Bipartisan Policy Center

# Electricity 101

## Session 1: The Physical Grid and Who Does What

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# Electricity 101: The Physical Grid and Who Does What

## Speakers:

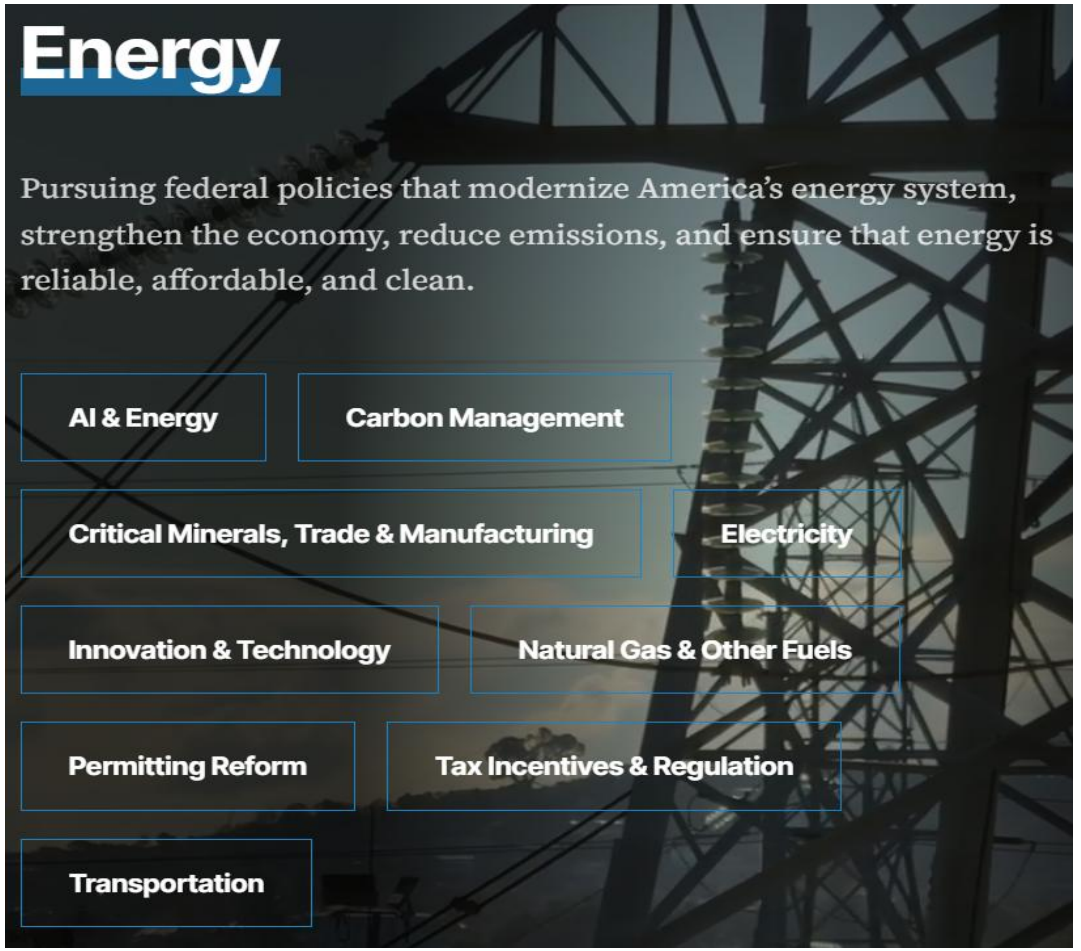
**Kathryn Kline Tyndall** | Associate Director, Energy, BPC

**Devin Hartman** | President, Lighthouse Energy Institute

**Dr. Liza Reed** | Director for Climate and Energy Policy, Niskanen Center

# About the Bipartisan Policy Center

- The Bipartisan Policy Center was founded in 2007 by four former Senate majority leaders.
- They believed that cooperation across party lines was essential to solving the nation's toughest challenges.
- Their vision was clear: bring the best ideas from both sides of the aisle to create effective, durable policy solutions.
- Today, BPC advances pragmatic solutions, improves lives, and builds a stronger America.



# Course Overview

01

Session 1

## The Physical Grid and Who Does What

How electricity flows from generation to consumer, and who regulates each piece.

02

Session 2

## Markets, Reliability, and Resource Adequacy

How wholesale markets work, how RTOs operate, and how the grid stays reliable.

