distributed vs. centralized generation is an important one, as changing from remote suppliers of electricity to local affects the business model for utility companies and has consequences for resilience, technology, infrastructure and cost.

### 1.3.2 Intermittent vs. firm energy

**Intermittent energy** is energy that is not constant and predictable, such as the energy generated by the sun and wind. The opposite of intermittent energy is **firm energy,** which is predictable and can be **dispatched** for use at will, such as the energy generated by a coal or gas plant or by a geothermal system. The distinction is important because intermittent energy poses operational challenges for utility companies and grid operators. “Because the grid has very little storage capacity, the balance between electricity supply and demand must always be maintained to avoid a blackout or other cascading problem. Intermittent renewables are challenging because they disrupt the conventional methods for planning the daily operation of the electric grid.” [24]

However, new technologies relating to battery storage and electric power management are reducing or eliminating the problems associated with intermittency.

### 1.3.3 Dispatch

**Dispatchable generation** refers to sources of electricity that can be dispatched (sent off to respond to an order) at the command of power grid operators. Dispatchable generators can adjust their power output according to an order. Non-dispatchable renewable energy sources such as wind power and solar photovoltaic (PV) power cannot always be controlled by operators. Other types of renewable energy that are dispatchable without separate energy storage are hydroelectric, biomass, geothermal, and ocean thermal energy conversion. [25]

### 1.3.4 Virtual Power Plants

A **Virtual Power Plant (VPP)** is a network of distributed generators and storage that is connected to the electric grid and coordinated with software. Most anyone with generating capability can participate, such as a homeowner or small business with rooftop solar. Also, participants can reduce their demand for electricity and share when necessary. The advantages of using VPPs are increased resilience, avoiding building more infrastructure, and the ability to be compensated by trading power on the energy market. VPPs are different from **microgrids** (see Section 2.5); they're not intended to operate off-grid as microgrids do. VPP resources can be anywhere on the grid, whereas microgrid resources must be local.

### 1.3.5 Nameplate energy or capacity

The term **nameplate** capacity means the maximum output that a generator can produce. "For example, if XYZ Power Plant has a nameplate capacity of 500 megawatts, it means the plant is capable of producing 500 megawatts operating at continuous full power." [26] It may not always produce that much electricity, but it is capable. Nameplate capacity may also be referred to as **rated capacity**, nominal capacity, installed capacity, or maximum effect.

### 1.3.6 Levelized Cost of Electricity (LCOE)

The **levelized cost of electricity** (LCOE, pronounced L-C-O-E), or **levelized cost of energy**, measures the net present cost of electricity generation for a generator over its lifetime. It may be used to compare the cost of different methods of electricity generation on a consistent basis. [27]

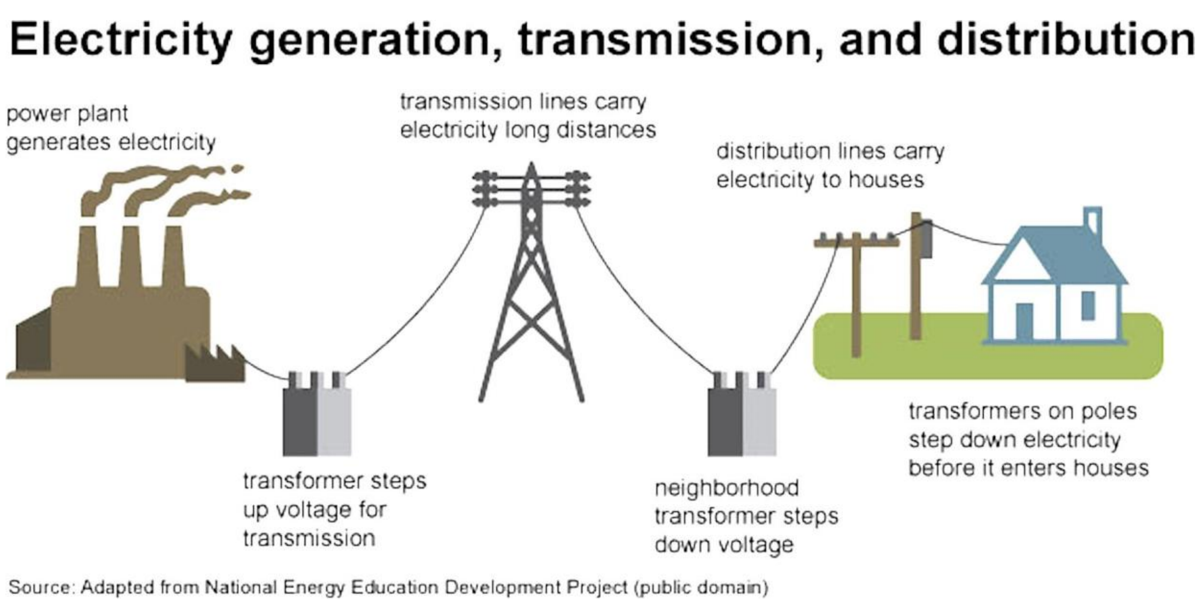
### 1.3.7 Stranded Assets and Legacy Contracts

**Stranded assets,** in the energy context, are assets that have premature write-downs, devaluation, or conversion to liabilities. An example would be a gas peaker plant that was a major public investment and is not yet amortized, but is retired in order to transition to renewable energy resources or because of high operating costs. "Changes to the physical environment driven by climate change, and society's response to these changes, could potentially strand entire regions and global industries within a short time frame, leading to direct and indirect impacts on investment strategies and liabilities." [28] The goal of reaching net zero emissions will make renewable energy more efficient, cheaper, and stable, while fossil fuels will be hit by more price volatility. "Many carbon assets, such as oil or coal reserves, will be left unburned, while machinery will also be stranded and no longer produce value for its owners." [29] **Legacy contracts** refers to old contracts for fossil fuel resources, or electricity generated with them, that are no longer desired, but still legally binding.

### 1.3.8 Packetization of electricity

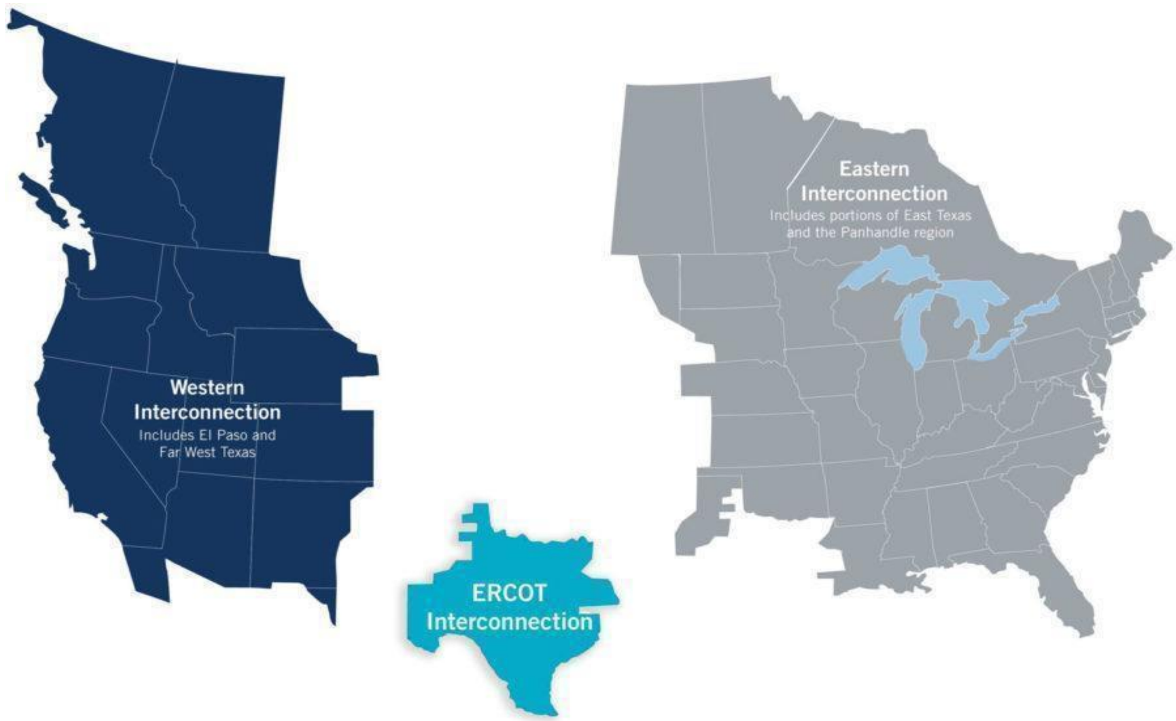
**Packetized energy management (PEM)** is a new technology that allows the coordination between generation and consumption at a fine scale to give more reliability and reduce the need for backup supply (e.g. peaker plants). It works on a token system where a user sends a request for energy, and a coordinating authority evaluates the request as to quantity and timing to either honor the request immediately or delay it until the resource becomes available. The priority of such requests and maximum servicing times are assigned depending on the device and use. For example, an energy request to supply a home water heater may be delayed, but an energy request for a hospital may not. The packetized system would also allow distributed resources to notify the coordinating authority when excess energy is available and ready for sale. Packetized energy management has the potential to reduce cost of energy, increase reliability and reduce the need for overcapacity to meet critical times. [30]

# 2. Transmission of Energy




## 2.1 What is the Grid?

The electricity **grid is a network** of power plants and transmission lines that connects thousands of **local distribution networks** in the United States. There are three primary **interconnections**: the **Eastern Interconnection, the Western Interconnection, and the Electric Reliability Council of Texas (ERCOT)**. These interconnections operate independently of each other and have limited transfers of power between them. [31]




*Source: ERCOT, http://www.ercot.com/news/mediakit/maps*

## 2.2 What is transmission?

**Transmission** is the movement of high voltage electrical energy through the grid over big power lines and distances to a local distribution grid. The U.S. Energy Information Administration explains: "Electricity generated at power plants moves through a complex network of electricity substations, power lines, and distribution transformers before it reaches customers. The power system in the United States consists of more than 7,300 power plants, nearly 160,000 miles of high-voltage power lines, and millions of low-voltage power lines and distribution transformers, connecting 145 million customers." [32]

The U.S. Energy Information Administration (EIA) estimates that electricity transmission and distribution (T&D) losses equaled about 5% of the electricity transmitted and distributed in the United States. [33]

### 2.2.1 Transformers and substations

**Transformers** play a crucial role in the power grid by converting electricity from high voltage to low voltage and vice versa. This conversion is necessary because electricity transmission on the grid is carried out at high voltage (often several hundred kilovolts) for efficiency purposes. As the electricity approaches its destination, the voltage is lowered to a much lower level, typically 7,000 to 15,000 volts at the local distribution level. **Substations** house the transformers, and there are different types of substations, such as **transmission, distribution, collector, converter**, and others. **Transmission substations** connect two or more transmission lines, while **distribution substations** are located near the end-users. [34] [35]


*Typical Substation: https://www.osha.gov/etools/electric-power/illustrated-glossary/sub-station*

### 2.2.2 Are transmission lines AC or DC voltage? What is the difference?

Approximately 98% of the U.S. transmission system uses **alternating current (AC)** power, in which the direction of electrical charge flow changes 60 times per second. The remainder uses **direct current (DC)**, in which the direction of charge flow does not change. AC power can be converted relatively easily and cheaply between high and low voltages with transformers, making it more suitable for delivering to low-voltage AC customers (e.g., 120 V for most household uses). DC lines require expensive conversion stations but are more efficient and less expensive for distances greater than about 500 miles. DC lines are better suited for specialized applications, such as undersea cables. [36]

**Ultra-High Voltage** (UHV) transmission lines carry more than 800 kilovolts of electricity. UHV transmission lines may be **ultra-high voltage alternating current (UHVAC)** or **ultra-high voltage direct current (UHVDC)**. The higher voltage allows more power to be transmitted on the same size wire. UHVDC is a new technology that is uncommon in the United States; China is a world leader in UHVDC transmission over great distances.

