Track: Electric Generation for Natural Gas Utility Employees

Unit #7: Practical Applications & Case Studies

Presentation Outline

- Calculation Review
- The Grid in Practice
- Electric Generation Examples
- Trends & Commentary
- Onsite Energy Technical Assistance Partnerships (TAPs)
- Role of Natural Gas

Calculation Review

Power

Voltage (V) – Volts, V
Current (I) – Amperes, Amps, A
Resistance (R) – Ohms, Ω
Power (P) – Watts, W
Energy – Watthours, Wh

V = I x R	P = I x V	Energy = Power x Time
I = V / R	I = P / V	Power = Energy / Time
R = V / I	V = P / I	

A microwave runs at 1kW and 120V for 30 minutes during a day.

Find Amps: P / V = I

1,000W / 120V = 8.3A

Find Ohms: V / I = R

120V / 8.3A = 996Ω

Find kWh used for the day:

Power x Time = Energy

1kW x 0.5 hr = 0.5 kWh

Volts, Amps, and Phase

Single-Phase	Three-Phase
P = V x I	**P = V x √3 x I**

Three phase AC power delivers more constant and efficient power, through less material, with fewer losses over long distances. Three phase is used directly by some larger equipment but converted to single phase for most everyday needs. Power converted to additional phases is used in some specialty cases.

Example:

Single-Phase	Three-Phase
120W = 120V x 1A	207W = 120V x √3 x 1A

Load Factor

Load factor is the amount of energy a load uses over a given time divided by its maximum load potential to use energy. This is a number between 1 and 0 where lower corresponds to less usage.

Load factor can apply to a single device, a building, or even a city or grid. It is often calculated for a year, using **Effective Full Load Hours (EFLH)**, which describe how many hours that equipment "effectively" runs at full power over the year.

Effective Full Load Hours (EFLH) =Total Annual Usage (kWh) / Registered Demand (kW)

Load Factor = EFLH / Hours in a Year

Load Factor

Examples:

A space heater can use 1500W when on, but is set to a 1000W setting on average, and is used for 8 hours a day.

(1 kW x (8 hrs per day x 365 days per year)) / 1.5kW = **1,947 EFLH**

1,947 EFLH / (24 hrs per day x 365 days per year) = **0.22 Load Factor**

A microwave uses 1000W when on and is used for a total of about 30 minutes a day in a Monday – Friday office.

(1 kW x (52 weeks per year x 5 workdays per week x .5 hrs per day)) / 1kW = **130 EFLH**

130 EFLH / (24 hrs per day x 365 days per year) = **0.015 Load Factor**

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Power Factor

Power factor is defined as the useful power in watts (real power) divided by the product of the input voltage and input current (apparent power). Effectively, when current and voltage are not in phase, power factor suffers.

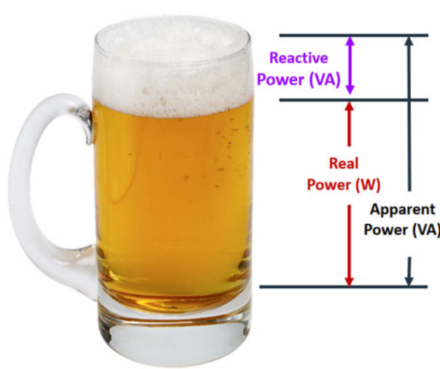
PF = Real Power / Apparent Power

A motor has an output power of 1kW, but has an input voltage and current rating of 120V and 10A respectively.

Apparent Power: 120V x 10A = 1,200 W = 1.2 kW

Real Power: 1.0 kW

1.0 kW / 1.2 kW = 0.83 Power Factor



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kW to BTU Conversion

3,412 Btu = 1 kWh
3,412 Btu/hr = 1kW

1 cubic foot natural gas (cf) ≈ 1,036 Btu
3.29 cf ≈ 1kWh

Energy

Gas		Electricity
0.00329 cf	3.412 Btu	1Wh
3.29 cf	3,412 Btu	1kWh
32.9 Ccf	3.412 MMBtu	1MWh
3.29 MMcf	3,412 MMBtu	1GWh

Power

Gas		Electricity
0.197 cf/min	3.412 Btu/hr	1W
3.29 cf/hr	3,412 Btu/hr	1kW
32.9 Ccf/hr	3.412 MMBtu/hr	1MW
3.29 MMcf/hr	3,412 MMBtu/hr	1GW

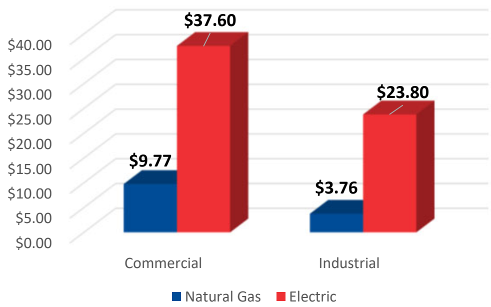
kW to BTU Conversion Examples

If running at full power for 1 hour…

Example	Electric Power	Gas Power	Electric Usage	Gas Usage	
Incandescent Lightbulb	100 W	341.2 Btu/hr	0.1 kWh	341.2 Btu	0.329 cf
LED Lightbulb	10 W	34.12 Btu/hr	0.01 kWh	34.12 Btu	0.0329 cf
Space Heater	1.5 kW	5,120 Btu/hr	1.5 kWh	5,120 Btu	4.94 cf
Electric Furnace	10 kW	34,120 Btu/hr	10 kWh	34,120 Btu	32.9 cf
Electric Water Heater	4.5 kW	15,350 Btu/hr	4.5 kWh	15,350 Btu/hr	14.8 cf

Energy Efficiency & Costs

2024 Average Retail Energy Prices ($/MMBTU)



Converting Gas & Electric Prices to $/MMBTU

- Average Retail Natural Gas Prices
  - Commercial = $10.12/MCF
    - $10.12/MCF / 1.036 BTU/MCF = $9.77/ MMBTU
  - Industrial $3.90/MCF
    - $3.90/MCF / 1.036 BTU/MCF = $3.76/ MMBTU
- Average Retail Electric Prices
  - Commercial = 12.85 cents/kWh
    - $.1285/kWh / 3412 BTU/kWh * 1,000,000 = $37.60/MMBTU
  - Industrial 8.15 cents/kWh
    - $.0815/kWh / 3412 BTU/kWh * 1,000,000 = $23.80/MMBTU

https://www.eia.gov/dnav/ng/ng_pri_sum_a_epg0_pcs_dmcf_a.htm , https://www.eia.gov/electricity/data/browser/#/topic/7?agg=1,0&geo=vvvvvvvvvvvvo&endsec=2&freq=A&start=2001&end=2024&ctype=linechart&ltype=pin&rtype=s&pin=&rse=0&maptype=0

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

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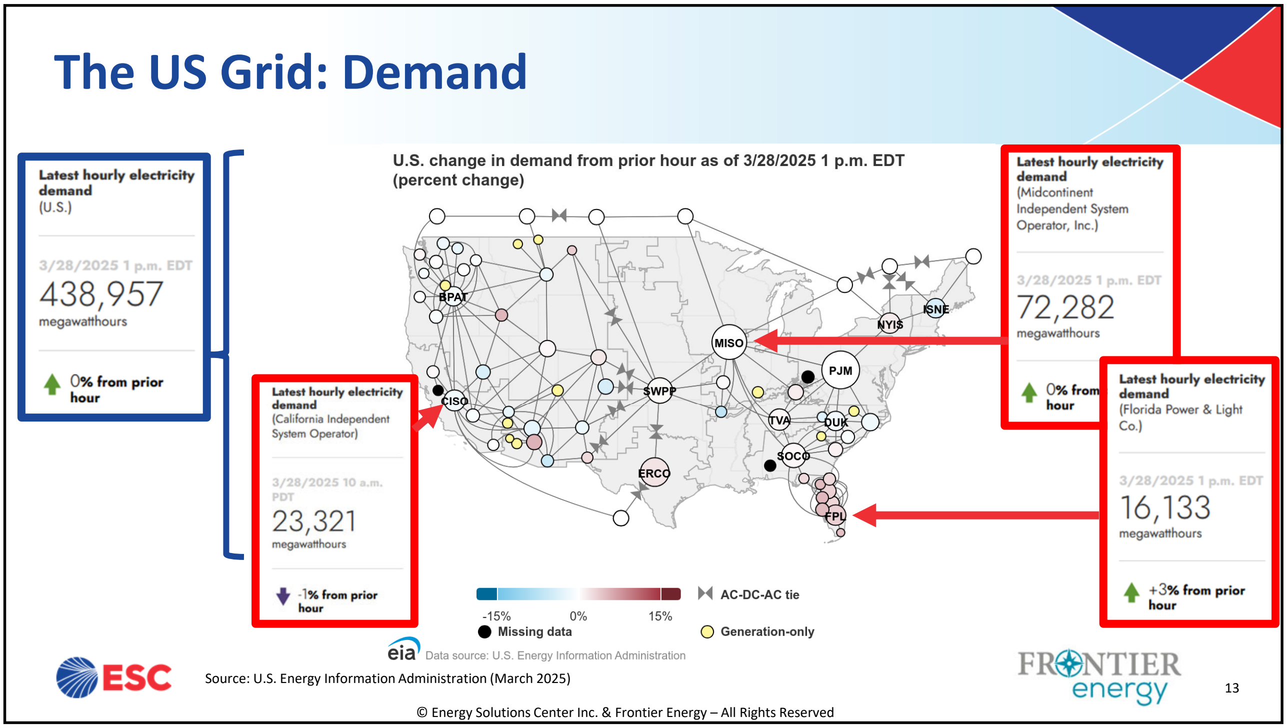
The Grid in Practice