03

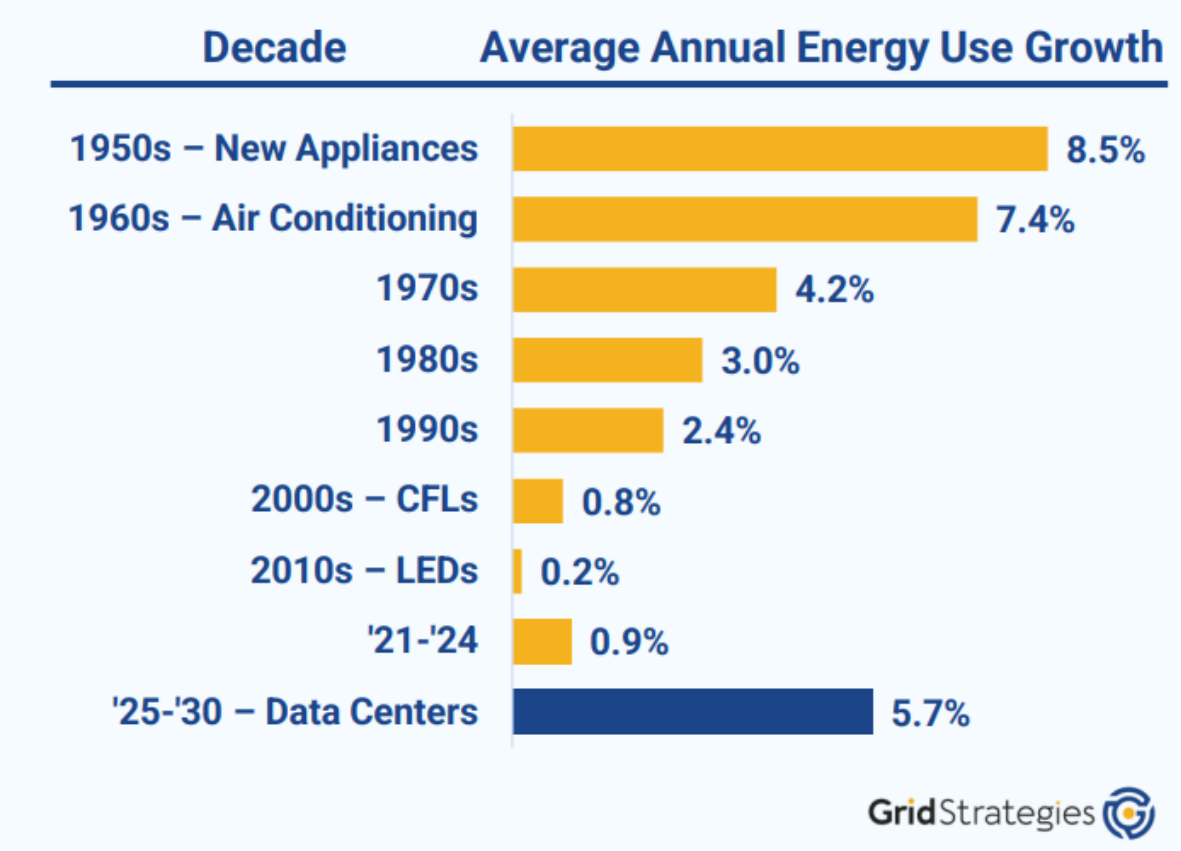
Session 3

## The Path Forward

New demand, new technologies, challenges, and how Congress can shape the next era of electricity.

# The Moment We're In: New Demand Growth

**After about 20 years of flat demand, U.S. electricity consumption is projected to rise significantly over the next decade.**




*Source: GridStrategies 2025 National Load Growth Report; Edison Electric Institute; BNP Paribas*

## Key Drivers

### Data centers

Economically imperative development seeking speedy interconnection.

### Manufacturing and industrial uses

Reshoring and new industrial facilities increase industrial load.

### Electrification

Transportation and building electrification shift fuel demand to the grid.

## Unprecedented Investment

### Utilities plan to spend $1.1 trillion from 2025–2029.

Hyperscalers' capex exceeds $700 billion in 2026 alone.

PART 1

# The Physical Grid

## Dr. Liza Reed, Niskanen Center

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# The Physics of the Grid

Electricity behaves differently from other commodities.

## Physics Governs the Grid

*Electricity flows according to physical laws, not contracts.*

- Electrons follow the path of least resistance, which means power generated in one system can flow into another interconnected system.
- Operators can guide flows with controls and pricing but cannot force a specific route.
- Congestion or reliability challenges in one area can impact prices and reliability across a wide region.