### 2.2.3 Who owns transmission lines?

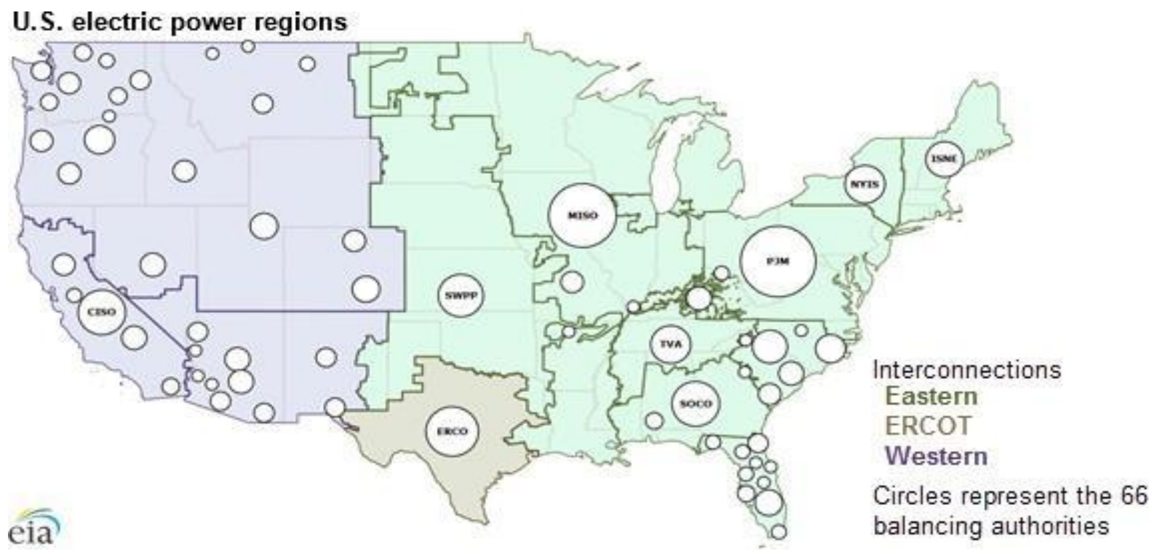
Most transmission lines are owned by private, for-profit companies, though some are owned by public entities: the federal government, publicly-owned utilities (e.g. divisions of a municipal government), or member-owned electric cooperatives. [37] (See Section 5.4 for the regulation of transmission lines).

### 2.2.4 Who runs and operates transmission lines? What are balancing authorities?

The operation of the electric system is conducted by **balancing authorities**, which are generally electric utilities. They ensure that **power supply and demand** are balanced to maintain the reliability of the power system. If demand and supply are out of balance, local or wide-area blackouts can result. Balancing authorities do this by controlling the generation and transmission of electricity throughout their own regions and between neighboring regions. [38]

All of the **regional transmission organizations (RTOs)** in the United States also function as balancing authorities (see Section 5.4 for discussion of RTOs). Balancing authorities must comply with reliability standards issued by the North American Electric Reliability Corporation ("NERC") and approved by the Federal Energy Regulatory Commission ("FERC"). (See Section 5.4 for a discussion of NERC and FERC).

The Eastern Interconnection has 36 balancing authorities, and the Western Interconnection has 37. ERCOT is unique in that the balancing authority, interconnection, and regional transmission organization are all the same entity and physical system. [39]




## 2.3 Future transmission needs

There has been increased interest in expanding and enhancing the U.S. transmission system. Part of this interest relates to a desire to use more renewable energy for electricity generation. Many of the country's best renewable energy resources are concentrated in a few areas: onshore wind in the central United States, solar in the Southwest, and offshore wind in the Northeast. New transmission lines are likely needed to develop these resources cost-effectively and deliver electricity to consumers. Some advocates propose a greater use of DC transmission to move electricity from these areas across the country. (See Section 2.2.2 above).

Additional interest relates to the reliability, resilience, and security of the transmission system: Additional transmission lines could help deliver electricity from neighboring regions during times of electricity shortages, alleviating reliability risks.

Critics object to massive investment in new national transmission, pointing to environmental impact, permitting delays, and cost and emphasizing the advantages of localized distributed generation. [40]

## 2.4 Terminology associated with the transmission of electricity

### 2.4.1 What is an electrical load?

An electrical **load** is any component of a circuit that consumes electrical power. The most obvious examples of electrical loads in a household setting include light bulbs and appliances. At the large-scale level, load means the amount of electricity on the grid at any given time.

### 2.4.2 What are microgrids?

A **microgrid** is a small network of electricity users with a local source of supply that is usually attached to a larger distribution and transmission grid but is able to disconnect from the grid and function independently. A microgrid can power a single facility like a school or hospital or a larger area like a neighborhood, business district, or town. Microgrids are usually powered by solar panels or wind power. They have a **microgrid controller**, a computer, and control software that together determine which resources to use at any given moment. A microgrid relies on batteries or other types of energy storage to maintain uninterrupted power. [41]

### 2.4.3 What is the joule effect?

Transmission lines lose energy through heat as the electricity is transmitted mainly due to conductor resistance. The **joule effect** (See Section 1.1) is the heating that occurs when an electric current flows through resistance and the resultant loss of energy. Proponents of localized power (distributed generation) point to losses from the joule effect. The U.S. Energy Information Administration (EIA) estimates that electricity transmission and distribution (T&D) losses equaled about 5% of the electricity transmitted and distributed in the United States in 2017 through 2021. [42]

# 3. Distribution/Delivery of Energy

## 3.1 What is distribution?

Distribution lines are local and deliver the electricity to consumers at their businesses or residences. Not long ago, distribution only involved sending energy from a transmission line through a distribution line to customers. It is becoming more complex as Distributed Energy Resources (DERs) such as rooftop or ground-mounted solar and wind add electricity to the local distribution system. [43]

## 3.2 Terminology associated with the distribution of electricity

### 3.2.1 What are Distributed Energy Resources (DERs)?

Distributed Energy Resources (DERs) are energy sources that are typically located near the point of electricity consumption, such as rooftop solar panels and battery storage. (See Section 1.3.1) DERs can also be used on a larger scale for commercial purposes. DERs allow customers to both deliver power to and receive power from utilities.

The rapid growth of DERs is changing not just the way electricity is generated but also how it is traded, delivered, and consumed. Utilities are now faced with new questions regarding ownership and control of DER assets, as well as the procurement of their own DERs, and how DER markets will operate. [44]

### 3.2.2 What is Net Energy Metering?

**Net energy metering (NEM)** is a public policy incentive system to encourage private investment in distributed energy generation, usually rooftop/ground-mounted solar. Property owners, whether commercial or residential, pay for the installation of a rooftop/ground-mounted solar system on their property. In exchange, the utility company gives the property owner, now a **customer generator**, credit on their bill for any electricity they generate. If that electricity is beyond the customer's needs, the surplus electricity goes back into the local distribution grid for use by other customers. The customer generator's return on investment is low utility bills, and, at a certain point, usually 7-10 years, the customer-generator has amortized his original investment. At that point, the investment is paid off and the customer generator "profits" as he continues to have low utility bills. [45] [46]

The word **metering** refers to the bidirectional meter that the utility company installs at the property to measure electricity flow going into the home and out of the home to the distribution grid. "Net" refers to the fact that the difference between the in-flow and the outflow of energy is the amount of the credit. Often, the credits are valued at the same price per kilowatt hour that the customer-generator would otherwise be charged for electricity consumed; this is called the **retail rate.** Some critics of NEM argue that customer-generators should receive a credit based on the wholesale rate that the utility would pay a utility-scale supplier like the developer of a large solar farm. For example, suppose the NEM customer uses 50 kilowatts of electricity, but his rooftop solar system generates only 40 kilowatts. In that case, the customer imports 10 kilowatts of electricity from the grid, and pays the retail rate for that electricity, like a customer that does not have an installed solar system. But if that customer's rooftop solar system generates 50 kilowatts in one day, and the household uses only 40, the surplus 10 kilowatts of electricity flows to the grid. In that case, the utility company sells the 10 kilowatts to other customers at the retail rate. The customer-generator receives a credit on his bill for 10 kilowatts at the retail rate.

**Virtual net metering (VNEM)** is a way to extend the benefits of rooftop solar and net energy metering to renters in multifamily housing. The owner of the rental property can install a solar PV system and sell the electricity it generates to the utility company, then share the payments it receives with the tenants. Different states have varying rules about VNEM and how it is managed and compensated.

### 3.2.3 What is a Feed-in-tariff and how is it different from NEM?

**Feed-in-tariff** is a policy that, like NEM, compensates a customer with a solar PV system for electricity that they generate and feed into the grid in excess of the energy that they use. The difference between Feed-in-tariff and NEM is that the customer in a Feed-in-tariff system is not credited at the retail rate for the surplus electricity. Their bill is credited at a lesser rate (tariff) based on the theory that the utility company should be fully compensated for generation and delivery costs and gain a profit. [47]

### 3.2.4 What does shared renewables mean?

The Environmental Protection Agency (EPA) describes **shared renewables**, also known as community renewables, as an emerging procurement model allowing multiple customers to buy, lease, or subscribe to a portion of a shared green power system that is usually located away from their home or business. The model is especially appealing to customers whose on-site resource potential is limited; customers who rent; or customers who are otherwise unable or unwilling to install a renewable energy generator on their residences or commercial buildings." [48]

### 3.2.5 What is community solar?

The Department of Energy (DOE) defines **community solar** as: "any solar project or purchasing program…in which the benefits of a solar project flow to multiple customers such as individuals, businesses, nonprofits, and other groups." [49] The solar panels may be located in the multifamily housing building, somewhere in the community, or at a remote location. Community solar subscribers typically receive an electric bill credit for electricity generated by their share of the community solar system—similar to someone who has rooftop panels installed on their home. Just as residential rooftop solar customers benefit from net metering, community solar subscribers benefit from Virtual Net Metering (VNM), which is net metering for electricity generated by a solar system that is located at a different place than where the energy is consumed. [50]

Community solar projects and programs can also be designed with set-asides for low-income customers in order to expand solar PV accessibility.

# 4. Energy Storage

## 4.1 What is energy storage?

**Energy storage** technology provides a reliable way to store electrical energy for later use. **Electrical Energy Storage Systems (ESS)** store energy when it is not needed and convert it back to electricity when it is needed, proving particularly useful during peak hours or power supply disruptions. **Batteries** are a type of electrical energy storage.

Energy storage can be a battery on private property connected to a rooftop solar system, or part of a microgrid. Storage can also be part of a large system managed by a utility, or part of an electric power plant that feeds electricity into the grid. This may be called **bulk energy storage**.

For readers who want to take a "deep dive" into grid-level energy storage systems, the 2020 U.S. Department of Energy (DOE) Energy Storage Handbook (ESHB) [51], and the USAID Gride-Scale Energy Storage Technologies Primer [52] are two in-depth resources.

## 4.2 The role of energy storage in the transition to non-fossil fuels

Widespread deployment of electrical energy storage systems over the next few decades will help reduce greenhouse gas emissions because it solves the problem of intermittent solar and wind-energy electricity. Storage works at night and when the wind is not blowing.