The US Grid: Demand
Latest hourly electricity demand
(U.S.)
3/28/2025 1 p.m. EDT
438,957
megawatthours
0% from prior hour
U.S. change in demand from prior hour as of 3/28/2025 1 p.m. EDT
(percent change)
Latest hourly electricity demand
(California Independent System Operator)
3/28/2025 10 a.m. PDT
23,321
megawatthours
-1% from prior hour
Latest hourly electricity demand
(Midcontinent Independent System Operator, Inc.)
3/28/2025 1 p.m. EDT
72,282
megawatthours
0% from prior hour
Latest hourly electricity demand
(Florida Power & Light Co.)
3/28/2025 1 p.m. EDT
16,133
megawatthours
+3% from prior hour
BPAT
CISO
SWPP
MISO
PJM
NYIS
ISNE
TVA
DUK
SOCO
ERCO
FPL
-15%
0%
15%
AC-DC-AC tie
Missing data
Generation-only
eia Data source: U.S. Energy Information Administration
Source: U.S. Energy Information Administration (March 2025)
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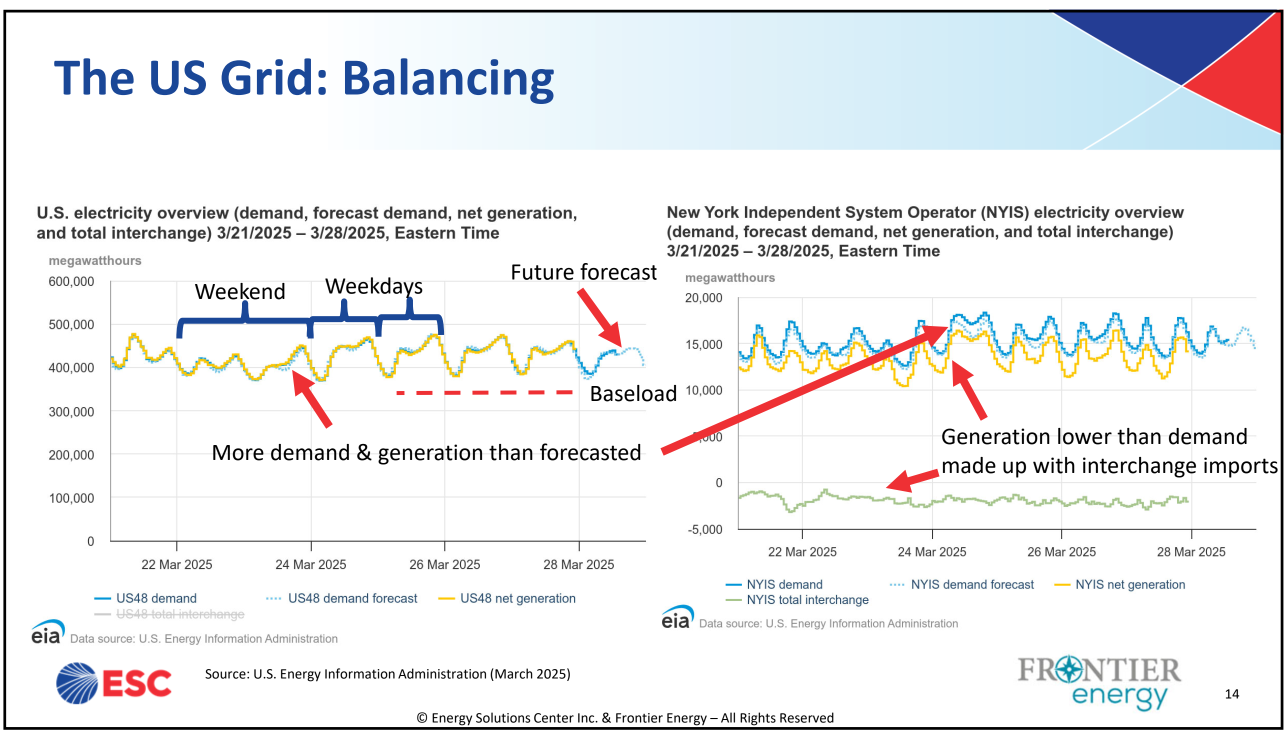
The US Grid: Balancing
U.S. electricity overview (demand, forecast demand, net generation, and total interchange) 3/21/2025 – 3/28/2025, Eastern Time
megawatthours
600,000
500,000
400,000
300,000
200,000
100,000
0
22 Mar 2025
24 Mar 2025
26 Mar 2025
28 Mar 2025
Weekend
Weekdays
Future forecast
Baseload
More demand & generation than forecasted
US48 demand
US48 demand forecast
US48 net generation
US48 total interchange
eia Data source: U.S. Energy Information Administration
New York Independent System Operator (NYIS) electricity overview (demand, forecast demand, net generation, and total interchange) 3/21/2025 – 3/28/2025, Eastern Time
megawatthours
20,000
15,000
10,000
0
-5,000
22 Mar 2025
24 Mar 2025
26 Mar 2025
28 Mar 2025
Generation lower than demand
made up with interchange imports
NYIS demand
NYIS demand forecast
NYIS net generation
NYIS total interchange
eia Data source: U.S. Energy Information Administration
Source: U.S. Energy Information Administration (March 2025)
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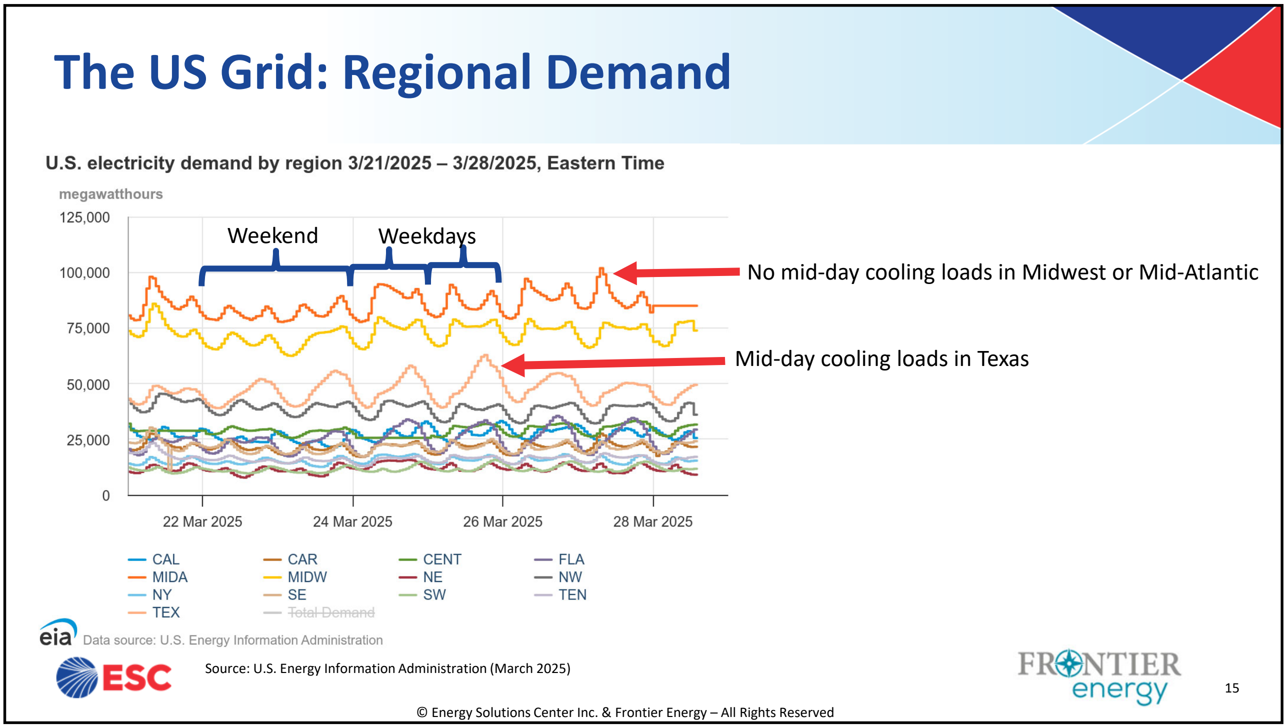
The US Grid: Regional Demand
U.S. electricity demand by region 3/21/2025 – 3/28/2025, Eastern Time
megawatthours
125,000
100,000
75,000
50,000
25,000
0
22 Mar 2025
24 Mar 2025
26 Mar 2025
28 Mar 2025
Weekend
Weekdays
No mid-day cooling loads in Midwest or Mid-Atlantic
Mid-day cooling loads in Texas
CAL
MIDA
NY
TEX
CAR
MIDW
SE
Total Demand
CENT
NE
SW
FLA
NW
TEN
eia Data source: U.S. Energy Information Administration
ESC
Source: U.S. Energy Information Administration (March 2025)
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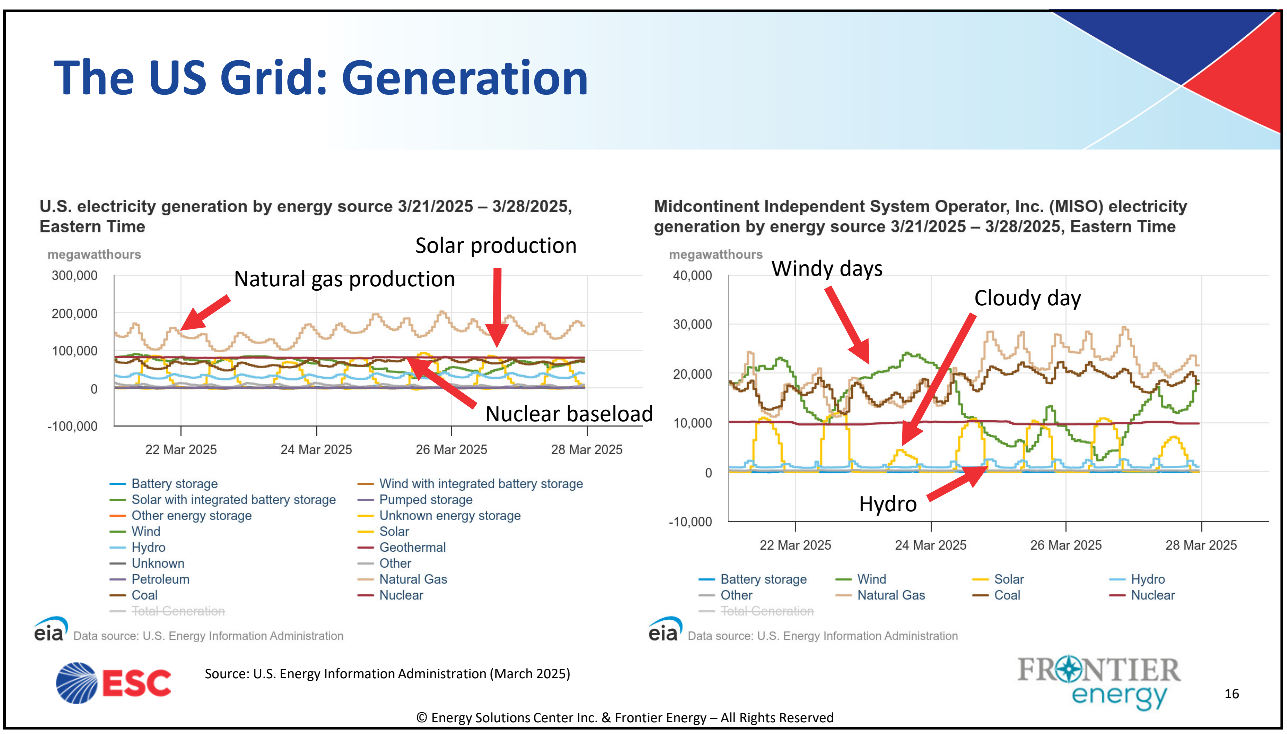
The US Grid: Generation
U.S. electricity generation by energy source 3/21/2025 – 3/28/2025, Eastern Time
megawatthours
300,000
200,000
100,000
0
-100,000
22 Mar 2025
24 Mar 2025
26 Mar 2025
28 Mar 2025
Natural gas production
Solar production
Nuclear baseload
Battery storage
Solar with integrated battery storage
Other energy storage
Wind
Hydro
Unknown
Petroleum
Coal
Total Generation
Wind with integrated battery storage
Pumped storage
Unknown energy storage
Solar
Geothermal
Other
Natural Gas
Nuclear
eia Data source: U.S. Energy Information Administration
Midcontinent Independent System Operator, Inc. (MISO) electricity generation by energy source 3/21/2025 – 3/28/2025, Eastern Time
megawatthours
40,000
30,000
20,000
10,000
0
-10,000
22 Mar 2025
24 Mar 2025
26 Mar 2025
28 Mar 2025
Windy days
Cloudy day
Hydro
Battery storage
Other
Total Generation
Wind
Natural Gas
Solar
Coal
Hydro
Nuclear
eia Data source: U.S. Energy Information Administration
ESC
Source: U.S. Energy Information Administration (March 2025)
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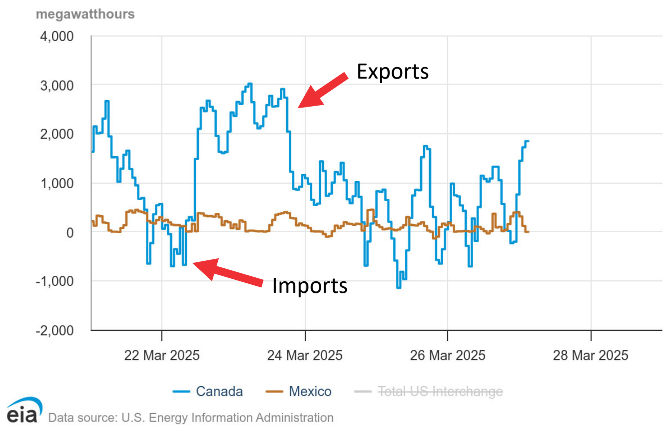
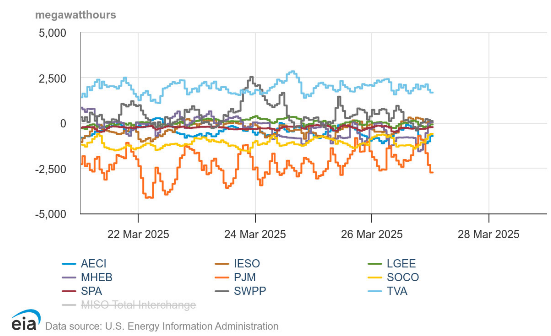
The US Grid: Interchange