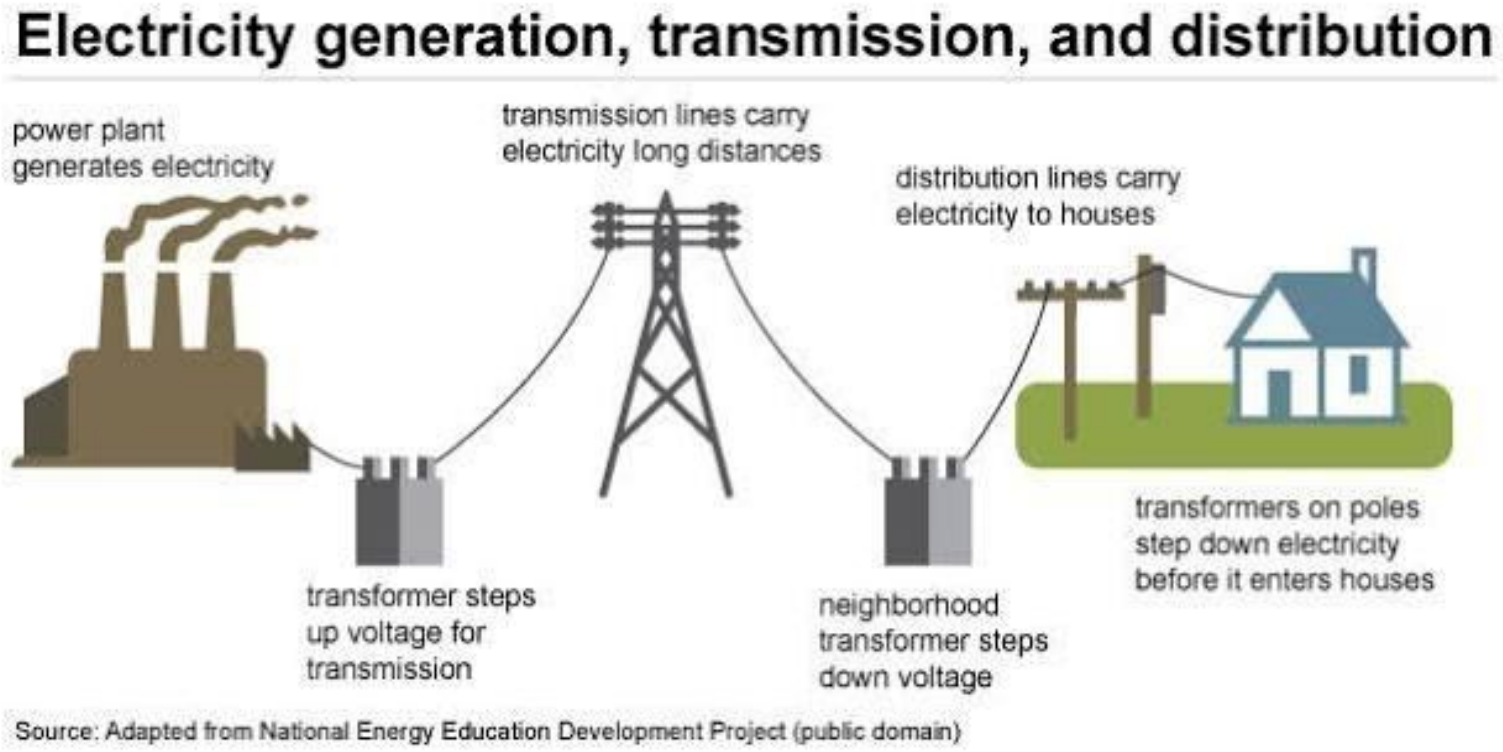
## Supply Must Meet Demand

*Mismatches create frequency and voltage problems.*

- Operators balance the grid every second, 24/7/365.
- Frequency in North America is held at 60 Hz across each interconnection.
- Imbalances can reduce power quality, damage equipment, and trigger cascading outages.

# Generation, Transmission, and Distribution

These three services move electricity to consumers and account for the primary cost components of electricity service.



# Types of Generation and Basic Profiles

Resources differ in how often they run, how fast they can respond, and whether they are dispatchable or weather-dependent.

## Baseload

**Runs continuously**

Large plants designed to run many hours each year.

- Nuclear
- Hydroelectric
- Coal
- Geothermal
- Some natural gas combined cycle

## Intermediate

**Ramps up and down daily**

Considered *load following* with flexible operations.

- Natural gas combined cycle
- Battery energy storage

## Peaking

**Quick-start for highest demand**

~999 peaker plants in the U.S. (2021), run less than 15% of hours.

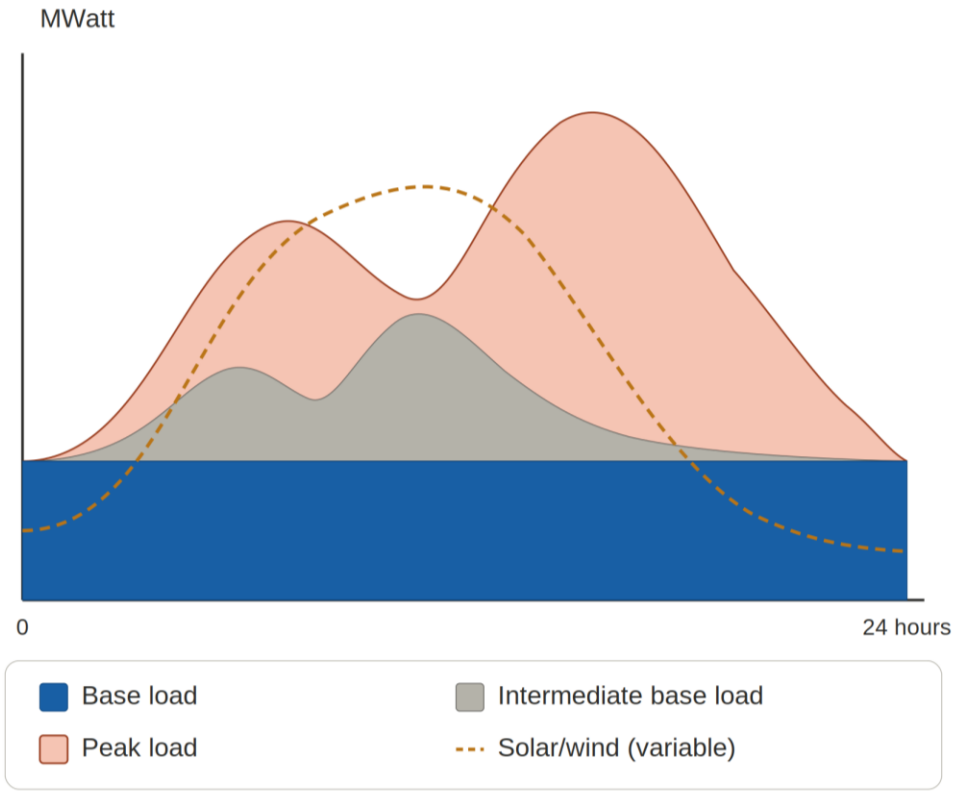
- Natural gas combustion turbines
- Oil and dual-fuel combustion plants
- Battery energy storage