**Renewables-plus-storage** projects, in particular **solar-plus-storage**, are becoming commonplace globally. Rapidly evolving battery technology is driving the global energy storage market. **Lithium-ion batteries** account for the majority of installations at present, but many other storage technologies are under development in the United States and around the world. [53]

Energy storage will be even more important as we change our transportation system to run mainly on electricity. [54]

## 4.3 Benefits of energy storage for electrical generation

ESS (See Section 4.1) can facilitate more efficient and less costly generation, transmission, and distribution systems in the following ways: [55]

1. Balancing grid supply and demand
2. Peak electricity demand shaving
3. Storing and smoothing renewable electricity generation
4. Deferring electricity infrastructure investments
5. Back-up power during emergencies and grid outages
6. Integration of ESS with microgrids to provide reliability

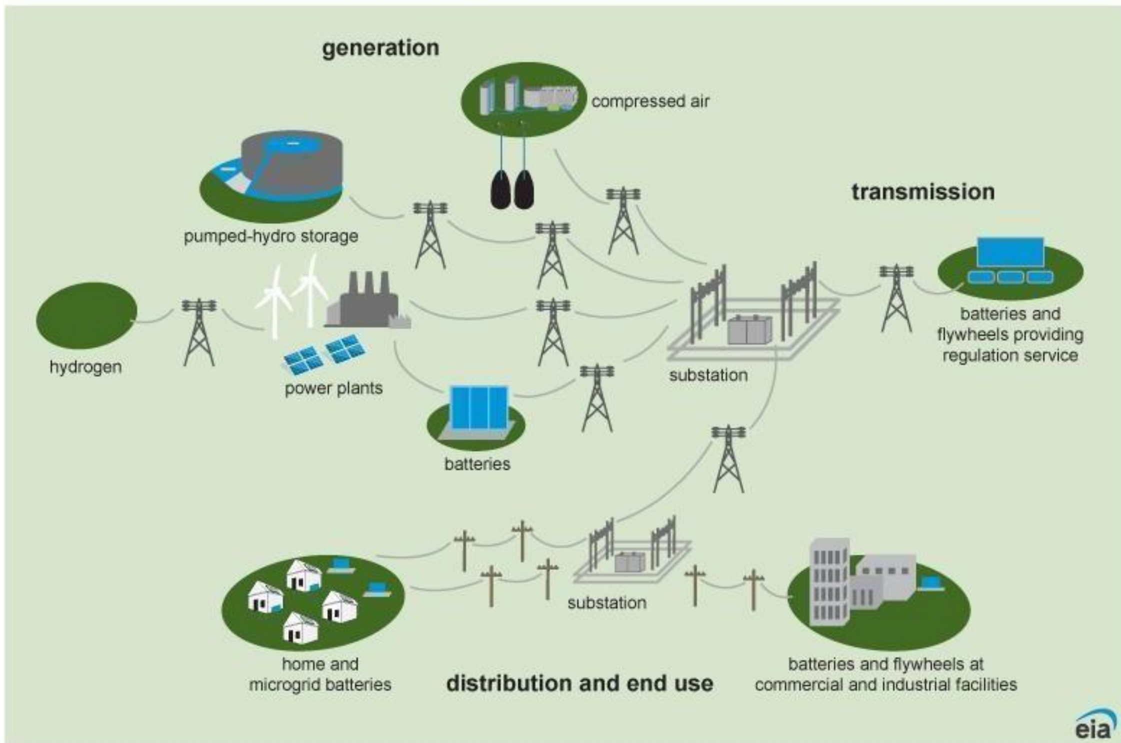
## 4.4 What are the different types of storage of electricity in use today?

Electrical energy storage systems may be grouped in the following categories: [56]

- **Mechanical**. This is energy that is stored using motion (kinetic energy) and released using gravity.
    - **Pumped Storage Hydropower (PSH)** utilizes water which is pumped from a low elevation reservoir to a high elevation reservoir when there is low demand on the grid for energy. When the energy is needed the water is released forcefully through a turbine to generate electricity as needed.
    - **Gravity storage** is another form of mechanical storage. It works by using available energy to elevate heavy material such as concrete blocks and then lowering them to reclaim the energy.
    - **Compressed Air Energy Storage**. Compressed air is stored in an underground cavern or container. When energy is needed the compressed air is discharged through a turbine/generator to generate electricity.
    - **Flywheels** store electricity as kinetic energy by spinning a rotor in a low friction enclosure.

- **Electrochemical.** This refers to batteries of various types that use electrochemical reactions and vary in performance, charging capability, safety and cost. There are dozens of types of electrochemical batteries, with new inventions emerging at a rapid pace internationally. Here are some of the electrochemical storage technologies being used or studied but the list is constantly expanding. [57]
    - lithium ion. This is the workhorse of electrical energy storage batteries.
    - sodium ion
    - lead acid
    - iron air (for large scale energy storage, inexpensive) [58]
    - zinc air
    - flow (zinc bromine, vanadium)
- **Thermal Storage**. Heat is captured and stored in water, **molten salts**, or other working fluids for later use in generating electricity, particularly when intermittent resources (e.g., solar) are unavailable.
- **Hydrogen.** Hydrogen can be stored and used later in fuel cells, engines, or gas turbines to generate electricity without harmful emissions, provided that the hydrogen is produced without using fossil fuels. (See Section 4.4.6)

**General locations of energy storage technologies for electricity generation on an electricity grid**

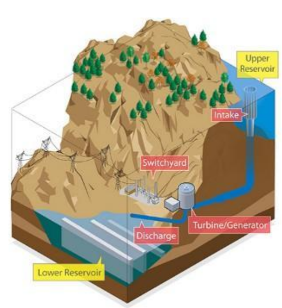



Source: U.S. Energy Information Administration
Note: Hydrogen, and batteries at homes, neighborhoods, and at commerical and industrial facilities are presented here as potential energy storage technologies to supply electricity to electric power grids.

[59]

## 4.4.1 Pumped Storage Hydropower (PSH)

Pumped Storage Hydropower (PSH) is a configuration of two water reservoirs at different elevations that generate power as water moves down from one to the other (discharge), passing through a turbine. The system also requires power as it pumps water back into the upper reservoir (recharge). [60]

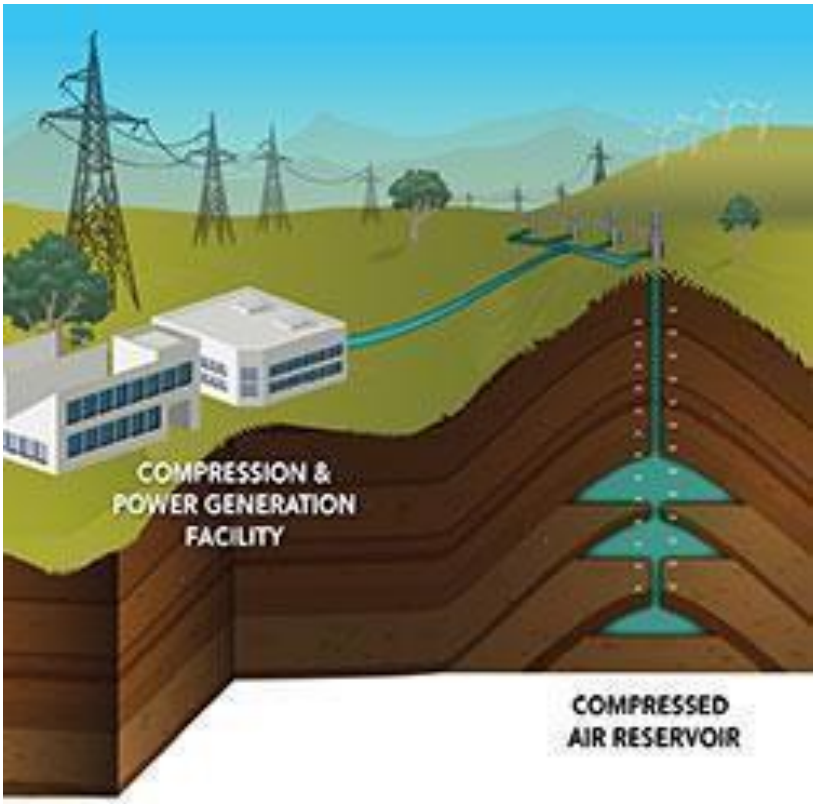



*A closed-loop pumped hydropower system relies on an upper and lower reservoir. Graphic by Al Hicks, NREL*

PSH currently accounts for 93% of all utility-scale energy storage in the United States. [61] Most pumped hydro systems were built in the 1970s to accompany the new fleet of nuclear power plants. [62] Although PSH is flexible and the energy can be stored indefinitely, it requires a large water supply and land, so it is not suitable for drought-prone or urban areas.

### 4.4.2 Compressed Air Storage (CAES)

Compressed Air Storage (CAES) permits the use of excess or low-cost electricity to run an electric compressor, which compresses air and stores it in a high-pressure container or in an underground cave. When electrical energy is needed, such as during peak demand periods, the compressed air is directed towards a modified gas turbine, which converts the stored energy to electricity. CAES systems have a large power rating, high storage capacity, and long lifetime. However, because CAES plants require an underground reservoir, currently there are limited suitable locations for them. Only two commercial CAES plants exist in the world today, located in Germany and Alabama, but there are plans for CAES in California, Ohio and Iowa [63] Research is being conducted to expand CAES from traditional storage in salt caverns to much more prevalent underground porous and permeable rock structures. [64]




***August 2019*** | *Pacific Northwest National Laboratory*

### 4.4.3 Flywheel Energy Storage (FES)

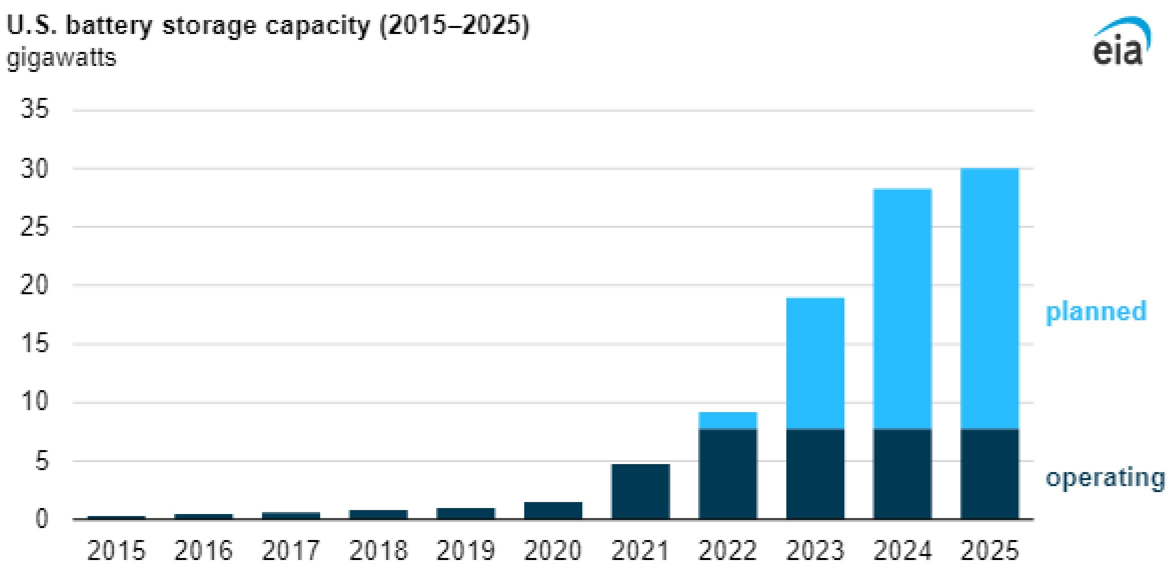
Flywheel Energy Storage (FES) is used to balance short term fluctuations in power supply and demand. It works by accelerating a cylindrical rotor (flywheel) to a very high speed and maintaining the energy in the system as rotational energy. When generated power exceeds load, the flywheel speeds up; when load exceeds generation, the flywheel is slowed to convert the energy for distribution. [65]

### 4.4.4 Battery (electrochemical storage)

Battery (electrochemical storage) technologies use different electrochemical reactions to store electricity: lead-acid batteries, lithium-ion (Li-ion) batteries, lithium iron phosphate batteries, iron air batteries (Fe-Air), solid state batteries, sodium-sulfur batteries (NaS), sodium-ion batteries (NaI), Sodium-Nickel-*Chloride* (Na-NiCl2), flow batteries, Zinc-air batteries, and supercapacitors. The batteries, depending on type, may be suitable for a short duration (few minutes) or longer duration (8+ hours) applications. [66]

Li-ion is currently the most widely used energy storage technology for grid-scale, due to the declining costs of Li-ion batteries in recent years. However, the anticipated growth of demand for EV batteries coupled with the growth of renewables may make Li-ions increasingly expensive soon and there are issues about the supply of lithium. The development of new energy storage options such as NaS, NaI, Ni-$H_2$ [67] and Fe-air rechargeable batteries and Fe-chloride flow batteries will provide cost-effective and environmentally friendly options to Li-ions in future generations for grid-scale storage. [68]