U.S. electricity interchange with neighboring countries 3/21/2025 – 3/28/2025, Eastern Time



Midcontinent Independent System Operator, Inc. (MISO) electricity interchange with neighboring balancing authorities 3/21/2025 – 3/28/2025, Eastern Time



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

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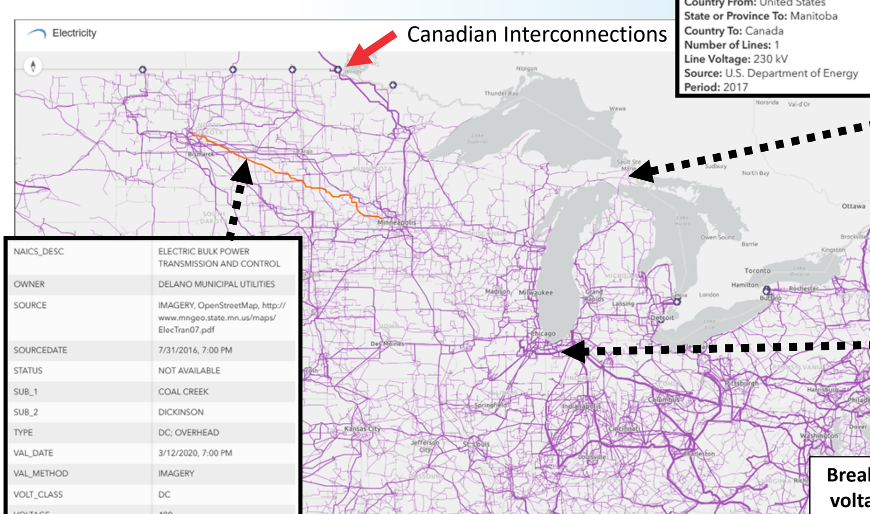
The US Grid: Transmission

Name of Electric Line: Roseau county 230
Owner: Minnkota Power Coop
City (Site Name): Roseau County
County: Roseau
State: Minnesota
State or Province From: Minnesota
Country From: United States
State or Province To: Manitoba
Country To: Canada
Number of Lines: 1
Line Voltage: 230 kV
Source: U.S. Department of Energy
Period: 2017

NAICS_DESC	ELECTRIC BULK POWER TRANSMISSION AND CONTROL
OWNER	NOT AVAILABLE
SOURCE	IMAGERY, http://www.atcllc.com/wp-content/uploads/2014/03/ATC-Territory-34x34-January-2014.pdf
SOURCEDATE	11/30/2016, 6:00 PM
STATUS	IN SERVICE
SUB_1	9 MILE SW STA
SUB_2	TAP139929
TYPE	AC; OVERHEAD
VAL_DATE	3/16/2020, 7:00 PM
VAL_METHOD	IMAGERY
VOLT_CLASS	UNDER 100
VOLTAGE	69



NAICS_DESC	ELECTRIC BULK POWER TRANSMISSION AND CONTROL
OWNER	DELANO MUNICIPAL UTILITIES
SOURCE	IMAGERY, OpenStreetMap, http://www.mngeo.state.mn.us/maps/ElecTran07.pdf
SOURCEDATE	7/31/2016, 7:00 PM
STATUS	NOT AVAILABLE
SUB_1	COAL CREEK
SUB_2	DICKINSON
TYPE	DC; OVERHEAD
VAL_DATE	3/12/2020, 7:00 PM
VAL_METHOD	IMAGERY
VOLT_CLASS	DC
VOLTAGE	400

NAICS_DESC	ELECTRIC BULK POWER TRANSMISSION AND CONTROL
OWNER	COMED
SOURCE	IMAGERY, OpenStreetMap, http://www.pjm.com/pub/account/trans-fac/aepsct.xls
SOURCEDATE	3/30/2015, 7:00 PM
STATUS	IN SERVICE
SUB_1	WILTON
SUB_2	DUMONT
TYPE	AC; OVERHEAD
VAL_DATE	2/11/2016, 6:00 PM
VAL_METHOD	IMAGERY
VOLT_CLASS	735 AND ABOVE
VOLTAGE	765