## Variable

**Output depends on weather**

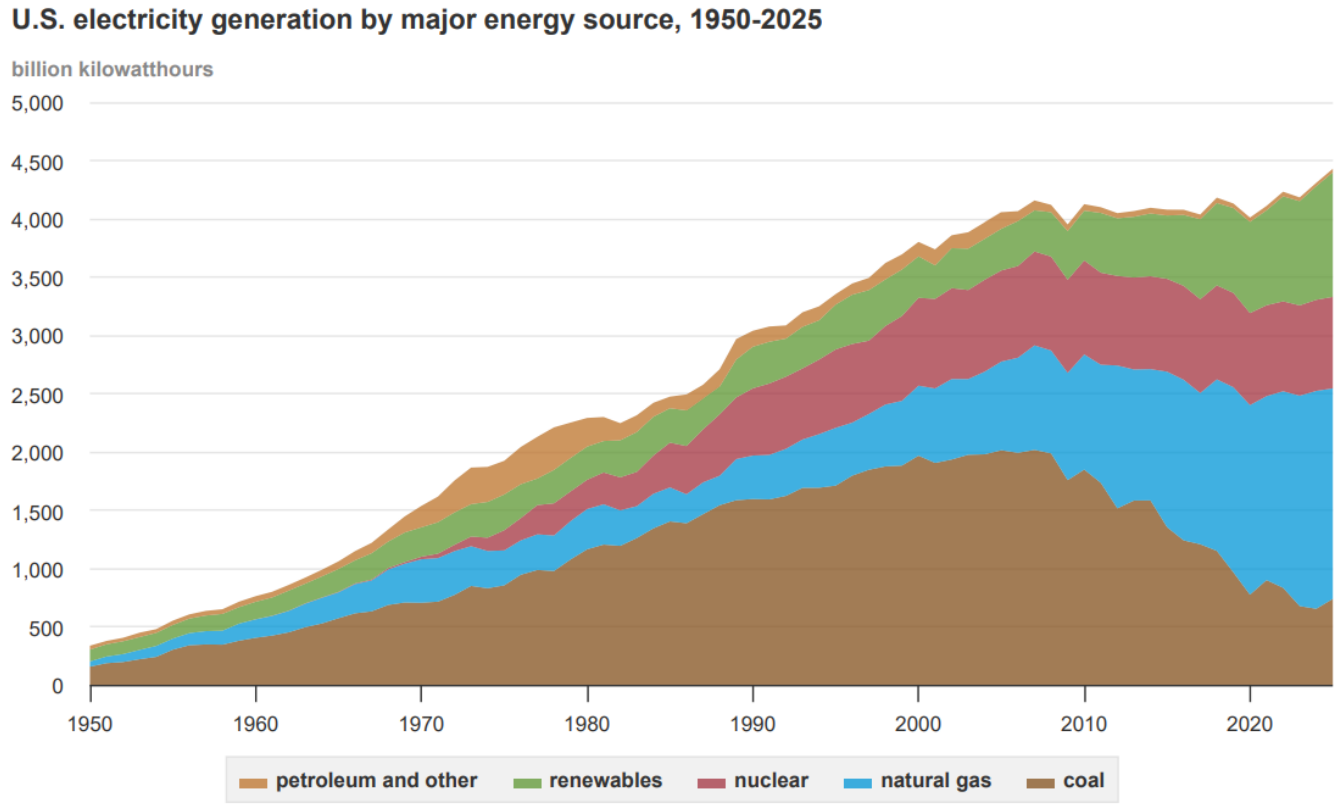
Intermittent resources with zero marginal cost. Can be paired with battery storage.

- Onshore and offshore wind
- Solar




*Source: U.S. GAO (2024)*

# A Diverse Portfolio Powering the Nation




## Why Diversity Matters

### Location, Location, Location

Different resources are better suited for different locations based on pipeline supply, wind and solar resources, and more.

### Diversity Manages Risks

No single resource is immune to weather, fuel supply, or market shocks.

### Complementary Attributes

Some energy resources are dispatchable, some are weather-dependent, and some are low-cost. Mixing attributes improves overall system reliability.

### Resilience

Diverse portfolios hedge against supply disruptions and price spikes.

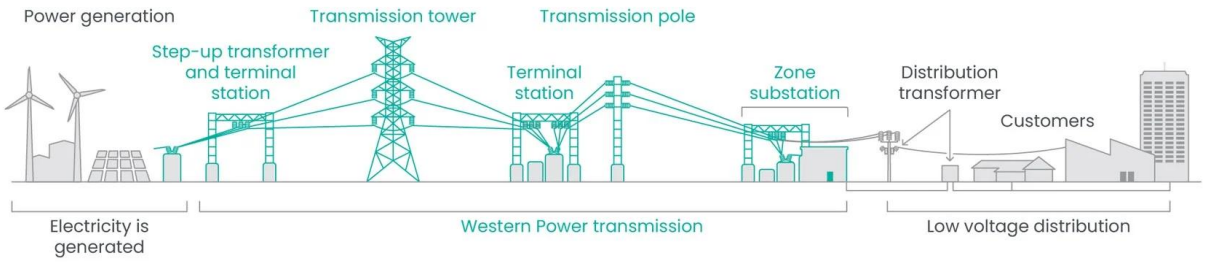
*Source: U.S. Energy Information Administration (2025).*

# Transmission: The Highway for Electrons

Transmission moves bulk power long distances at high voltage—minimizing losses and connecting generation to load.

## The categories of transmission lines:

1. **Local** transmission lines tend to be intrastate but high voltage (100 kV and above).
2. **Regional** lines connect generators to nearby load centers within a single planning region.
3. **Interregional** lines cross operator boundaries, enabling power to flow between regions during extreme weather events, supply shortfalls, or when one region has inexpensive surplus power that another region could use.




*Source: ASCE 2025 Infrastructure Report Card; GridStrategies Transmission Congestion for 2024; Graphic: https://www.westernpower.com.au/*

### Scale of the System

- 600,000 circuit miles of transmission lines in the U.S., of which 240,000 miles are high-voltage.
- 70,000 substations move power between voltage levels.

### What Is Congestion?

- When more power wants to flow on a line than capacity allows, operators must use more expensive generation.
- Congestion costs exceeded $12 billion in 2024.