Developers and power plant owners plan to significantly increase utility-scale battery storage capacity in the United States over the next three years, reaching 30.0 gigawatts (GW) by the end of 2025. [69]




***Data source:*** *U.S. Energy Information Administration,*
*Preliminary Monthly Electric Generator Inventory, October 2022*

### 4.4.5 Solar electric with thermal

Solar electric with thermal storage involves storing energy in the form of heat. It uses excess electrical energy to heat or cool down a material (e.g. molten salt, silicon, aluminum or water). The energy that is stored can be recovered by reversing the process. There are multiple variations of this technology, most of which are currently in the development stage. [70]

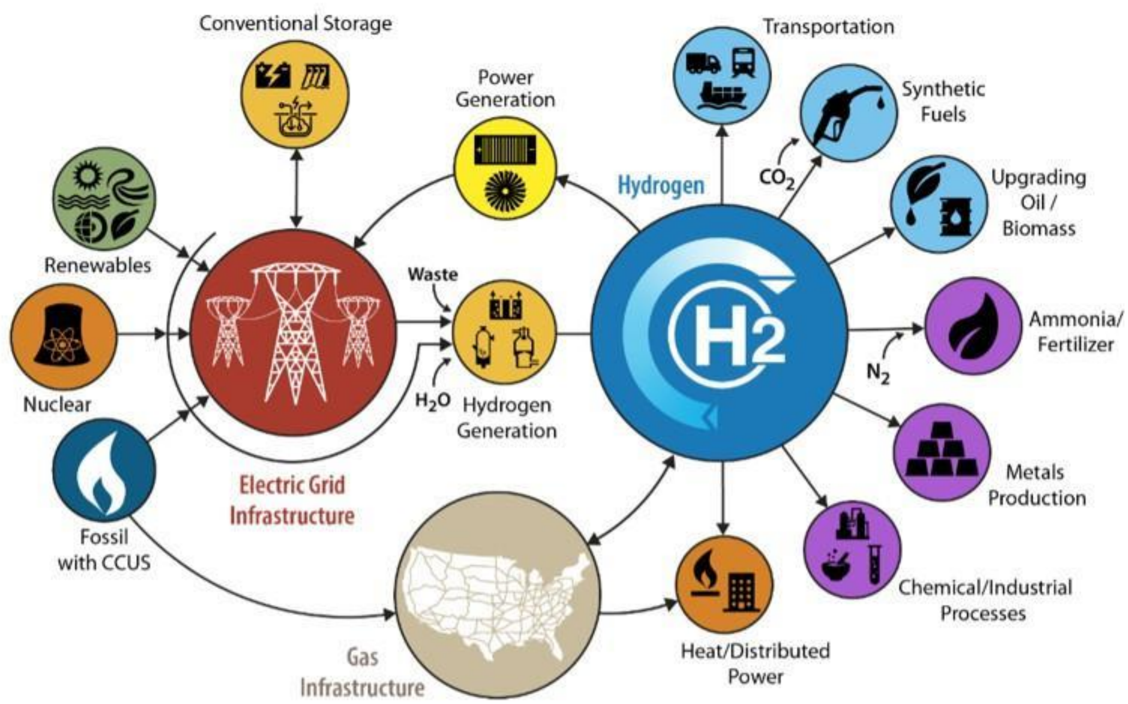
### 4.4.6 Hydrogen

Hydriogen can be used as a method for storing, transporting and supplying electricity generated from other sources. Although it is the most abundant element in the universe, it very rarely exists in its pure form in nature and must be derived from other substances such as water, fossil fuels or biomass. The process of extracting hydrogen from these sources requires a significant amount of energy, and this poses a challenge as the energy required to produce hydrogen should not exceed the amount it can provide. Additionally, it is important to avoid using fossil fuels in the process of hydrogen production, which would lead to increased greenhouse gas emissions. [71] Recently hydrogen was discovered in underground caverns in Europe and elsewhere. [72] This form of hydrogen is called “white” hydrogen.

Hydrogen can be used for long-duration energy storage, which can be essential for power grids with high deployment of renewable energy. During periods when there is an excess of renewable energy, such as in summer when solar resources are most abundant, electrolysis (the process of using electricity to split water into hydrogen and oxygen) can be used to produce hydrogen. This hydrogen can be used by local industries or stored for later use to provide power to the grid at times when demand is higher than supply. Currently, the storage of hydrogen on a large scale is mostly done in geologic formations, such as salt caverns, which are limited in their availability in certain regions. Ongoing research is being conducted to investigate alternative approaches that are not limited by geographic location. [73] However, there are still challenges related to the upfront costs for electrolyzers and fuel cells, hydrogen distribution, round-trip efficiency, and safety. Despite the lower efficiency and high up-front cost, if large amounts of energy need to be stored, hydrogen is ultimately a cheaper storage option than batteries. [74]

Hydrogen has additional benefits outside of the electric grid. A hydrogen-based energy storage system could be the connection point to other energy sources currently dominated by fossil fuels. [75]

**Conceptual H2@scale (hydrogen at scale) energy system**




Source: U.S. Department of Energy, *Hydrogen Program Plan*, Figure 3, November 2020
Note: CCUS is carbon capture, utilization, and storage.

Hydrogen, commonly found in compounds like water ($H_2O$) and methane ($CH_4$), must be separated from other elements to produce pure hydrogen ($H_2$) for use. Two common methods for producing hydrogen are steam-methane reforming and electrolysis (splitting water with electricity). [76] Researchers are exploring other ways to produce hydrogen as well. Although hydrogen is odorless and invisible to our eyes, it is often described using a range of colors based on how it is produced. It's worth noting that the Department of Energy supports source-neutral hydrogen production but doesn't use a color code system. [77]

| Table 1. Classification of Hydrogen Based on Energy Source and Carbon Intensity | | |
|---|---|---|
| **Classification Based on Energy Source** | **Energy Source for Hydrogen Production** | **Classification Based on Carbon Intensity** |
| Black Hydrogen | Bituminous coal | High Carbon Hydrogen |
| Gray Hydrogen | Natural Gas or Methane | |
| Brown Hydrogen | Lignite (brown coal) | |
| Blue Hydrogen | Natural Gas or Methane with CCUS | Lower Carbon Hydrogen |
| Green Hydrogen | Electrolysis powered by renewable energy | |
| Pink Hydrogen | Electrolysis powered by nuclear energy | |

*Hydrogen 101: Frequently Asked Questions About Hydrogen for Decarbonization* [78]

Hydrogen in shades of gray, black, and brown can be highly polluting by releasing carbon dioxide ($CO_2$) and methane into the atmosphere. These types of hydrogen are currently utilized in the production of synthetic nitrogen fertilizers, plastics, and steel. [79] However, some scientists warn that blue hydrogen (produced using natural gas with carbon capture) may actually be more detrimental to the climate than burning fossil fuels. [80]

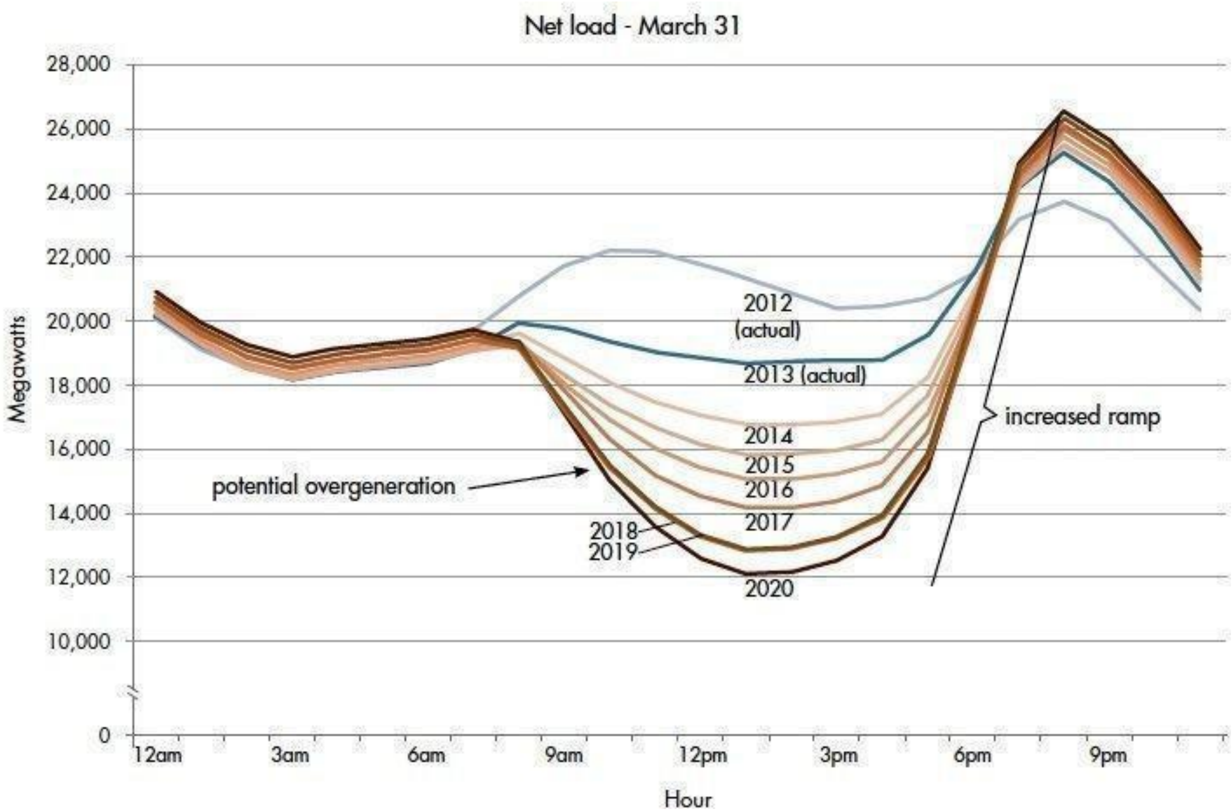
For those concerned with the environment, green hydrogen is the only viable option as a storage technology. Additionally, green hydrogen may be a promising alternative to fossil fuels in high-energy applications, including fuel for heavy-duty trucks and aviation. [81]

## 4.5 Long Duration Energy Storage (LDES)

**Long Duration Energy Storage** are storage systems that provide at least 10 hours of energy before they must be recharged. Most lithium ion batteries economically store energy for only 4 hours. [82] More economical long duration storage technologies are needed for more adoption of wind and solar energy.

## 4.6 What is the “Duck Curve”?

The **duck curve** is a graph of power production over the course of a day that shows that solar power is produced at a different time than it is needed. In other words, there is a timing imbalance between solar power generation and peak demand. A line chart of electricity demand shows higher demand during the day and the highest demand in the evening peaking at sunset. Generation of solar peaks in the middle of daylight hours. The intersection of the two curves looks like a duck. When renewable energy exceeds the capacity of the grid, power plant generators sometimes have to be throttled down to accommodate the incoming renewable energy (*curtailment* - see Section 4.7 below). One strategy to overcome this generation/demand imbalance is to store the surplus renewable energy generation produced in the middle of the day so that it can be used later when it is needed. [83]




https://www.energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy

## 4.7 What is curtailment?

**Curtailment** is the reduction of output of a renewable energy resource below what it could have otherwise produced because of oversupply. Renewable energy curtailment happens due to two main reasons: system-wide oversupply and local transmission constraints. The former occurs when there is not enough demand for all the renewable electricity that is available, while the latter occurs when there is insufficient transmission infrastructure to deliver that electricity to a place where it could be used. Oversupply during the middle of the day, when the sun is brightest, is common especially in the spring. [84]

There are three ways that curtailments can happen. The first is when energy is sold at a low price or negative price, called **economic curtailment.** The second is when a generator reduces their energy output from their original plan, called **self-scheduled cuts**. The third is when the ISO tells generators to reduce their output, called **exceptional dispatch**.