Breakout voltages in kV

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

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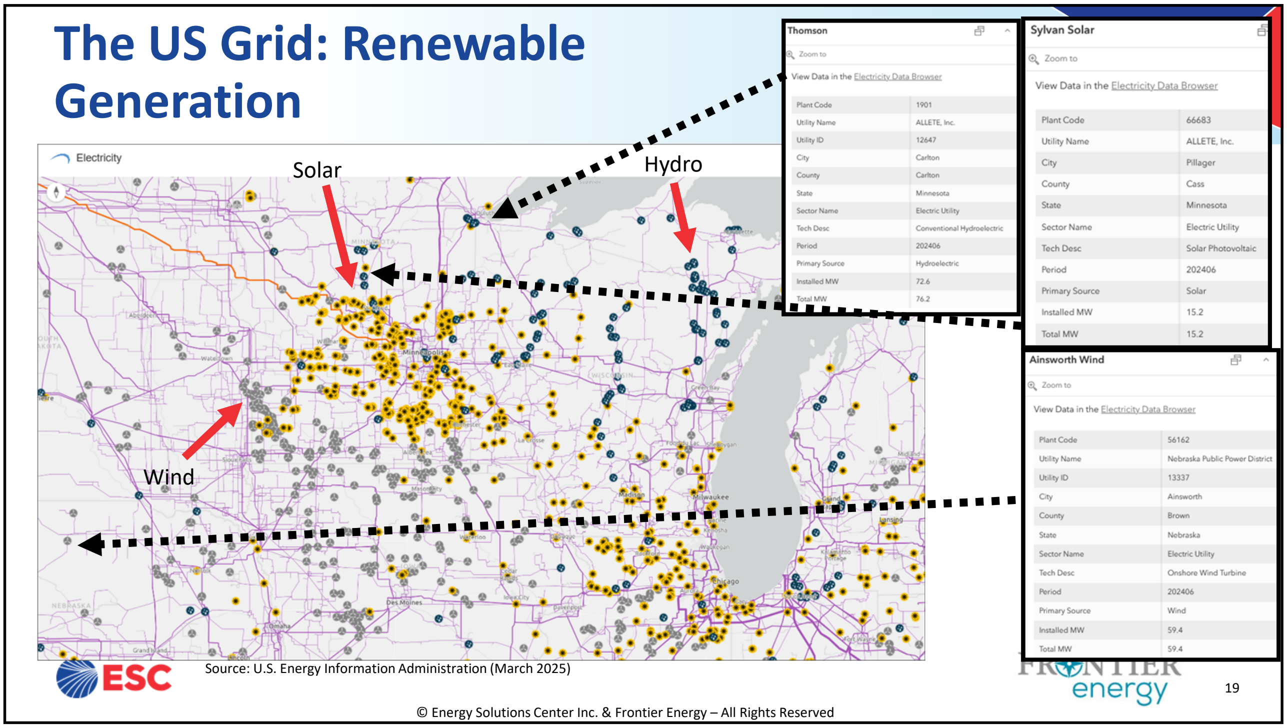
The US Grid: Renewable Generation
Electricity
Solar
Hydro
Wind
Thomson
Zoom to
View Data in the Electricity Data Browser
Plant Code 1901
Utility Name ALLETE, Inc.
Utility ID 12647
City Carlton
County Carlton
State Minnesota
Sector Name Electric Utility
Tech Desc Conventional Hydroelectric
Period 202406
Primary Source Hydroelectric
Installed MW 72.6
Total MW 76.2
Sylvan Solar
Zoom to
View Data in the Electricity Data Browser
Plant Code 66683
Utility Name ALLETE, Inc.
City Pillager
County Cass
State Minnesota
Sector Name Electric Utility
Tech Desc Solar Photovoltaic
Period 202406
Primary Source Solar
Installed MW 15.2
Total MW 15.2
Ainsworth Wind
Zoom to
View Data in the Electricity Data Browser
Plant Code 56162
Utility Name Nebraska Public Power District
Utility ID 13337
City Ainsworth
County Brown
State Nebraska
Sector Name Electric Utility
Tech Desc Onshore Wind Turbine
Period 202406
Primary Source Wind
Installed MW 59.4
Total MW 59.4
ESC
Source: U.S. Energy Information Administration (March 2025)
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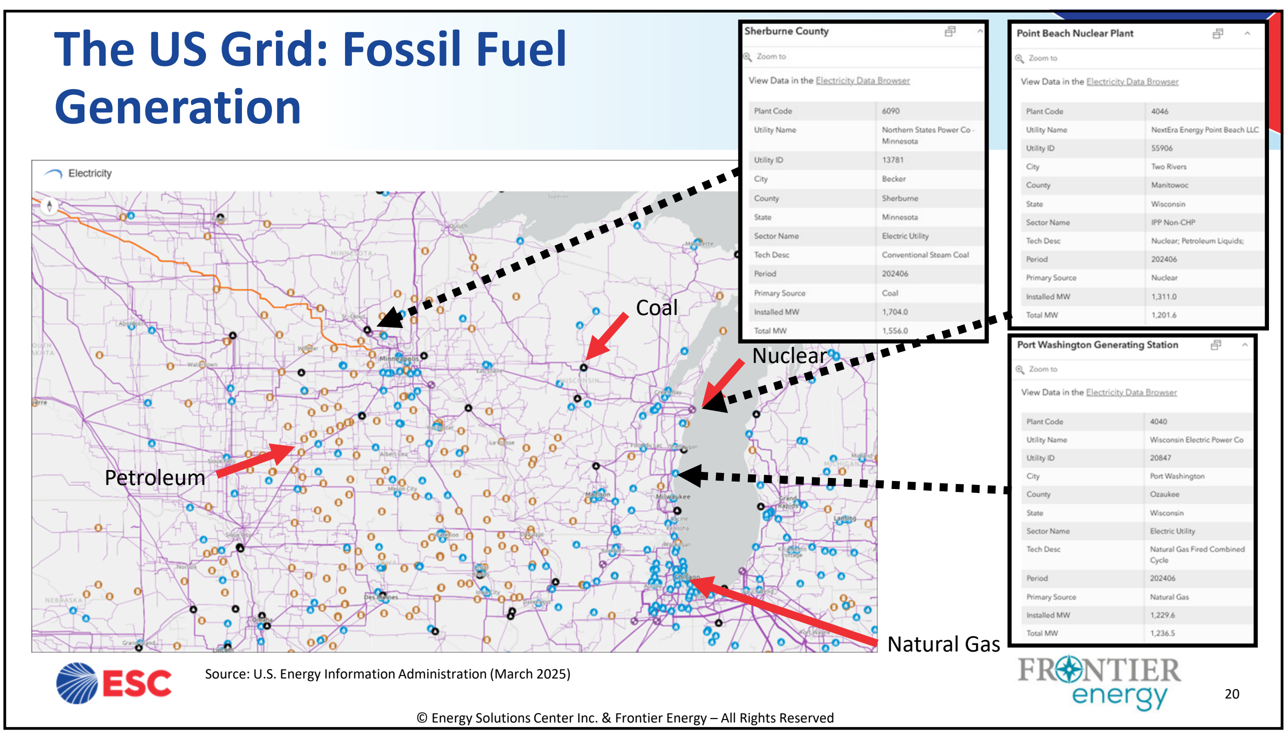
The US Grid: Fossil Fuel Generation
Electricity
Coal
Nuclear
Petroleum
Natural Gas
Sherburne County
Zoom to
View Data in the Electricity Data Browser
Plant Code 6090
Utility Name Northern States Power Co - Minnesota
Utility ID 13781
City Becker
County Sherburne
State Minnesota
Sector Name Electric Utility
Tech Desc Conventional Steam Coal
Period 202406
Primary Source Coal
Installed MW 1,704.0
Total MW 1,556.0
Point Beach Nuclear Plant
Zoom to
View Data in the Electricity Data Browser
Plant Code 4046
Utility Name NextEra Energy Point Beach LLC
Utility ID 55906
City Two Rivers
County Manitowoc
State Wisconsin
Sector Name IPP Non-CHP
Tech Desc Nuclear; Petroleum Liquids;
Period 202406
Primary Source Nuclear
Installed MW 1,311.0
Total MW 1,201.6
Port Washington Generating Station
Zoom to
View Data in the Electricity Data Browser
Plant Code 4040
Utility Name Wisconsin Electric Power Co
Utility ID 20847
City Port Washington
County Ozaukee
State Wisconsin
Sector Name Electric Utility
Tech Desc Natural Gas Fired Combined Cycle
Period 202406
Primary Source Natural Gas
Installed MW 1,229.6
Total MW 1,236.5
ESC
Source: U.S. Energy Information Administration (March 2025)
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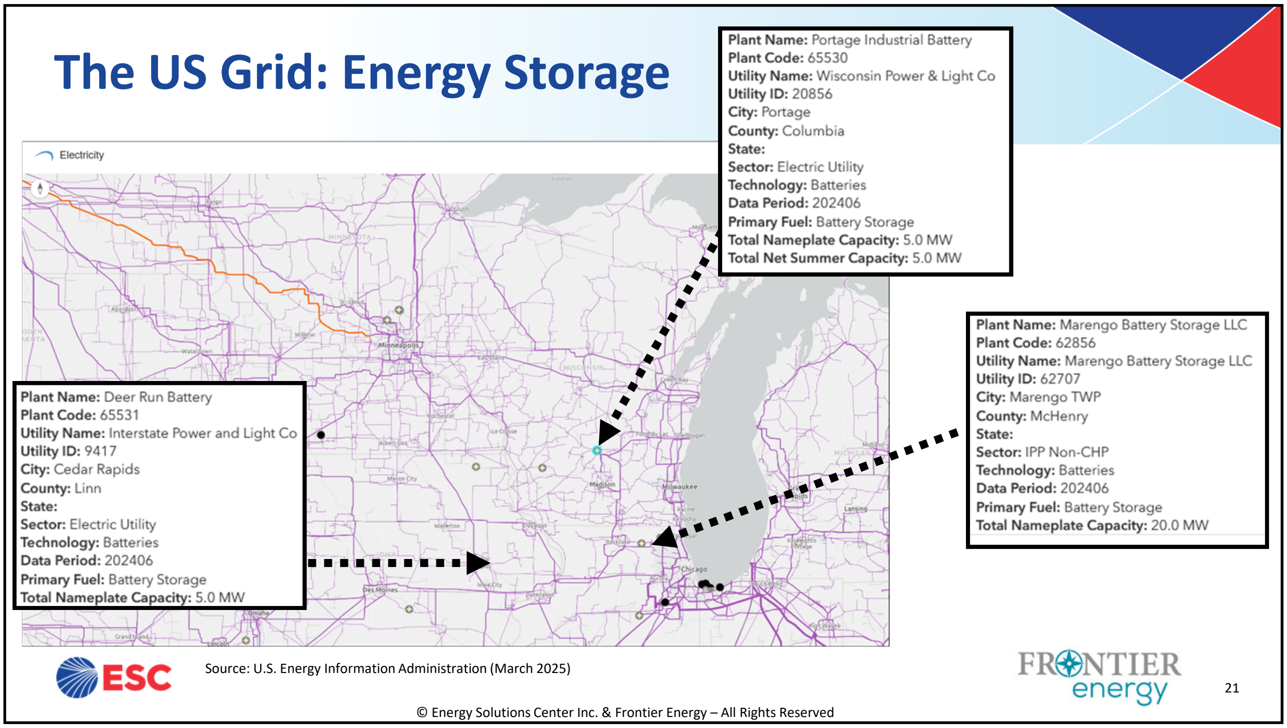
The US Grid: Energy Storage
Electricity
Plant Name: Portage Industrial Battery
Plant Code: 65530