### Why High Voltage?

- Higher voltage (500 kV and above) dramatically reduces energy lost as heat.
- Voltage is stepped up at generators and stepped down at substations before reaching customers.

# Distribution: The Last Mile

The low-voltage network that delivers power from local substations to homes, businesses, and industrial customers.

## What It Is

### Voltage range:

4 kV to 35 kV, stepped down from transmission at local substations.

### Hardware:

Poles, wires, transformers, switchgear, and increasingly smart meters.

### Footprint:

Millions of miles of lines nationwide, mostly at street level.

## Why It Matters

### Where most outages happen:

The vast majority of outages are due to distribution-system events.

### Aging infrastructure:

Much of the network was built decades ago. Utilities spend ~$51B/year on distribution upgrades.

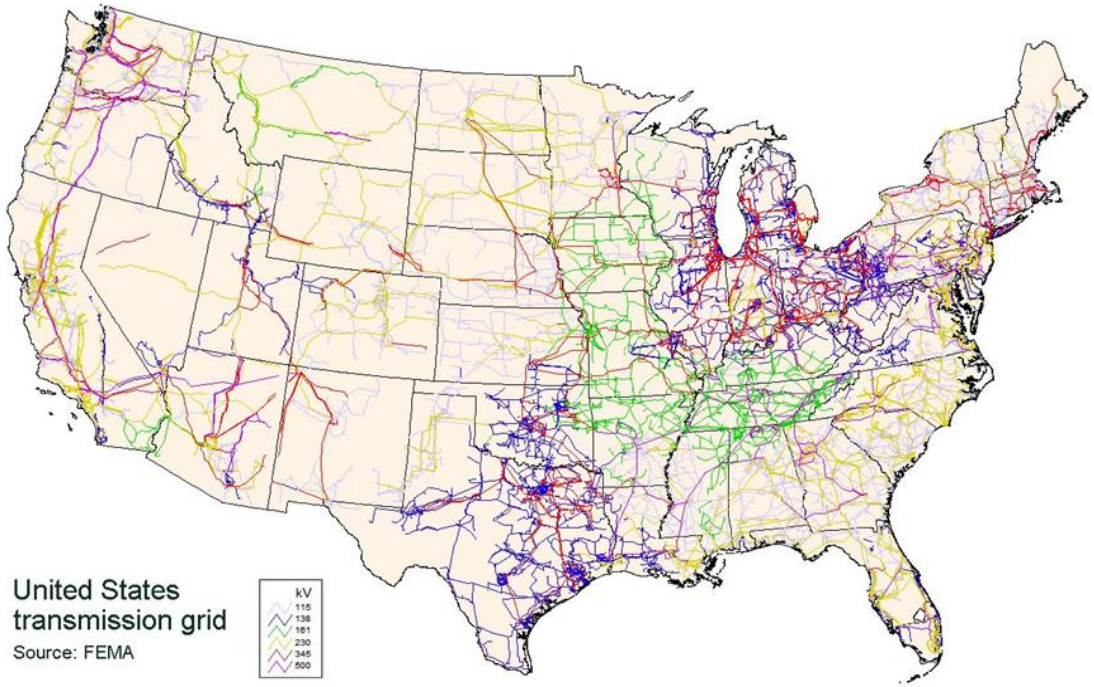
### Evolving role:

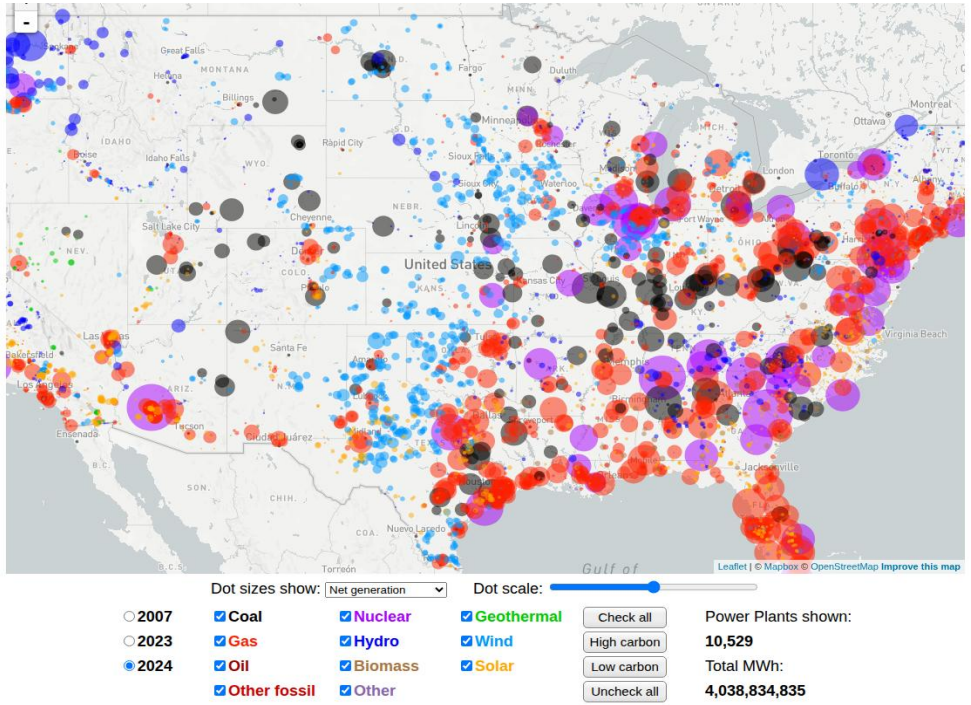
Rooftop solar, home batteries, smart meters, and other distributed energy resources are changing the role distribution plays.