Curtailing renewables results in lost opportunities for clean resources to generate all of the carbon-free power that otherwise could be produced. There are various methods to address oversupply and curtailment, such as increasing storage, implementing **demand response** systems, and utilizing **time-of-use (TOU) rates**. [85]

## 4.8 Demand Reduction and Demand Response

**Demand reduction** refers to reducing the load in an electric system, usually by incentivizing customers to use less electricity. Utility company planners see demand reduction as a "resource option" for balancing supply and demand. Demand reduction strategies include **time of use** rates, **critical peak pricing**, variable peak pricing, and critical peak rebates. [86] Public education is also important in getting customers to change their habits and conserve energy.

Grid modernization (Smart Grid) and customer notification devices and displays facilitate demand reduction. **Advanced metering devices** installed on residential and business property are sometimes necessary for demand reduction.

More interventionist methods of demand reduction include direct load control programs that empower the utility company to turn off air conditioners and water heaters during peak demand times. **Load shedding** or emergency load reduction program (ELRP) refers to situations when the utility imposes demand reduction by targeted blackouts or rolling black outs. Utilities may also enter into agreements with commercial customers to shed load at specified times in exchange for financial compensation. [87]

# 5. Regulation and Management

The field of electricity generation, distribution, and management in the U.S. involves all three levels of government – federal, state, and local – and many agencies and industries.

## 5.1 Who owns the electric system?

The Office of Electricity within the U.S. Department of Energy explains: "The electric system, which includes generation, transmission, and distribution, is owned by a mix of entities. For example, 192 Investor-Owned Utilities (IOUs) account for a significant portion of net generation (38%), transmission (80%), and distribution (50%). About 2,900 publicly owned utilities and cooperatives account for 15% of net generation, 12% of transmission, and nearly 50% of the nation's electric distribution lines. Approximately 2,800 independent power producers account for 40% of net generation. The Federal Government owns nine power agencies (including four Power Marketing Administrations and the TVA) with 7% of net generation and 8% of transmission. And 211 Electric Power Marketers account for approximately 19% of sales to consumers." [88]

## 5.2 What are utility companies?

Utility companies, also referred to as public utilities, manage the distribution of electricity. In industry parlance, they are referred to as **load-serving entities (LSEs).**

**Load** is industry terminology for the amount of electricity that is being used; so, utilities serve the load.

There are 4 different types of utility company ownership.

### 5.2.1 Investor-owned utilities (IOUs)

Investor-owned utilities (IOUs) are private for-profit companies that distribute electric power to **ratepayers** (customers) over a defined **service territory**. Typically, electricity from IOUs comes from a combination of generating their own electricity and purchasing electricity from public and private markets. [89] In the U.S., almost three-quarters of utility customers get their electricity from IOUs. [90] IOUs are a legal monopoly because state laws authorize them; they are guaranteed a customer base, are protected from competition and generally are guaranteed a profit. In exchange, the rates they charge customers are regulated by state **utility commissions.**

### 5.2.2 Publicly owned utilities (POUs)

Publicly owned utilities (POUs) are local government-owned, not-for-profit entities governed by a city council or an elected or appointed board of a city or utility district. Community residents have a voice, through their elected representatives, in utility decisions, including the rates it charges and its sources of electricity. [91] POUs serve one in seven electricity customers across the U.S. [92]

### 5.2.3 Community Choice Aggregators (CCAs)

Community Choice Aggregators (CCAs) are an alternative to IOUs. CCAs are local, not-for-profit entities that take on the decision-making role about the sources of energy for electricity generation, but work with IOUs that continue to manage transmission, distribution and customer billing. Once established, the governing city may choose to make the CCA the **default service provider** for the electric power delivered to customers. CCAs typically offer customers a choice of packages: an energy mix similar to that provided by the IOU, a 100% renewable package, and often a medium choice somewhere in between. In some cities that have selected CCAs, all customers are treated as renewable energy customers unless they opt out, an approach that means that some localities will call their energy supply 100% renewable. [93]

The municipality initiating the CCA sets up a governing board, usually including local elected officials, which makes key decisions about procurement, rates, and what local energy programs to fund. In a CCA service territory, the incumbent utility (IOU) continues to own and maintain the transmission and distribution infrastructure and manages the metering and billing. [94] CCAs do not operate where there is a POU. As of 2022, ten states – California, Illinois, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Rhode Island and Virginia – have enacted CCA legislation [95] while a number of other states are actively investigating it.

### 5.2.4 Cooperatives (Co-ops)

Cooperatives (Co-ops) are not-for-profit member-owned utilities. Co-ops are located in 47 states but are most prevalent in the Midwest and Southeast. [96] Unlike the rest of the electric sector, electric co-ops sell the majority of their power to households rather than businesses. [97]

## 5.3 What is electric utility deregulation?

In deregulated energy states, utility companies continue to own the infrastructure for transmission and distribution of electric power, but customers have some degree of choice in selecting the provider of electric power. **Deregulation** does not mean that utility companies are not regulated at all; rates, energy sources and a wide range of other matters are regulated by state law and utility commissions.

As background, in the 1990s, the United States government passed a series of laws that promoted market competition in the generation and transmission of electrical energy. Utility companies were required to provide companies that generate electricity with **open access to transmission** services, thereby reducing the power of big vertically integrated utilities. Companies offering transmission services began to separate from power generation plants. Many states began passing different types of deregulation laws that opened competition among electric providers.

As of 2022, Texas, California, Connecticut, the District of Columbia, Delaware, Illinois, Maine, Maryland, Massachusetts, Michigan, Montana, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island all have some form of deregulation. [98]

Defenders of deregulation claim that it promotes cost competition in free markets. Critics of deregulation argue that it has not ensured competition, and that it has increased the cost of electricity to consumers, and decreased reliability.

### 5.3.1 What are exit fees?

Utility customers (whether individuals, CCAs, or co-ops) often decide to leave a utility company as their power supplier because they desire more emissions-free power, access to less expensive wholesale markets, and more freedom to make local decisions.[99] **Exit fees** are designed to allow the original power supplier to recoup costs when customers elect to make the switch. [100] Consumer advocates frequently oppose such exit fees.

Other terms for exit fees include a Power Charge Indifference Adjustment (PCIA) and Early Termination Fees (ETF).

The amount of exit fees raises disagreements. A dispute over the appropriate methodology for determining an exit fee reached the Federal Energy Regulatory Commission (FERC) (See Section 5.4.1) in 2021, and FERC decided that the original power supplier's methodology failed to provide fair and transparent procedures for customers considering termination. In September 2022, FERC's Administrative Law Judge (ALJ) adopted a balance sheet approach to measuring the liabilities (i.e., debt and other obligations) that the original power supplier had incurred to serve a departing customer and assigned a pro-rata share of these liabilities. [101] In 2024, the FERC ruled again on the formula for determining exit fees. [102]

## 5.4 National agencies and organizations involved with electric power

### 5.4.1 Federal Energy Regulatory Commission (FERC)

The **FERC** is an independent agency of the United States government created in 1977, in the aftermath of the 1973 oil crisis, for the purpose of regulating the transmission of electricity and natural gas, the wholesale sale of electricity and natural gas, and the transportation of oil and natural gas by pipeline. [103] A central function of the FERC is to regulate the prices private for-profit companies that own transmission lines can charge for delivering electricity across state lines.

FERC's legal authority comes from the Federal Power Act, which tasks FERC with ensuring that wholesale rates are "just and reasonable" and not "unduly discriminatory or preferential." 16 U.S.C.A. § 824e.

There are five commissioners with staggered five-year terms appointed by the President and confirmed by the U.S. Senate. In 2021, FERC established the Office of Public Participation (OPP) to assist the public with Commission proceedings. The FERC Report on the OPP is available online and provides information about FERC's history, organizational structure and scope of responsibility. [104] The Center for Progressive Reform calls the OPP a "promising experiment in energy democracy." [105]

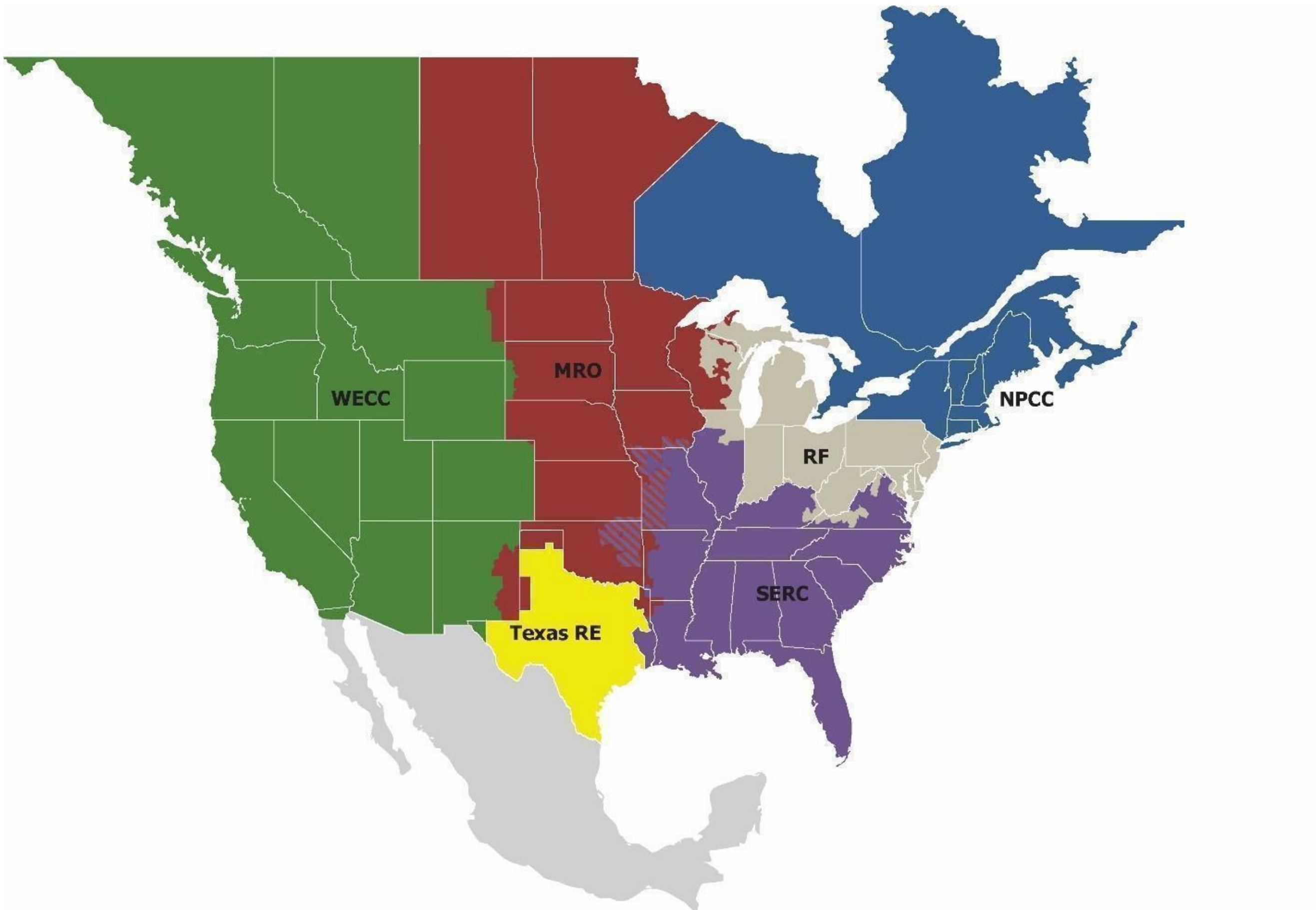
FERC has a major role in transitioning the U.S. away from fossil fuels and towards renewable energy. In February 2022, FERC issued the Interim GHG Policy Statement to explain how it will assess the impacts of natural gas infrastructure projects on climate change in its reviews under the National Environmental Policy Act (NEPA) and the Natural Gas Act (NGA). [106]