Utility Name: Wisconsin Power & Light Co
Utility ID: 20856
City: Portage
County: Columbia
State:
Sector: Electric Utility
Technology: Batteries
Data Period: 202406
Primary Fuel: Battery Storage
Total Nameplate Capacity: 5.0 MW
Total Net Summer Capacity: 5.0 MW
Plant Name: Marengo Battery Storage LLC
Plant Code: 62856
Utility Name: Marengo Battery Storage LLC
Utility ID: 62707
City: Marengo TWP
County: McHenry
State:
Sector: IPP Non-CHP
Technology: Batteries
Data Period: 202406
Primary Fuel: Battery Storage
Total Nameplate Capacity: 20.0 MW
Plant Name: Deer Run Battery
Plant Code: 65531
Utility Name: Interstate Power and Light Co
Utility ID: 9417
City: Cedar Rapids
County: Linn
State:
Sector: Electric Utility
Technology: Batteries
Data Period: 202406
Primary Fuel: Battery Storage
Total Nameplate Capacity: 5.0 MW
ESC
Source: U.S. Energy Information Administration (March 2025)
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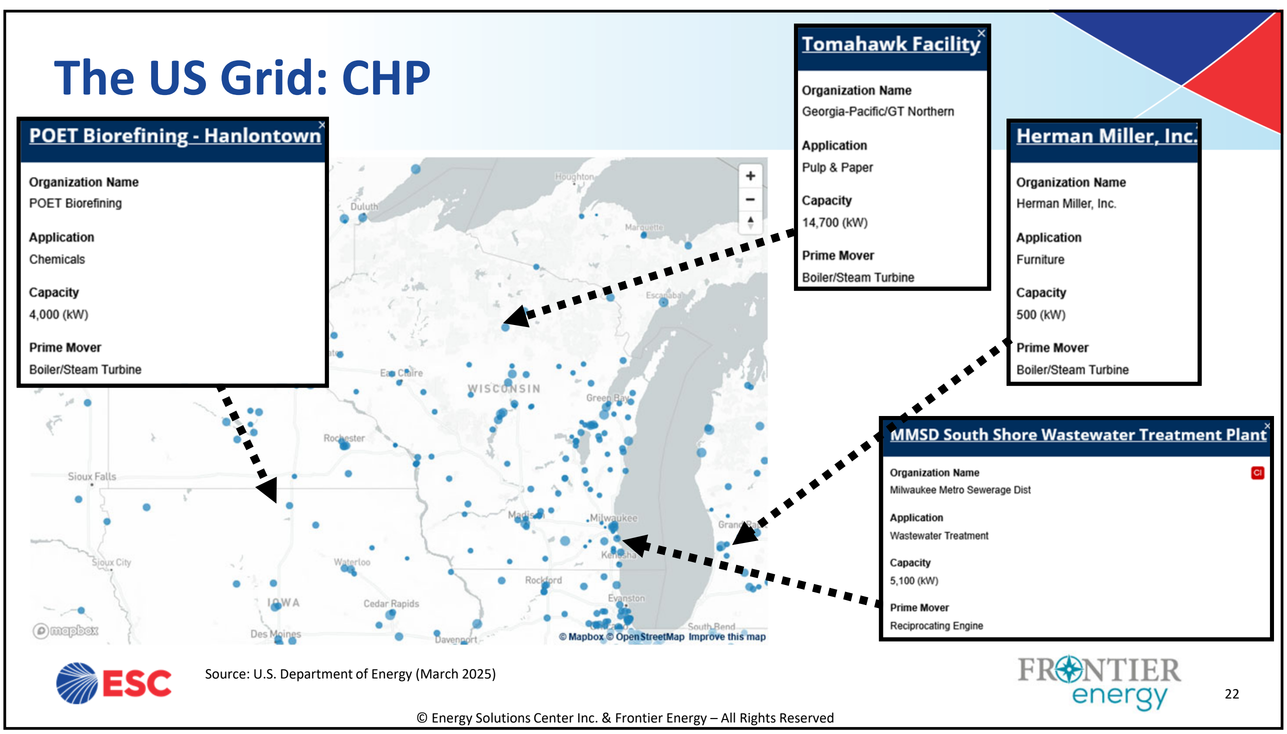
The US Grid: CHP
POET Biorefining - Hanlontown
Organization Name
POET Biorefining
Application
Chemicals
Capacity
4,000 (kW)
Prime Mover
Boiler/Steam Turbine
Tomahawk Facility
Organization Name
Georgia-Pacific/GT Northern
Application
Pulp & Paper
Capacity
14,700 (kW)
Prime Mover
Boiler/Steam Turbine
Herman Miller, Inc.
Organization Name
Herman Miller, Inc.
Application
Furniture
Capacity
500 (kW)
Prime Mover
Boiler/Steam Turbine
MMSD South Shore Wastewater Treatment Plant
Organization Name
Milwaukee Metro Sewerage Dist
Application
Wastewater Treatment
Capacity
5,100 (kW)
Prime Mover
Reciprocating Engine
WISCONSIN
IOWA
© Mapbox © OpenStreetMap Improve this map
ESC
Source: U.S. Department of Energy (March 2025)
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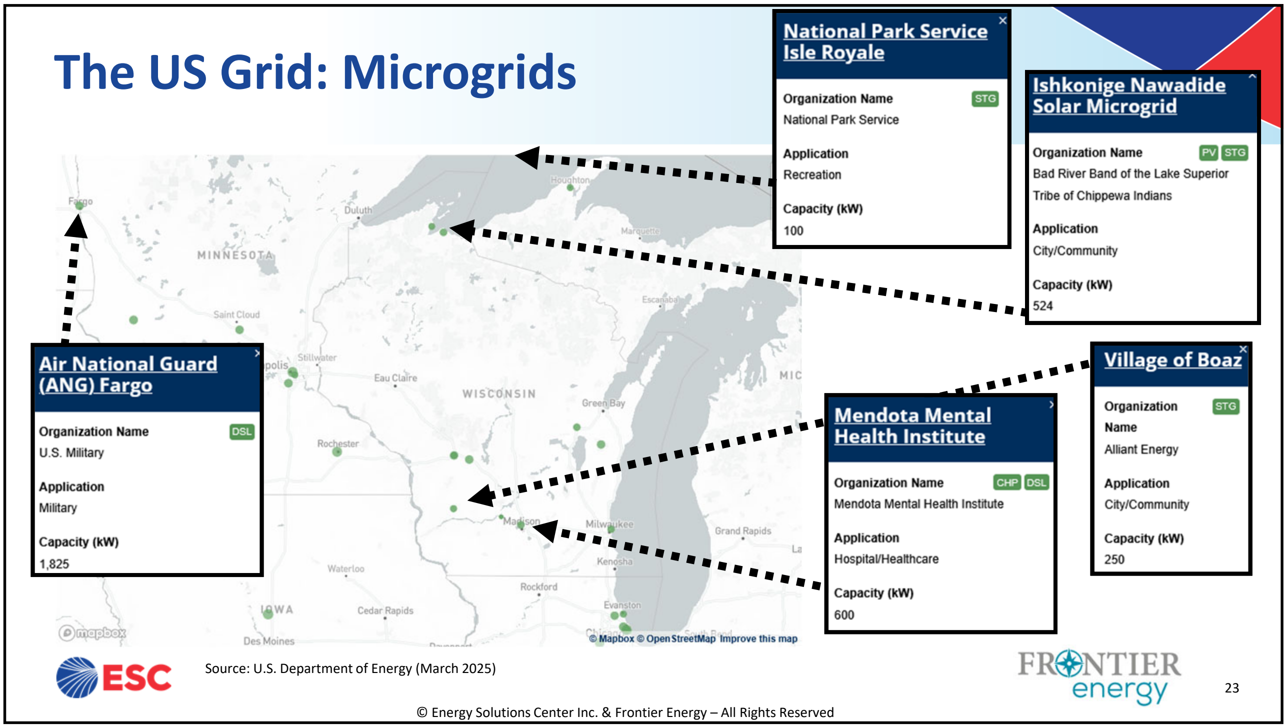
The US Grid: Microgrids
National Park Service Isle Royale
Organization Name
STG
National Park Service
Application
Recreation
Capacity (kW)
100
Ishkonige Nawadide Solar Microgrid
Organization Name
PV STG
Bad River Band of the Lake Superior Tribe of Chippewa Indians
Application
City/Community
Capacity (kW)
524
Air National Guard (ANG) Fargo
Organization Name
DSL
U.S. Military
Application
Military
Capacity (kW)
1,825
Mendota Mental Health Institute
Organization Name
CHP DSL
Mendota Mental Health Institute
Application
Hospital/Healthcare
Capacity (kW)
600
Village of Boaz
Organization Name
STG
Alliant Energy
Application
City/Community
Capacity (kW)
250
MINNESOTA
WISCONSIN
IOWA
© Mapbox © OpenStreetMap Improve this map
ESC
Source: U.S. Department of Energy (March 2025)
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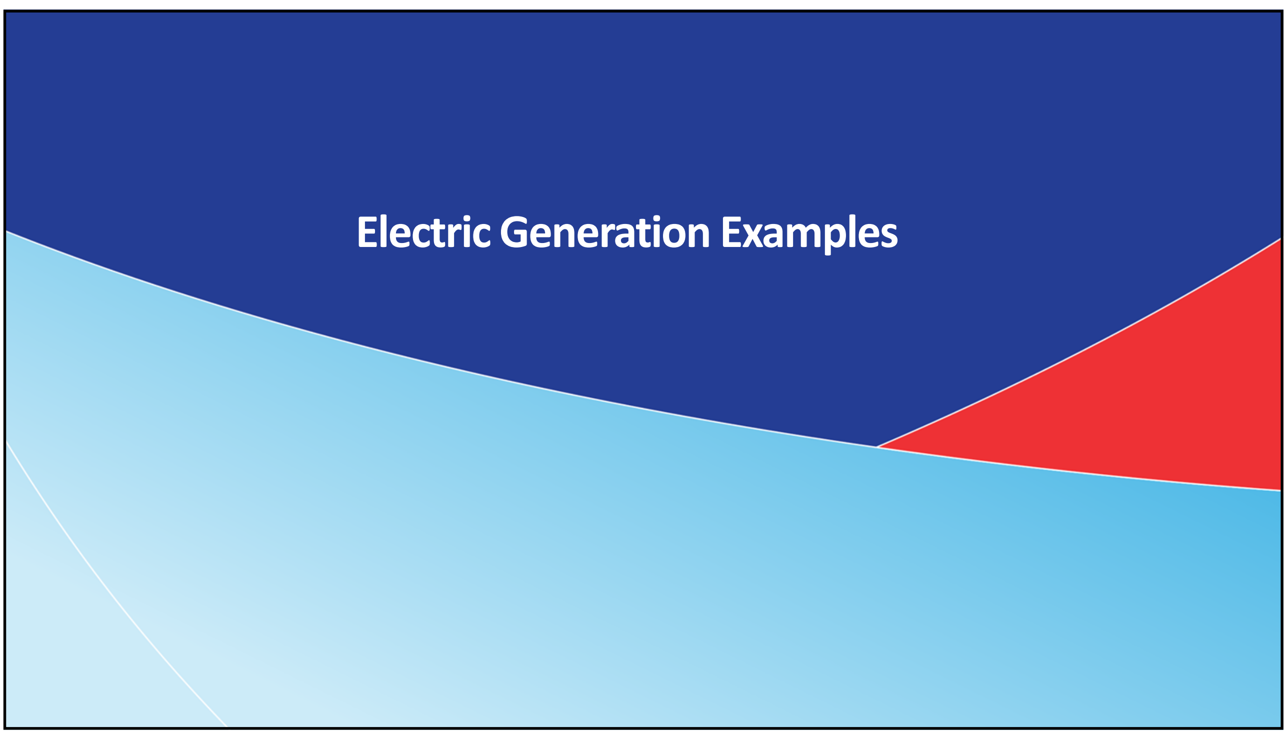
Electric Generation Examples