*Source: https://texashistory.unt.edu/ark:/67531/metapth769678/*

# Grid Regionalization Brings Benefits

The U.S. grid is interconnected, but not efficiently. These maps illustrate that reality: transmission lines crisscross the country (Map 1), and generation resources of every type are distributed unevenly across regions (Map 2).




## Why Regionalization Matters

**Generation diversity:** A larger and more diverse pool of resources for operators to call upon; increases reliability and access to lower-cost resources.

**Load diversity:** Peak demand occurs at different times across regions. A connected grid can serve all peaks using less total generation capacity than isolated systems require.

**Weather diversity:** Weather systems can vary within a region. A larger footprint creates an opportunity to potentially moderate generator or load stress from local weather.

*Source: EIA Electricity Maps (eia.gov/maps); Open Infrastructure Map*

# Grid Infrastructure: Built for Peak Demand

The grid is sized for the worst hours of the year, which carries significant implications for utilization and costs.

## Sized for the Peak

The grid is designed to serve peak demand, which occurs in a handful of hours each year. For the rest of the year, that infrastructure sits idle.

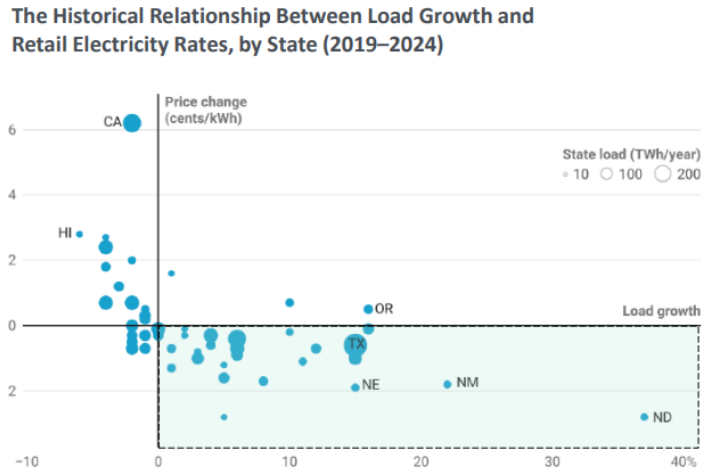
**53%**

Average generation capacity utilization rate, 2016–2024

## Load Growth as an Opportunity

**$11–17 billion per year**

In customer savings with greater infrastructure utilization




*24 states experienced load growth and declining inflation-adjusted retail electricity rates between 2019 and 2024*

*Source: Nicholas Institute for Energy, Environment & Sustainability; Brattle; Lawrence Berkeley National Laboratory (LBNL)*

# From Physical Grid to Consumer Costs

Three categories of costs flow to electricity customers, and rate design and costs for each category vary significantly by region.


## GENERATION

This covers the cost of producing the electricity you use from traditional power plants and renewable sources. District residents can choose a licensed competitive electricity supplier, or they can receive default Standard Offer Service. **The DCPSC does not regulate these rates;** they are driven by regional wholesale market prices and the costs of meeting the city's Renewable Portfolio Standard (RPS) goals.

## TRANSMISSION

This covers the cost of moving high-voltage electricity from power generation plants across long distances to the local distribution system. Because this involves moving power across state lines, these transmission rates are regulated by the Federal Energy Regulatory Commission, rather than the DCPSC.

## DISTRIBUTION*

This covers the cost of physically delivering electricity to your home, including local poles, wires, transformers, grid maintenance, and low-income customer assistance. **The DCPSC strictly regulates these charges.** Your utility cannot increase delivery rates without a rigorous technical and legal review process, known as a "rate case," approved by the DCPSC.

*includes certain surcharges

## SURCHARGES & TAXES

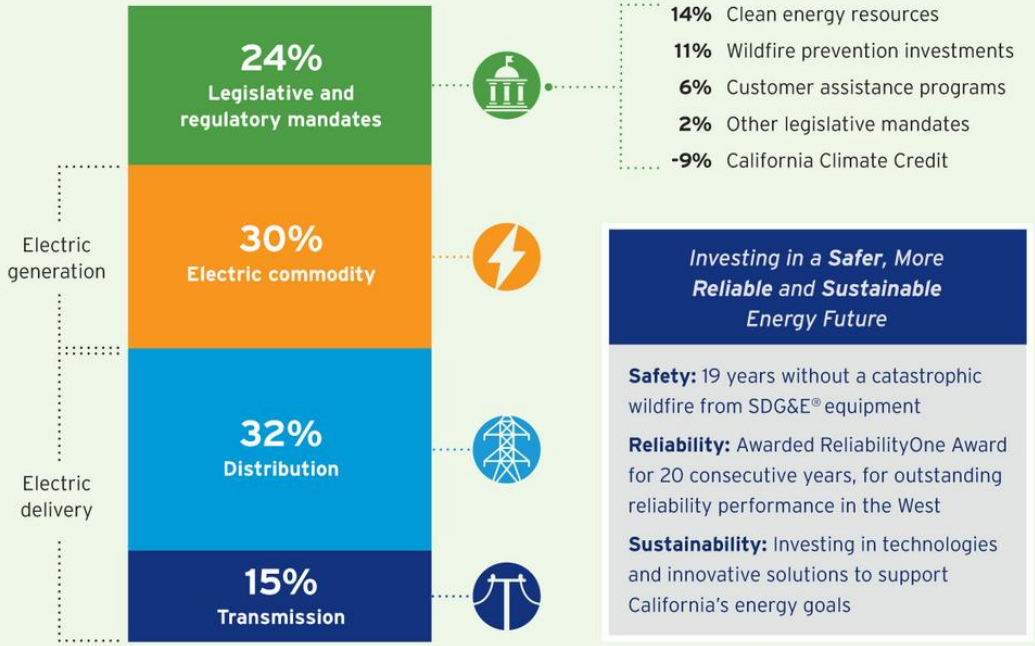
These line items fund important initiatives, including energy efficiency programs, renewable energy sponsored programs, and critical underground infrastructure projects. They are mandated by a mix of different authorities, including the DC Council and the federal government.