In addition to regulating the rates that transmission owners charge for delivering electricity across state lines, the FERC can approve financial incentives for certain construction and operational activities. For example, FERC can incentivize the use of new technologies and participation in regional transmission organizations in which power resources are shared in a region.[107]

## 5.4.2 The North American Electric Reliability Corporation (NERC)

The **North American Electric Reliability Corporation (NERC)** is a not-for-profit international regulatory authority, subject to FERC oversight, whose mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid. [108]

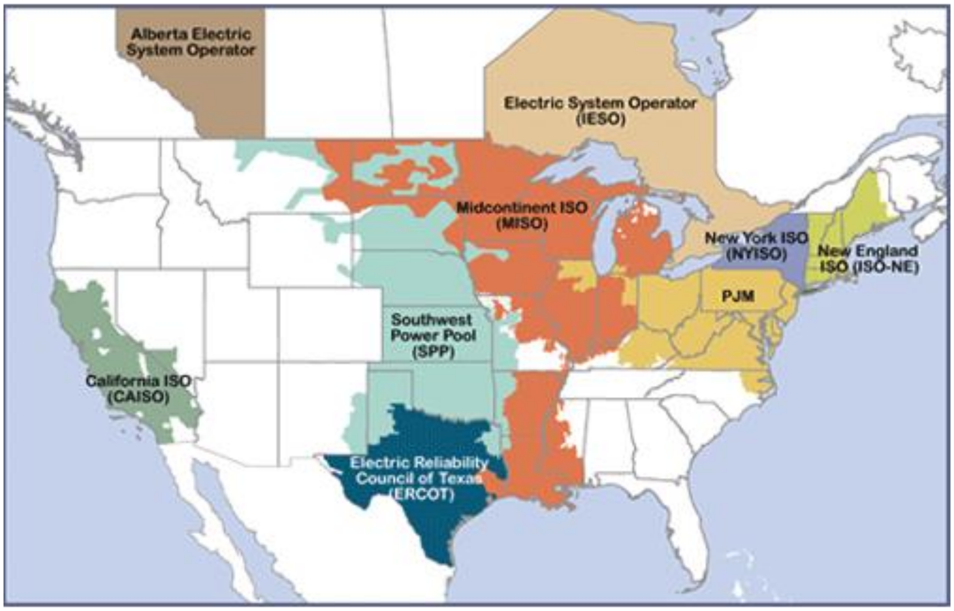
NERC was established in 1968, before the FERC, following an extensive blackout in 1965 that impacted the northeastern United States and southeastern Ontario, Canada. In 2006, FERC certified NERC as the **electric reliability organization (ERO)** for the United States. “NERC develops and enforces Reliability Standards; annually assesses seasonal and long-term reliability; monitors the bulk power system through system awareness; and educates, trains, and certifies industry personnel. NERC’s jurisdiction includes users, owners, and operators of the bulk power system, which serves nearly 400 million people.” [109] The following map illustrates NERC’s six regional organizations.




The regional entities have delegated authorities and responsibilities, as approved by FERC, to enforce NERC and regional reliability standards, and perform other standards-related functions assigned by NERC. The impacts of climate change on the resiliency of the electric grid also come within NERC's purview. [110]

### 5.4.3 Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs)

The FERC created Regional Transmission Organizations (**RTOs)** and Independent System Operators (**ISOs)** to administer the transmission grid on a regional basis in the U.S. and parts of Canada. RTOs and ISOs perform similar functions, but RTO geographic areas are larger. Their main responsibilities are to ensure reliability and **non-discriminatory access to the grid**. [111] For example, California ISO (CAISO) serves primarily California and a small part of Nevada. The map below from FERC's website shows their territories. Nine ISOs/RTOs serve two-thirds of electricity consumers in the United States and more than 50 percent of Canada's population.




Coordination among RTOs and ISOs and among federal and state regulators is important. In 2003, ISOs and RTOs created an industry-wide collaboration called the **ISO/RTO Council (IRC)** [112] which focuses on "access to affordable, reliable and sustainable power – made possible through efficient administration of independent and transparent wholesale energy markets."

### 5.4.4 National Association of Regulatory Utility Commissioners (NARUC)

Founded in 1889, NARUC is a non-profit organization representing the state public service commissions that regulate utilities; members include all 50 states, the District of Columbia, Puerto Rico, and the Virgin Islands. Most state commissioners are appointed to their positions by their governor or legislature, whereas commissioners in 11 states are elected by the public and in two states by the general assembly. NARUC is focused on improving the quality and effectiveness of public utility regulation. [113]

In June 2021, the FERC established the **Joint Federal-State Task Force on Electric**

**Transmission** "to ensure important cooperation between federal and state regulators, via a partnership between FERC and the **National Association of Regulatory Utility Commissioners (NARUC),** on electric transmission-related issues." [114]

### 5.4.5 Department of Energy (DOE)

The United States Department of Energy (DOE) was created in 1977 when President Carter signed the authorizing act. In the aftermath of the energy crises of the 1970s, [115] it was important to have a federal agency that would coordinate energy policy and develop a strategic plan. Today the DOE has multiple program offices and supervises 17 **national laboratories** that research, develop, and deploy clean energy technologies, including battery storage, renewable power, electric vehicles, carbon capture, and resilient grid infrastructure. [116]

Within the DOE is the **Office of Energy Efficiency and Renewable Energy (EERE)** which works on decarbonizing the electricity sector. [117] Also within the DOE is the Office of Electricity, focused on making sure that our country's energy delivery system is secure, resilient, and reliable, and includes divisions that work closely with the private and public sectors to make sure the nation's critical energy infrastructure is able to recover rapidly from disruptions. [118] The DOE has launched the "Building a Better Grid" Initiative to tackle the climate crisis at the national, state, and local levels by delivering clean energy from where it's produced to where it's needed. [119] The DOE is responsible for many of the climate change and renewable energy programs initiated by the Inflation Reduction Act of 2022.

The DOE manages the **United States Energy Information Administration (EIA),** a rich source of data, statistics, forecasts, analysis and news about electric power and other energy types, including an Annual Energy Outlook assessing long term trends through 2050. [120] A focus area for the EIA is the transition from fossil fuels to renewable energy sources for electricity. [121]

The DOE includes the **Advanced Research Projects Agency-Energy (ARPA-E)** which funds and provides technical assistance to high impact energy technologies that are too early for private-sector investment. [122] Their website provides glimpses into exciting new technologies that are likely to hasten the transition to renewable electric power.

### 5.4.6 National Renewable Energy Laboratory (NREL)

**The National Renewable Energy Laboratory (NREL)** is one of the 17 applied science laboratories managed by the Department of Energy via operation and management contracts with private entities. Based in Colorado, NREL conducts research focusing on new technologies related to wind, solar, geothermal, storage and other renewable energy resources. NREL also provides services to utility companies, for example, by developing in 2021 the LA 100 plan for the Los Angeles Department of Water and Power to transition to carbon-free electric power by 2035. NREL publishes the **Annual Technology Baseline (ATB)** [123] a large database that provides up-to-date information on technology cost and performance that is used by utilities nationwide in their planning.

### 5.4.7 Environmental Protection Agency (EPA)

Among its many other duties, the **EPA** provides renewable energy information and resources to state, local and tribal governments. [124] Consumers can also tap into many resources provided by the EPA to learn about energy efficiency and the impact of electric power on the environment. Among these is the **Emissions and Generation Resource Integrated Database (eGRID)** which is a comprehensive source of data and data visualizations on the environmental characteristics of electric power generated in the United States. [125] Another [126] is the EPA's compilation of the climate action plans prepared by many federal agencies, including the EPA.

### 5.4.8 Congressional Committees

The United States Congress has several committees focused on energy policy and legislation, including the **House Committee on Energy & Commerce** [127] and the **Senate Committee on Energy & Natural Resources.** [128]

## 5.5 State entities involved with electric power

### 5.5.1 State legislatures

Each state has legislatures that enact many laws that have an impact on electric power. More than half of the states have enacted laws that set **Renewable Portfolio Standards (RPS)** that require that a certain percentage of the electricity that utilities sell to customers come from renewable energy with a time schedule for achieving carbon free electric power.[129] See Section 5.7.1. States also enact a multitude of laws on greenhouse gas emissions, renewable energy incentives and support programs, energy resilience and security, nuclear energy, DER, community solar, and carbon trading. A useful directory and trend analysis of state legislation related to electric power is published by the National Conference of State Legislatures. [130]

### 5.5.2 Public Utility Commissions

**Public utility commissions (PUCs)** regulate the provision of essential services (electricity, natural gas, and telecommunications) in each state. These commissions have various names (e.g., Illinois Commerce Commission and New York State Public Service Commission). PUCs typically regulate investor-owned utilities (IOUs) in their state, while publicly owned and cooperative utilities are often exempted or have limited regulation. Utility regulation takes many forms, including price regulation, resource planning and acquisition, reliability, and quality of service regulation. In most states, PUC commissioners are appointed by the governor for 4-to-6-year terms. Ten states elect their commissioners, and two state legislatures appoint them. [131]

PUCs influence clean energy investments through oversight of **Integrated Resource Planning (IRP)** by utilities [132] See Section 5.7.2.

### 5.5.3 State Energy Organizations and Programs

Each state has an entity or program as the contact point for its energy policies, programs, and financial incentives. There is wide variation in how states organize these functions and where they fit into a state's administrative structure. Some are independent and report to the governor's office; others are units of a state's commerce or natural resources department.

Some state energy offices specifically include renewable energy, climate change, and/or environmental sustainability in their descriptions, while others only mention energy efficiency goals. For example, Delaware has a Division of Energy and Climate that focuses on "statewide climate change mitigation and adaptation programs," while Mississippi has an Energy and Natural Resources Division to develop energy-sector growth. A list of each state's energy office and a description of its mission is available online. [133]

## 5.6 Concepts and terminology used in state and federal regulation of utilities

### 5.6.1 Renewable Portfolio Standard (RPS)

"A renewable portfolio standard (RPS) is a regulatory mandate to increase production of energy from renewable sources such as wind, solar and other alternatives to fossil and nuclear electric generation. An RPS is most successful in driving renewable energy projects when combined with the federal production tax credit." [134] Wisconsin was the first state to enact a RPS in 1999. [135] As of the end of 2021, 31 states and the District of Columbia had renewable portfolio standards (RPS) or clean energy standards (CES). "States with legally binding RPSs collectively accounted for 67% of total electricity retail sales in the United States in 2020. In addition to the 31 states with binding RPS or CES policies, 7 states have nonbinding renewable portfolio goals." [136]

### 5.6.2 Integrated Resource Plans (IRPs) and Power Sourcing

Utilities use IRPs as a planning tool for **power sourcing** (how they will obtain enough electricity to provide for electricity distribution needed for their customers). In the complex IRP process the utility examines the anticipated energy demand (load) over a period of years, identifies **resources** (ways to generate and purchase electricity including both fossil fuel and carbon-free), predicts supply and cost, and identifies risks that could prevent the utility from meeting their customers' energy needs at reasonable costs.

Typically, the utility retains expert consultants who forecast load, resource supply, prices and assess risk analyses using **computer modeling** of multiple scenarios. A number of competitive commercial software programs are available to conduct the modeling, each with different attributes. The utility of computer modeling depends on the availability, objectivity, and accuracy of the data that is fed into the model. For example, data concerning the future prices of gas-generated electricity or of solar-generated electricity may be speculative, especially for years far in the future. Consultants gather data from public sources like the National Renewable Energy Laboratory (NREL) Annual Technology Baseline (ATB) Database (See Section 5.4.6) as well as private data analysis companies. Some of the data comes from private database vendors and their sources may not be open to the public, raising issues about transparency.