Nuclear Power Plant
Two Rivers, WI

This 1960s nuclear plant has two reactors that boil water to create steam. It generates about 16% of all Wisconsin-produced electricity.

Capacity Factor (2024): 96%

By Yodel2010 - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=137493246

Point Beach Nuclear Plant

Zoom to

View Data in the Electricity Data Browser

Plant Code	4046
Utility Name	NextEra Energy Point Beach LLC
Utility ID	55906
City	Two Rivers
County	Manitowoc
State	Wisconsin
Sector Name	IPP Non-CHP
Tech Desc	Nuclear; Petroleum Liquids;
Period	202406
Primary Source	Nuclear
Installed MW	1,311.0
Total MW	1,201.6

https://atlas.eia.gov/
https://en.wikipedia.org/wiki/Point_Beach_Nuclear_Plant

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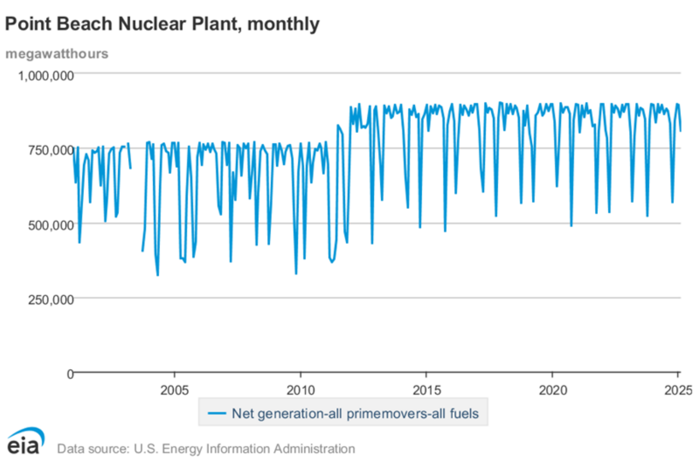
Nuclear Power Plant
Two Rivers, WI



- Primarily operates as a grid baseload.
- Dips in production happen primarily in shoulder months.

https://atlas.eia.gov/
https://en.wikipedia.org/wiki/Point_Beach_Nuclear_Plant

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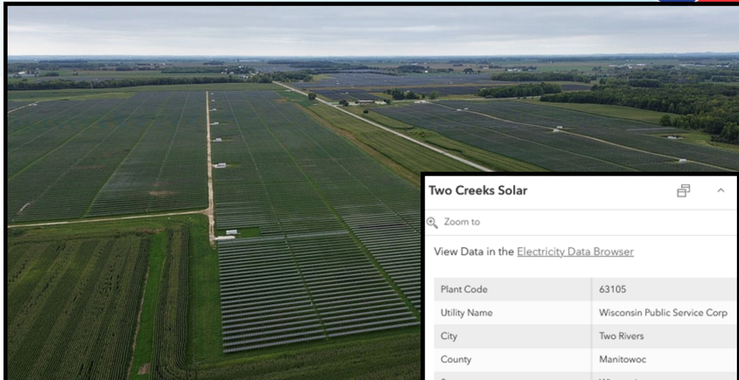
Solar Power Installation Two Creeks, WI

This 2020 solar installation is the first utility-scale solar plant constructed in Wisconsin.

Consists of 533,000 PV 2x1 meter panels covering 800 acres.

Capacity Factor (2024): 15%



By Yodel2010 - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=137494962

Two Creeks Solar

Zoom to

View Data in the Electricity Data Browser

Plant Code	63105
Utility Name	Wisconsin Public Service Corp
City	Two Rivers
County	Manitowoc
State	Wisconsin
Sector Name	Electric Utility
Tech Desc	Solar Photovoltaic
Period	202406
Primary Source	Solar
Installed MW	150.0
Total MW	150.0

https://atlas.eia.gov/
https://en.wikipedia.org/wiki/Two_Creeks_Solar_Park

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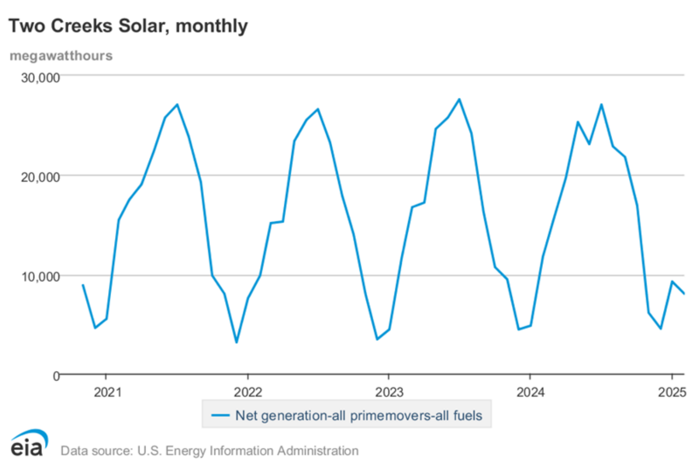
Solar Power Installation Two Creeks, WI



- Dips in production happen in winter months as sun is not as direct.
- Low capacity factor, but generally high output during peak demand periods.

https://atlas.eia.gov/
https://en.wikipedia.org/wiki/Two_Creeks_Solar_Park

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Wind Power Installation
Fond du Lac County, WI

88 wind turbines installed in 2008.