PUBLIC SERVICE COMMISSION
District of Columbia
Your Energy. Your Voice.

*Source: District of Columbia Public Service Commission*

## Average residential bill breakdown[5]

More than half of SDG&E's residential bill for customers, where SDG&E provides both the electricity and the delivery, is driven by legislative mandates, regulatory requirements and commodity costs, which are passed through to customers with no markup.




[5]The average residential bill breakdown based on February 2025 bills.

*Source: San Diego Gas & Electric*

## Key Design Choices

**Fixed Costs Dominate**

Most T&D costs are recovered even when customers use less.

**Underutilization**

Sizing for peaks spreads costs across fewer kWh.

**Regional Variation**

States choose how to allocate costs across customer classes.

# Q&A
# The Physical Grid

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PART 2

# Who is in Charge of What?

## Devin Hartman, President, Lighthouse Energy Institute

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# State and Federal Authority: The Division of Power

*The Federal Power Act (FPA), enacted in 1935, remains the primary statute governing the electric system and establishes a clear division of power for regulating the energy system between state and federal regulators.*

## Federal Energy Regulatory Commission

**Wholesale sales and interstate transmission**

The Federal Energy Regulatory Commission regulates the transmission of electricity in interstate commerce and its sale at wholesale (for resale). Those rates must be just, reasonable, and not unduly discriminatory.

## States

**Retail sales, generation investment, and local distribution**

States regulate retail sales to end-use customers, local distribution systems, and the siting of generation and transmission facilities.

## The Public Power Carve-Out

**From rate authority, not reliability regulation**

Federal, state, and municipal utilities and rural electric cooperatives are largely exempt from FERC regulation under the FPA.

## What "Public Utility" Means

**A defined legal term**

Under the FPA, "public utility" is a defined term covering privately owned utilities that make interstate wholesale sales or transmit power; publicly owned utilities and cooperatives generally fall outside it.

# Divided Jurisdiction

| | Generation | Transmission | Distribution |
|---|---|---|---|
| **States** | • Sites and permits power plants<br>• Takes more active roles in planning, determines which plants utilities build, and recovers their costs through retail rates | • Sites and permits lines and grants eminent domain<br>• Passes FERC-approved transmission costs through to retail bills | • Sets retail rates, and regulates costs and investments of the local distribution utility<br>• Oversees local reliability and service |
| **Federal** | • Regulates wholesale power sales and the markets generators bid into<br>• Oversees reliability standards for large plants | • Sets interstate transmission rates and requires open access<br>• Sets transmission expansion planning requirements<br>• Narrow siting authority<br>• Oversees bulk-system reliability standards | • Has no authority |

# A Recent History of Key Decisions Shaping Federal Electric Rate Regulation

**Pre-1978**

## State or municipal regulated monopolies

Regulators treated utilities as natural monopolies, granting exclusive service territories under **cost-of-service regulation.**

**1978**

## Public Utility Regulatory Policies Act

After cost and overbuild challenges, PURPA required utilities to buy from independent power producers, introducing competition in generation.

**1992**

## Energy Policy Act

Congress affirmed support for competition. FERC gained authority to order transmission "wheeling" at just and reasonable rates.

**1996 and 1999**

## FERC Orders 888 and 2000

To combat rising costs, FERC required utilities to separate generation and transmission functions, granting open access to transmission, and defining regional wholesale power markets.

**2005**

## Energy Policy Act of 2005

Authorized mandatory reliability standards and established backstop siting authority for transmission.

## Cost of Service Regulation

A utility's local regulators determine what revenue it needs to recover its costs and earn a fair return to attract investment, balancing the commercial needs of the utility with the public interest. This regulatory process sets electric rates.

In return, utilities have a duty to serve new customers in their territory in accordance with the regulator's oversight.