### 5.6.3 Resource Adequacy and Planning Reserve Margins

**Resource Adequacy (RA)** is a set of rules and metrics employed by state laws, utilities and ISOs/RTOs to ensure that there will be enough electricity at the right time and the right locations to avoid power shortages and blackouts. [137] For example, in California, the California Public Utilities Commission, in cooperation with the California ISO (CAISO), requires all utilities to "maintain physical generating capacity and electrical demand response adequate to meet its load requirements, including, but not limited to, peak demand and planning and operating reserves." **Planning Reserve Margin (PRM)**: 15% over the peak demand for the year. CAISO requires some of the RA must be local and "flexible," meaning that it must be able to ramp up or down upon demand to meet variations in load and deal with intermittent energy production. [138] This means that solar and wind have low RA ratings unless they are paired with batteries because of their intermittency (the sun is not always shining, and the wind is not always blowing.) RA rules are in a state of flux as utilities try to balance reliability with the need to transition to renewable energy sources.

### 5.6.4 Power Delivery Plans

A **Power Delivery Plan (PDP)** is a long term detailed strategic plan focused on the distribution of electricity within a utility territory. In other words, once the electricity has come in on transmission lines, it must be distributed throughout a city all the way to customers' homes and businesses. PDPs address critical challenges, long-term strategies, and future guidance in order to maintain a safe, reliable, and cost-effective power delivery system.

### 5.6.5 Renewable energy certificate

A **renewable energy certificate (REC)**, pronounced like "wreck," is a way of keeping track of something that is evanescent, invisible and indistinguishable: the energy used in a system that was originally generated with renewable energy sources. Energy made with solar flows into the grid and joins with energy made by burning fossil fuels. But keeping track of energy from renewable energy sources is necessary in order to enforce laws requiring a transition to renewable energy. "Renewable energy credits are tradable, non-tangible commodities that represent proof that 1 MWh of electricity was generated from a renewable energy resource and was then fed into the shared system of power lines that transport energy." [139] In short, RECs are a way to show how much renewable energy a utility or a company is using.

Who keeps track of RECs? In the United States there are 10 **regional electronic tracking systems** (for example, the New York Generation Attribute System (NYGATs), the Midwest Renewable Energy Tracking System (M-RETS), the Western Renewable Energy Generation Information System (WREGIS) and the Electric Reliability Council of Texas (ERCOT). [140] These systems make sure that each REC is counted only once and assigns a unique serial number to each megawatt-hour of electricity.

When a utility company enters into a power purchase agreement with a renewable energy developer, it receives as part of the agreement RECs that reflect how many megawatt-hours of electricity generated with renewable sources it has purchased. The utility can then use the RECSs as proof of their use of renewable resources, or sell them to a third party (in which case it can't use the REC to prove that it is using renewably sourced electricity.) If the utility uses the electricity in its system, the REC is said to be **retired,** no longer has value and cannot be traded. If the utility chooses to sell the REC, it gets a payment. [141] The buyer of the REC can get credit for renewable resources without disturbing their existing power purchase agreements. **Bundled RECs** are those that are sold with the electricity that they document. **Unbundled RECs** are those that are sold separately from the energy as tradable instruments. [142]

RECs have been justified as a way to provide financial support to renewable energy project developers, thus hastening the transition to a clean energy future. However, they have received criticism as greenwashing, providing a way for a company to appear like it is making a transition to renewable resources while not changing their sources, operations or infrastructure. [143]

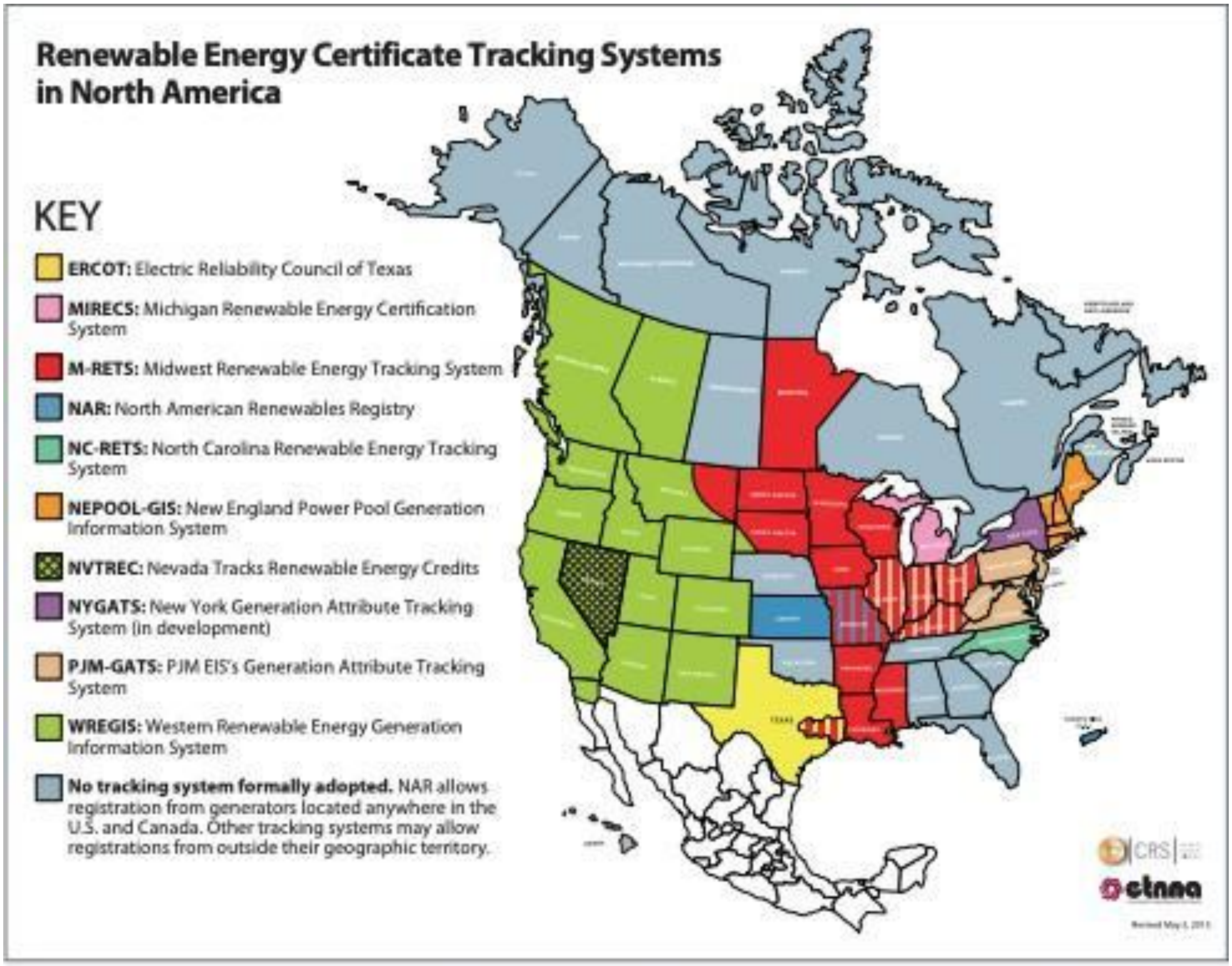



Figure 1. Renewable energy certificate tracking systems in the United States and Canada

*Source: NREL* [144]

## 5.6.6 Carbon Offsets

**Carbon offsets,** also known as **Voluntary Emission Reductions (VERs)** or **Carbon Reduction Tons (CRTs),** are different than RECs. RECs measure Megawatt-hours (MWh) of renewably generated electricity. By contrast, offsets measure metric tons of greenhouse gas emissions.  "Carbon offsets are tradable "rights" or certificates linked to activities that lower the amount of carbon dioxide (CO2) in the atmosphere. By buying these certificates, a person or group can fund projects that fight climate change, instead of taking actions to lower their own carbon emissions.

In this way, the certificates "offset" the buyer's CO2 emissions with an equal amount of CO2 reductions somewhere else." [145]

## 5.7 Private non-profit organizations

There are too many private non-profit organizations engaged in electric power policy to list. But a few are useful to mention here because they are great resources for information.

Rocky Mountain Institute (RMI) is a non-partisan, non-profit organization that works to transform global energy systems across the national economy.

Rewiring America is a leading electrification nonprofit, focused on electrifying everything in our communities.

American Public Power Association (APPA) is the voice of not-for-profit, community-owned utilities that power 2,000 towns and cities nationwide.

Local Energy Aggregation Network U.S. (LEAN) supports the expansion of clean energy CCAs through initiatives and activities that are both responsive and proactive.

# 6. Planning for the Energy Transition

Decarbonizing the planet to avoid the catastrophic impacts of climate change requires a global campaign to transition from energy powered by fossil fuels to energy powered by renewables. Climate scientists warn that CO2 emissions must peak by 2030 and decline thereafter, but the window is rapidly closing. [146] A recent Emissions Gap Report (Oct. 2022) shows that there is 'no credible pathway' to keep warming within 1.5C, leaving rapid societal transformation the only option. [147]

## 6.1 Intergovernmental Panel on Climate Change (IPCC)

The IPCC is part of the United Nations, and its job is to advance scientific knowledge about climate change caused by human activities. The World Meteorological Organization and the United Nations Environment Programme established the IPCC in 1988. The IPCC's reports are available online at https://www.ipcc.ch/. In recent years, the IPCC has focused on making its reports more accessible and understandable to the general public.

## 6.2 Conference of the Parties (COP)

Since 1995, many countries have been meeting annually as required by the UN Framework Convention on Climate Change (UNFCCC) to review the science and negotiate agreements concerning their plans to address climate change; and energy policy has been key to these discussions. [148] The League of Women Voters (US) has been granted official observer status at the COP meetings, which League delegates attend.

## 6.3 International Energy Agency (IEA)

The IEA was created in 1974 to ensure the security of oil supplies. With a membership of 31 countries today, the IEA is at the "center of the global energy debate, focusing on a wide variety of issues, ranging from electricity security to investments, climate change and air pollution, energy access and efficiency, and much more." [149]

## 6.4 States planning the energy transition

As of 2022, there are 33 states that have released a climate action plan or are in the process of revising or developing one. This includes 29 states that have released plans and 4 states that are updating or developing their plans. A complete list is available online at https://www.c2es.org/document/climate-action-plans/

## 6.5 Local governments and energy democracy

Decarbonizing our economy requires expertise in many fields, at many levels, but it won't succeed without the active engagement of consumers at the local level. "Energy democracy is a concept developed within the environmental justice movement that pairs the renewable energy transition with efforts to democratize the production and management of energy resources— including the social ownership of energy infrastructure, decentralization of energy systems, and expansion of public participation in energy-related policymaking". [150]

Local governments are an important counterpoint to the international, federal and state plans to address climate change because local decision-makers may be more responsive to their constituents, and capable of acting with greater flexibility and speed. Brookings reported in October 2020 that more than 600 local governments in the U.S. have developed climate action plans (CAP) since 1991. These local plans make **greenhouse gas (GHG) emission inventories** and establish reduction targets, reduction strategies, and monitoring efforts. After reviewing these plans, researchers concluded that "overall, the development and implementation of GHG plans and pledges --- while important and encouraging --- leaves room for improvement in terms of reach, rigor, and ambition." [151]

The Zero Energy Project has compiled a comprehensive list of local climate action plans, with links to the actual plans. [152] Climate Action Plans, however, are often aspirational documents that address a wide range of environmental topics and may not even address the sources of electric power.

**The League of Women Voters** has developed a **Ten Actions** framework listing the 10 most important specific actions that local governments can take to reduce GHG emissions, as well as the Ten Processes to be used in implementing those actions. [153]

Transitioning rapidly to a clean energy future requires decision-makers and the public to clearly see the merits of all of the arguments, and sift through the deliberate disinformation strategies promoted to thwart meaningful action.

DeSmog's Climate Disinformation Database provides a searchable database of individuals and organizations that are spreading climate disinformation. There are hundreds of such groups working at the federal, state, and local levels to influence the discussions about energy and the actions our elected and appointed officials take to address climate change.

# 7. Recommended Resources

*The Grid – The Fraying Wires Between Americans and Our Energy Future*, Gretchen Bakke, (Bloomsbury USA 2017). A comprehensive examination of our national power grid--how it developed, its current flaws, and how it must be completely reimagined for our energy future.