Generators operate at 600 volts and 3-phase.

Cut-in wind speed is 8mph.

Cut-out wind speed is 54mph.

Capacity Factor (2024): 26%


Blue Sky Green Field Wind Project

Zoom to

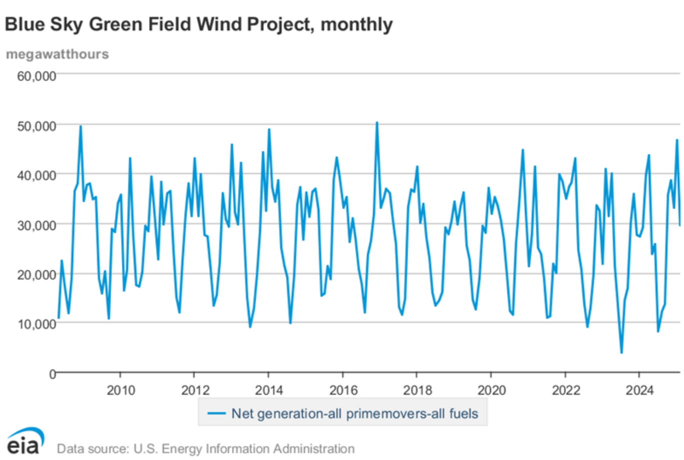
View Data in the Electricity Data Browser

Plant Code	56391
Utility Name	Wisconsin Electric Power Co
Utility ID	20847
City	Fond du Lac
County	Fond Du Lac
State	Wisconsin
Sector Name	Electric Utility
Tech Desc	Onshore Wind Turbine
Period	202406
Primary Source	Wind
Installed MW	145.2
Total MW	145.2

https://atlas.eia.gov/
https://en.wikipedia.org/wiki/Blue_Sky_Green_Field_Wind_Energy_Center

29

Wind Power Installation
Fond du Lac County, WI



- Dips in production happen in summer months.

https://atlas.eia.gov/
https://en.wikipedia.org/wiki/Blue_Sky_Green_Field_Wind_Energy_Center

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Coal Power Plant Sheboygan, WI

This 1930s coal-powered plant has most recently installed a boiler in 1985. Coal delivered by Lake Michigan routes and by rail.

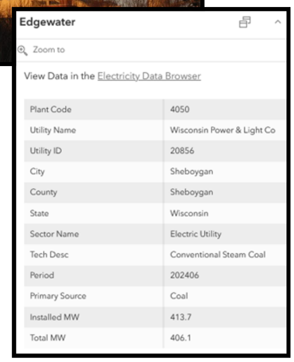
Net Generating Capacity (2024): 406.1 MW

Power Generated (2024): 2,092,135 MWh

Capacity Factor (2024): 59%

$$2{,}092{,}135 \text{ MWh} / (406.1 \text{ MW} \times 365 \frac{\text{days}}{\text{year}} \times 24 \frac{\text{hours}}{\text{day}})$$

By Royalbroil - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=37089955



Edgewater

Zoom to

View Data in the Electricity Data Browser

Plant Code	4050
Utility Name	Wisconsin Power & Light Co
Utility ID	20856
City	Sheboygan
County	Sheboygan
State	Wisconsin
Sector Name	Electric Utility
Tech Desc	Conventional Steam Coal
Period	202406
Primary Source	Coal
Installed MW	413.7
Total MW	406.1

https://atlas.eia.gov/
https://en.wikipedia.org/wiki/Edgewater_Generating_Station
https://www.wpr.org/energy/alliant-energy-plans-to-convert-sheboygan-coal-plant-to-natural-gas-in-2028

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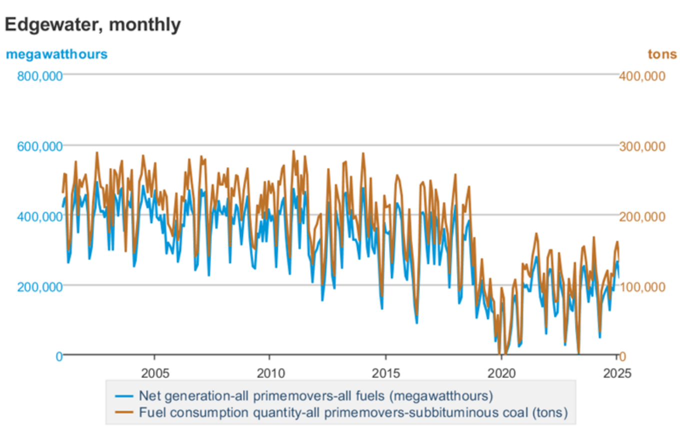
Coal Power Plant Sheboygan, WI



- Recent retirement of additional boilers has reduced total generating capacity.
- Peaking plant usage creates periods of no or little use.
- Little change to efficiency over time.

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Natural Gas Power Plant Port Washington, WI

This 1930s coal-powered plant, using highest-pressure boiler of its time, was converted in late 2000s to natural gas. The newer combined cycle technology more than doubled the efficiency of the original plant.

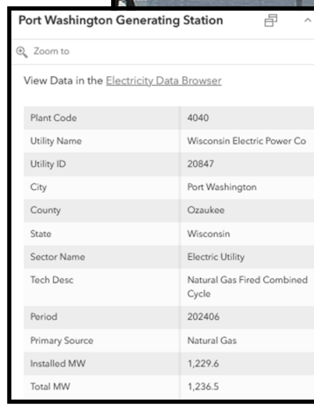
Two power blocks. Each consists of:

- Two combustion-turbine generators
- One steam turbine generator
- Two stacks

Uses Lake Michigan water (over 500,000 gallons per minute) to condense exhaust steam to water for reuse.

Capacity Factor (2024): 70%

By Freekee - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=7306657



Port Washington Generating Station

Zoom to

View Data in the Electricity Data Browser

Plant Code	4040
Utility Name	Wisconsin Electric Power Co
Utility ID	20847
City	Port Washington
County	Ozaukee
State	Wisconsin
Sector Name	Electric Utility
Tech Desc	Natural Gas Fired Combined Cycle
Period	202406
Primary Source	Natural Gas
Installed MW	1,229.6
Total MW	1,236.5

https://atlas.eia.gov/
https://www.we-energies.com/company/pdf/pwgs.pdf
https://www.powermag.com/port-washington-generating-station-phase-2-port-washington-wisconsin/
https://en.wikipedia.org/wiki/Port_Washington_Generating_Station
https://www.asme.org/wwwasmeorg/media/resourcefiles/aboutasme/who%20we%20are/engineering%20history/landmarks/51-port-washington-power-plant.pdf

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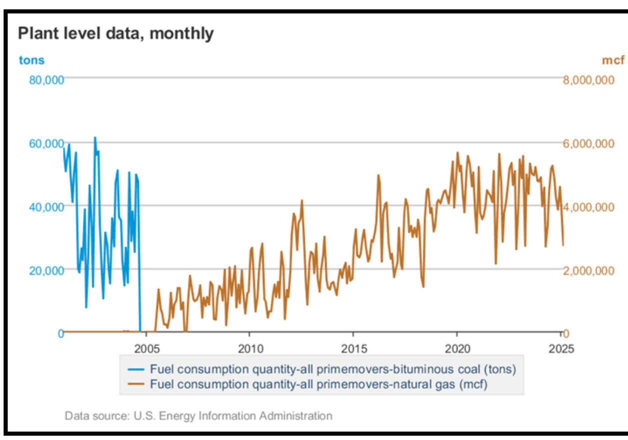
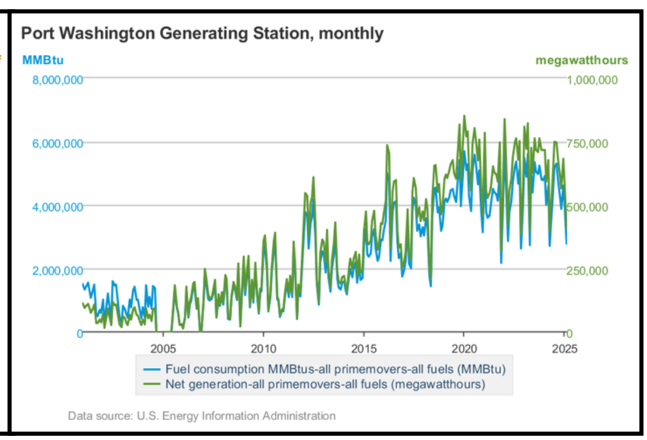
Natural Gas Power Plant Port Washington, WI

Fuel switchover (note unequal units)



Increase in efficiency



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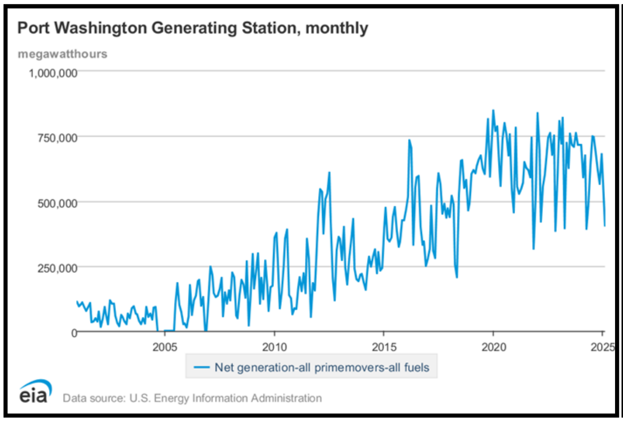
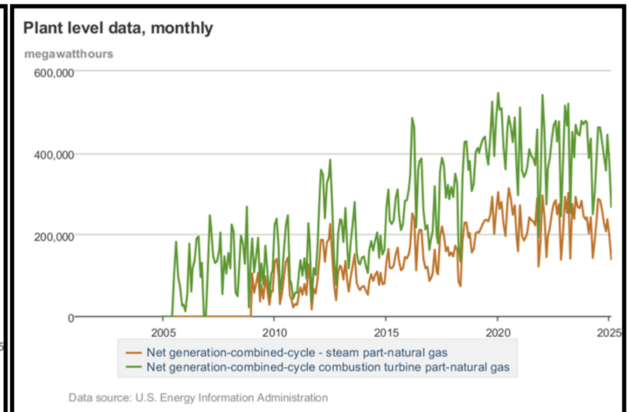
Natural Gas Power Plant
Port Washington, WI

Generation has increased significantly since conversion to natural gas.