# Investor-Owned Utilities

## What Are They?

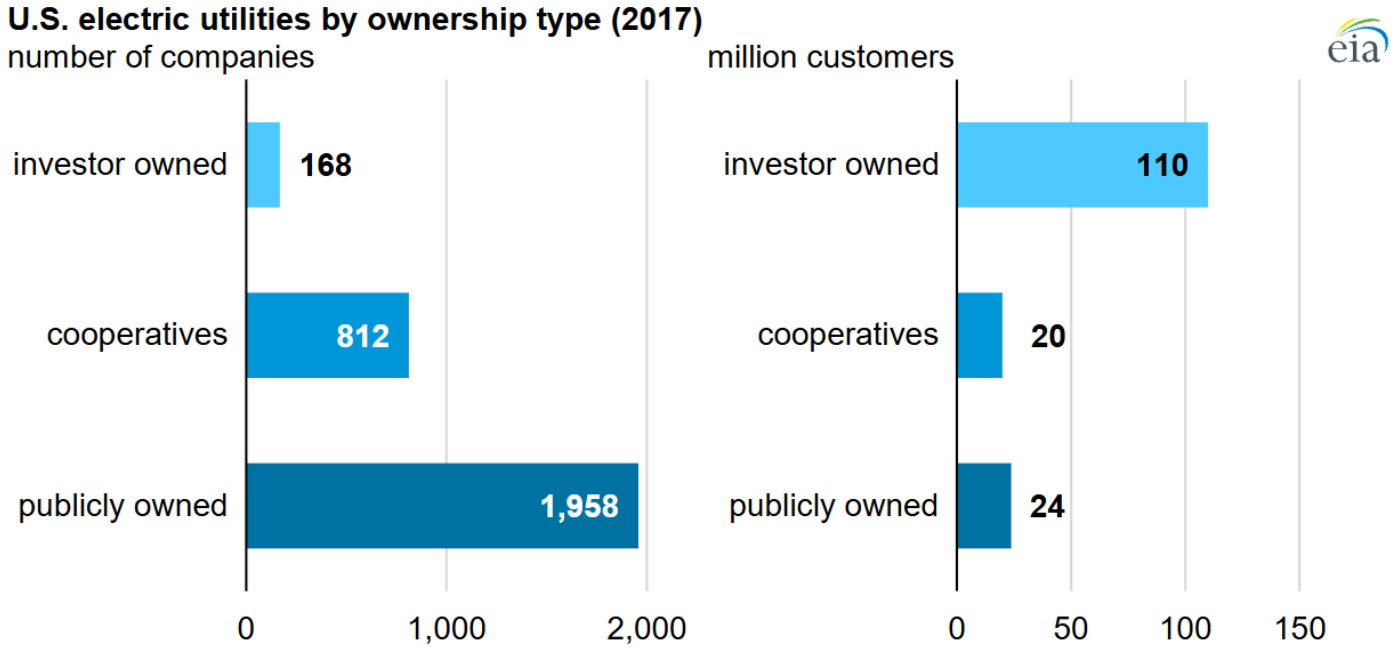
- Private, shareholder-owned utilities providing electric service to a majority of the nation's customers.
- Public utility regulation balances their profit motive with public interest.

## Earning Returns

- Under cost-of-service regulation, IOUs earn a regulated rate of return on their investments and have a duty to serve new customers in their territory.

## Operating Across Jurisdictions

- IOUs are regulated by states on retail rates and distribution, and on generation depending on the state's approach.
- Those same IOUs may own transmission, whose rates and regulation are overseen by FERC.




**Source:** U.S. Energy Information Administration, *Annual Electric Power Industry Report*

# Public Power

While investor-owned utilities serve a majority of customers, public power entities serve large portions of rural America and many large cities.


## Municipal Utilities

**~2,000 in the U.S.**

Owned and operated by cities or towns. Serve communities of all sizes—from Los Angeles to small townships. Governed by local officials and citizens.

## Federal Power Marketers

**Four federal agencies**

BPA, WAPA, SWPA, SEPA. Market electricity from federal hydroelectric projects, primarily to public power and cooperative customers.

## Electric Cooperatives

**~900 in the U.S.**

Member-owned, nonprofit utilities. Concentrated in rural areas. Together they serve 42 million people across 88% of U.S. counties.

*Source: U.S. Energy Information Administration*

# State Actors

States hold primary authority over retail rates, distribution, and most siting and permitting decisions.

## Public Utility Commissions

PUCs set retail electricity rates for utilities in their jurisdiction. They may require an integrated resource planning process to approve grid expansion plans.

PUCs balance the commercial needs of the publicly regulated utility with the public interest.

## State Legislatures

State legislatures implement carbon and clean energy goals, often in the form of Renewable Portfolio Standards, or set other grid-related policies.

## State Energy Offices

Shape energy policy by translating legislative directives and governors' goals into actionable programs.

## Consumer Advocates

Independent state offices that represent ratepayers in PUC proceedings, often advocating for affordable rates and adequate service.

## Governors

Governors set state priorities and the tone for the year's legislative session. Many also appoint commissioners to the PUCs.

## Environmental Agencies

Environmental agencies share responsibilities with PUCs for siting and permitting new grid infrastructure, including interstate transmission.

# Federal Actors

Federal agencies and grid operators set wholesale market rules, reliability standards, and environmental requirements for thebulk power system.

## FERC

**FERC** regulates wholesale electricity markets and interstate transmission rates, and oversees reliability frameworks.

**FERC** also oversees the RTOs/ISOs and approves their tariffs and market rules.

## NERC

The **North American Electric Reliability Corporation** develops and enforces mandatory reliability standards for the entire bulk power system across the U.S., Canada, and part of Mexico.

NERC operates under FERC oversight. Its standards apply to all users of the bulk power system.

## RTOs/ISOs

**Regional Transmission Organizations** and **Independent System Operators** operate the transmission grid and run competitive wholesale energy and capacity markets across most of the country.

They dispatch generation in real time, manage interconnection queues, and plan regional transmission expansion.

## Federal Agencies: DOE and EPA

**DOE** funds grid research and development, administers loan and grant programs, and can order emergency actions to preserve reliability under Federal Power Act Section 202(c).

**EPA** sets air, water, and waste standards for power plants under the Clean Air Act and related statutes.

# The Role of Congress

Congress shapes the rules of the road—and the federal-state balance—through statute, oversight, and the power of the purse.

## Statute

Establishes legal frameworks: Federal Power Act, PURPA, Energy Policy Act, and IIJA.

## Appropriations

Funds DOE programs, ARPA-E, national labs, and grid demonstration projects.

## Oversight

Holds hearings on FERC, NERC, DOE, and grid reliability.

## Tax Policy

Authorizes production and investment tax credits that shape generation investment.

## Federalism

Decides where federal authority ends and state authority begins—especially on siting and permitting.

## Trade and Supply Chains

Sets tariffs and trade policy affecting transformers, components, and critical minerals.

Q&A

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# Join us next time

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