*Electricity 101*, United States Department of Energy, https://www.energy.gov/oe/electricity-101

*Short Circuiting Policy: Interest Groups and the Battle Over Clean Energy and Climate Policy in the American States*, Leah Cardamore Stokes (Oxford University Press 2020). Short Circuiting Policy examines clean energy policies to understand why U.S. states are not on track to meet the climate crisis.

Jennie C. Stephens (2019) Energy Democracy: Redistributing Power to the People Through Renewable Transformation, Environment: Science and Policy for Sustainable Development, 61:2, 4-13, DOI: 10.1080/00139157.2019.1564212

## 7.1 Podcasts

VOLTS (podcast and newsletter) by David Roberts https://www.volts.wtf/- a podcast about leaving fossil fuels behind. "The transition away from fossil fuels to clean, carbon-free energy is underway, and it is accelerating every day. That transition has become an enormous, sprawling meta-story. It spans the entire economy, from heavy industry to tech to retail. It's unfolding on every level of government, from local zoning boards to the federal government to international treaties. It involves technology, politics, policy, psychology, even philosophy."

Cleaning Up Episode 68: Amory Lovins 'The Einstein of Energy Efficiency' – Dec. 15, 2021 https://www.youtube.com/watch?v=0BtpbmDBGFQ Amory Lovins is Cofounder and Chairman Emeritus of the Rocky Mountain Institute, author of 31 books and more than 700 papers, he has advised major firms and governments on energy in over 70 countries for more than 45 years.

Columbia Energy Exchange
https://www.energypolicy.columbia.edu/podcast/columbia-energy-exchange
"Columbia Energy Exchange features in-depth conversations with the world's top energy and climate leaders from government, business, academia and civil society. The program explores today's most pressing opportunities and challenges across energy sources, financial markets, geopolitics and climate change as well as their implications for both the U.S. and the world."

DRILLED hosted by investigative climate journalist Amy Westervelt
https://drilled.media/podcasts/drilled "Climate accountability — investigating the various drivers of delay on climate action — is critical to understanding and addressing climate change. Drilled is an independent news outlet focused on climate accountability."

Climate One hosted by Greg Dalton addressing the climate crisis, with Patti Poppe: Reinventing Utilities During a Climate Emergency
https://podcastaddict.com/episode/143089551

TILclimate "This award-winning MIT podcast breaks down the science, technologies, and policies behind climate change, how it's impacting us, and what our society can do about it. Each quick episode gives you the what, why, and how on climate change — from real scientists — to help us all make informed decisions for our future."

A Matter of Degrees hosted by Leah Stokes and Katharine Wilkinson – check out the episode on 8/30/21 about coal debt securitization. The 'Win-Win-Win' Strategy To

Retire Coal https://podcastaddict.com/episode/142598187

Local Energy Rules: A project of the Energy Democracy Initiative at the Institute for Local Self-Reliance, share stories of communities taking on concentrated power to transform the energy system. Their audience is researchers, grassroots organizers, and grasstops policy wonks who want vivid examples of how local, renewable energy can power local economies. https://ilsr.org/local-energy-rules-podcast-homepage/

Damages launched in 2022 hosted by investigative climate journalist Amy Westervelt focuses on climate lawsuits in the courtrooms around the world. https://podcastaddict.com/podcast/3792446

## 7.2 Resources focused on the intersection of energy and climate change

National Academies of Sciences, Engineering, and Medicine 2021. The Future of Electric Power in the United States. Washington, DC: The National Academies Press. (download free pdf here https://doi.org/10.17226/25968 )
C40 Knowledge ("Achieving 100% clean energy means eradicating greenhouse gas emissions from energy use in all sectors of the economy. It involves fundamental changes to how we generate electricity, transport people and goods, and heat and cool our buildings. As major consumers of energy, cities are playing a critical role in driving us toward this goal and can reap local benefits for health, jobs, energy cost savings and a return on investment.") How to create a roadmap for your city's renewable energy transition

Energy Efficiency 2021 -- the International Energy Agency's (IEA) annual update on global developments in energy efficiency. The report explores recent trends in energy efficiency markets at the economy-wide and sectoral levels, including developments in policy and investment.

DSIRE is a comprehensive source of information on incentives and policies that support renewable energy and energy efficiency in the United States. Established in

1995, DSIRE is operated by the N.C. Clean Energy Technology Center at N.C. State University.

Center for Climate and Energy Solutions (C2ES) is the successor to the Pew Center on Global Climate Change with a mission to "advance strong policy and ambitious action to: reduce greenhouse gas emissions; promote and accelerate the clean energy transition; strengthenadaptation and resilience to climate impacts; and facilitate the necessary financial investments to do so."

The Congressional Research Service (CRS) is a good resource for energy laws and policy. Search the database of reports using keywords. https://crsreports.congress.gov/ "U.S. Energy in the 21st Century: A Primer" - March 16, 2021 - https://crsreports.congress.gov/product/pdf/R/R46723 is a great place to begin.

Canary Media: Clean Energy Journalism for a Cooler Tomorrow. https://www.canarymedia.com/

DeSmog's Climate Disinformation Database provides a searchable database of individuals and organizations that are spreading climate disinformation.

## 7.3 Legal Resources

Federal Power Act: Joshua C. Macey & Matthew R. Christiansen, Long Live the Federal Power Act's Bright Line, 134 Harv. L. Rev. 1360, Feb. 10, 2021 https://harvardlawreview.org/2021/02/long-live-the-federal-power-acts-bright-line/ -- interprets a trio of recent Supreme Court cases that addressed jurisdictional disputes in energy markets to identify which policies respect the Federal Power Act's allocation of jurisdiction and which do not. And Jim Rossi, Energy Federalism's Aim, 134 Harv. L. Rev. F. 228, Feb. 20, 2021 https://harvardlawreview.org/2021/02/energy-federalisms-aim/

The State Energy & Environmental Impact Center at NYU Law studies and supports the work of state attorneys general in defending, enforcing, and promoting strong laws and policies in the areas of climate, environmental justice, environmental protection, and clean energy. https://stateimpactcenter.org/

The Law of Energy Transition in Federal Systems, Johannes Saurer and Jonas Monast, published online by Cambridge University Press: 01 July 2021 – Collects articles presented as part of a symposium focused on energy transition and federalism issues in Australia, South Africa, Switzerland, Germany, the U.S., and the EU. https://www.cambridge.org/core/journals/transnational-environmental-law/article/law-of-energy- transition-in-federal-systems/15B85ECABE57AD436F705A9287819C36#

Columbia Law School's Sabin Center for Climate Change Law, Environmental Defense Fund, and the Initiative on Climate Risk and Resilience Law released an Electric Resilience Toolkit to support policymakers and stakeholders working on issues around electric sector regulation and climate resilience planning. https://news.climate.columbia.edu/2022/06/16/announcing-the-electric-resilience-toolkit/

Columbia Climate School – Sabin Center for Climate Change Law includes Energy Law divided in the following categories: Clean Energy, Energy Sector Resilience, Fossil Fuels, Model Laws for Deep Decarbonization in the U.S., and Renewable Energy Legal Defense Initiative. https://climate.law.columbia.edu/content/energy-law

# 8. Term Index

## C



## D



## E



## F



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## I



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## K



## L

# 9. Endnotes

1 https://ourworldindata.org/electricity-mix#%3A~%3Atext%3DIn 2019%2C almost two-thirds%2Cbeen pretty stagnant for decades
2 https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php
3 https://www.buildinggreen.com/news-article/what-watt-anyway-understanding-energy-and-power-metrics
4 https://ratedpower.com/glossary/megawatt-and-megawatt-hour/#what-is-the-difference-between-a-megawatt-and-a-megawatt-hour
5 https://www.eia.gov/energyexplained/use-of-energy/electricity-use-in-homes.php
6 https://insideenergy.org/2015/11/06/lost-in-transmission-how-much-electricity-disappears-between-a-power-plant-and-your-plug/
7 https://www.epa.gov/energy/centralized-generation-electricity-and-its-impacts-environment
8 https://www.nrc.gov/docs/ML2214/ML22140A312.pdf
9 https://www.eia.gov/energyexplained/wind/wind-energy-and-the-environment.php#:~:text=Wind is an emissions-free source of energy&text=Overall%2C using wind to produce,not require water for cooling.
10 https://en.wikipedia.org/wiki/Wind_farm#:~:text=A wind farm or wind,be either onshore or offshore.
11 https://energyeducation.ca/encyclopedia/Solar_power#cite_note-6
12 https://energyeducation.ca/encyclopedia/Solar_power#cite_note-RE1-8
13 https://en.wikipedia.org/wiki/Concentrated_solar_power
14 https://e360.yale.edu/features/solar-energy-panels-recycling#https://e360.yale.edu/features/solar-energy-panels-recycling
15 https://www.eia.gov/energyexplained/geothermal/geothermal-power-plants.php
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18 https://www.nrel.gov/news/features/2023/full-steam-ahead-unearthing-the-power-of-geothermal.html
19 https://www.eia.gov/energyexplained/geothermal/geothermal-power-plants.php
20 https://www.eia.gov/energyexplained/biomass/
21 https://www.nrel.gov/research/eds-hydrogen.html
22 https://www.energy.gov/eere/slsc/renewable-energy-distributed-generation-policies-and-programs#:~:text=Distributed generation is the term,generation sources from power plants
23 https://www.epa.gov/energy/centralized-generation-electricity-and-its-impacts-environment#:~:text=
24 https://blogs.scientificamerican.com/plugged-in/renewable-energy-intermittency-explained-challenges-solutions-and-opportunities/
25 https://energyeducation.ca/encyclopedia/Dispatchable_source_of_electricity
26 https://www.nmppenergy.org/energy-education/understanding-energy-capacity-and-capacity-factor
27 https://en.wikipedia.org/wiki/Levelized_cost_of_electricity#:~:text=The levelized cost of

electricity,generation on a consistent basis
28 https://www.lloyds.com/strandedassets
29 https://www.theguardian.com/environment/ng-interactive/2021/nov/04/fossil-fuel-assets-worthless-2036-net-zero-transition
30 https://read.nxtbook.com/ieee/spectrum/spectrum_na_february_2022/packetizing_the_power_grid.html
31 https://www.eia.gov/energyexplained/electricity/delivery-to-consumers.php
32 https://www.eia.gov/todayinenergy/detail.php?id=27152
33 https://www.eia.gov/tools/faqs/faq.php?id=105&t=3
34 https://ia.cpuc.ca.gov/Environment/info/aspen/cltp/archive/Files_8_26_14/_2ElectricTransmissionFactSheet.pdf
35 https://www.osha.gov/etools/electric-power/illustrated-glossary/sub-station
36 https://crsreports.congress.gov/product/pdf/IF/IF12253
37 https://crsreports.congress.gov/product/pdf/IF/IF12253
38 https://www.energy.gov/sites/default/files/2023-08/Balancing Authority Backgrounder_2022-Formatted_041723_508.pdf
39 https://www.eia.gov/todayinenergy/detail.php?id=27152
40 https://crsreports.congress.gov/product/pdf/IF/IF12253
41 https://www.nrel.gov/grid/microgrids.html
42 https://www.eia.gov/tools/faqs/faq.php?id=105&t=3
43 https://www.nrel.gov/docs/fy02osti/31570.pdf
44 https://www.utilitydive.com/news/how-utilities-can-turn-ders-from-threat-into-opportunity/415515/
45 https://www.marketwatch.com/guides/solar/solar-net-metering/#:~:text=Net metering works as an,38 states and Washington%2C D.C.
46 https://my.lwv.org/california/pasadena/article/net-energy-metering-what-it-and-why-it-important
47 https://www.eia.gov/todayinenergy/detail.php?id=11471
48 https://www.epa.gov/green-power-markets/shared-renewables
49 https://www.energy.gov/eere/solar/community-solar-basics
50 https://news.energysage.com/virtual-net-metering-what-is-it-how-does-it-work/
51 https://www.sandia.gov/ess/publications/doe-oe-resources/eshb
52 https://www.nrel.gov/docs/fy21osti/76097.pdf
53 https://about.bnef.com/blog/global-energy-storage-market-to-grow-15-fold-by-2030/
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