Combined-cycle steam turbine is capturing 35% of total power generated.



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Trends & Commentary

Electrification

*"**Electrification** converts an energy-consuming device, system, or sector from non-electric sources of energy to electricity. It's an emerging economy-wide decarbonization strategy that is beginning to impact the electric power industry. "* – DOE

Electrification is a pathway that can support the following goals, but not necessarily in all scenarios.

- Carbon reduction
- Cost savings
- Grid flexibility
- Safety and reliability

Beneficial electrification is electrification that achieves at least one of the following goals:

- Saves consumers money over time.
- Benefits the environment and reduces greenhouse gas emissions.
- Improves product quality or consumer quality of life.
- Fosters a more robust or resilient grid.

Electrification's benefits are highly dependent on many different factors and is not always beneficial.

https://www.energy.gov/electricity-insights/what-electrification

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Commentary - Electrification

*"**Transportation, buildings, industry, and agriculture** are the economic sectors that are **beginning to electrify**. Within the transportation sector, individual light-duty **electric vehicles (EVs)** are increasing in popularity. Companies are electrifying their fleets of medium- and heavy-duty vehicles to **improve air quality** through reduced emissions. Some cities have set goals to electrify public transportation, school bus fleets, airports and shipyards.*

*New residential and commercial buildings now include electric appliances, including **heat pumps, water heaters, and electric or induction cooktops**, while existing buildings are being retrofitted with electric technology that is more efficient, reliable, and flexible.*

*The electrification of industrial processes and equipment, such as **electric forklifts or rock crushers**, can **improve indoor air quality and lower noise levels** in plants, factories, and warehouses. In agribusiness, electrifying **farm equipment** like tractors, field sprayers, and waste lagoon pumps will provide **energy and maintenance cost savings**."*

–DOE

"The U.S. power system can operate under [future] *scenarios with widespread electrification—and associated changes to electricity demand patterns—with high levels of VRE penetration (66% of annual national generation) through the expansion and investment in existing commercial technologies."* – NREL

https://www.energy.gov/electricity-insights/what-electrification
https://www.nrel.gov/docs/fy21osti/79094.pdf

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Focus on Transmission

Transmission is being put in the spotlight.

- While power generation efficiency sets a baseline for grid efficiency, transmission is key to grid efficiency as a whole.
- Resources for energy generation are not always where demand is. Infrastructure planning is important to efficiently and effectively leverage these resources.
- Insufficient transmission pathways limit electricity delivery. Flexibility is vital to address grid congestion.
- Demand is increasing and patterns are changing. AI, electric vehicles, LED lighting, digital electronics, and more are playing a role.
- Transmission technologies are changing. HVDC, advanced modeling and AI, smart meters and other technologies, connected equipment, remote monitoring and control capabilities.
- Distributed generation and grid-scale energy storage are both increasing grid efficiency and adding new infrastructure challenges.
- Aging plants and infrastructure need replacement.
- New threats emerging from weather, humans, and the digital world.

National Transmission Analysis Maps Next Chapter of US Grid Evolution | News | NREL

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Commentary – Distributed Grid

"A range of more distributed technologies—including flexible demand, distributed generation, energy storage, and advanced power electronics and control devices—is creating new options for the provision and consumption of electricity services." – MIT

"Distributed energy resources can be sited and operated to provide services in those areas of the power system where their services are most valuable. Understanding the specific services that have locational value is thus critical to understanding how distributed resources can create value in power systems" – MIT

https://energy.mit.edu/wp-content/uploads/2016/12/Utility-of-the-Future-Executive-Summary.pdf

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Commentary – Artificial Intelligence

"…with a more accurate picture of peaks in [renewables] *output, companies like Google are able to shift the timing of peak consumption, such as during heavy computing loads, to coincide with them. Doing so avoids the need to buy additional power from the market."* – IEA

"One of the most common uses for AI by the energy sector has been to improve predictions of supply and demand… Another key AI application is predictive maintenance, where the performance of energy assets is continuously monitored and analysed to identify potential faults ahead of time." – IEA

"Without AI, system operators and utilities will only be able to make effective use of a fraction of the new data sources and processes offered by emerging digital technologies, and they will miss out on a significant proportion of the benefits on offer. However, risks associated with AI must also be considered and addressed before the technology is scaled across the sector. These include, but are not limited to, threats to cybersecurity and privacy, the influence of biases or errors in data, and miscorrelations due to insufficient training, data or coding mistakes." - IEA

https://www.iea.org/commentaries/why-ai-and-energy-are-the-new-power-couple

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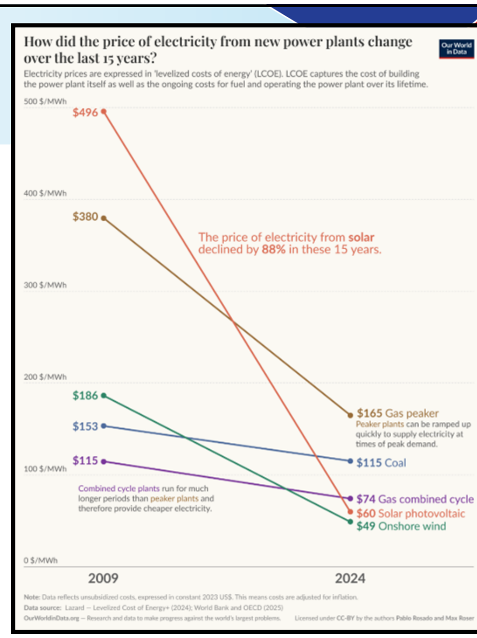
Increased Role for Renewables

Renewable energy sources are hitting economies of scale. Grid-scale solar and wind installations have become commonplace and now, along with hydroelectric, geothermal, and other renewable energy sources, account for 21% of US electricity generated. Other countries, such as Germany, have shown greater implementation is possible and practical.



Max Roser (2020) - "Why did renewables become so cheap so fast?" Published online at OurWorldinData.org. Retrieved from: 'https://ourworldindata.org/cheap-renewables-growth' [Online Resource]

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Energy Storage Rollout

Energy storage solutions are **already hitting grid scale implementation**, and **numerous different technologies** are being applied. While **costs are high**, real-world implementation at scale is helping the industry identify the technologies that meet grid needs and **future economies of scale** will bring costs down.

Energy storage stands to play several important roles:

- The grid without energy storage must always error on the side of more generation than demand. Energy storage can capture this extra energy in real time and put it to use when needed. This can **allow grid operators to more closely match grid production and consumption**, saving energy.
- The grid has cheap or excess energy generation available during periods of low demand. Grid-scale storage can **save this cheap energy for use during expensive peak demand**, lowering costs.
- Grid-scale electricity storage can **convert non-dispatchable power to dispatchable power**. Many non-dispatchable energy sources are renewable, meaning grid-scale storage can bridge the gap between renewable energy's inconsistent generation and the grid's need for reliable power.

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Rates, Efficiency, & Demand-side Management

Reducing grid demand from the customer side, especially peak demand and sharp demand swings, has huge potential to reduce generation and transmission costs. Many utilities are focusing on:

- **Restructuring rates** – Variable and time-of-use rates encourage customers to load-shift to off-peak times, and tiered rates encourage customers to lower consumption to benefit from rates in lower tiers.
- **Efficiency** – Customer-side efficiency reduces consumption, and all upstream production and infrastructure needed. Efficiency of equipment running during peak periods is especially impactful. ACs, refrigerators, lights, etc.
- **Demand-side management** – Smart technologies offer a way for utilities to better manage demand directly. Cycling customer ACs in batches during hot days, allowing customers to automatically run their dishwasher once rates decrease, incentivizing businesses to cut demand during critical peak periods, etc.

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Commentary – Rates

"Flat, volumetric tariffs are no longer adequate for today's power systems and are already responsible for inefficient investment, consumption, and operational decisions. Peak-coincident capacity charges that reflect users' contributions to incremental network costs incurred to meet peak demand and injection, as well as scarcity-coincident generating capacity charges, can unlock flexible demand and distributed resources and enable significant cost savings." – MIT

https://energy.mit.edu/wp-content/uploads/2016/12/Utility-of-the-Future-Executive-Summary.pdf

Commentary – Demand-Side Efforts

"Demand-side flexibility—mainly from optimized vehicle charging but also from flexible operations of other end-use equipment used in buildings and industry—can result in observable changes in how the power system operates, such as reduced system net load ramps and reduced thermal plant cycling." – NREL

"Assuming no or low operating costs with demand-side flexibility, flexible loads in highly electrified futures can lower power system operation costs by providing high-value grid services during periods of system stress and by increasing the utilization of more-efficient lower-cost units." – NREL

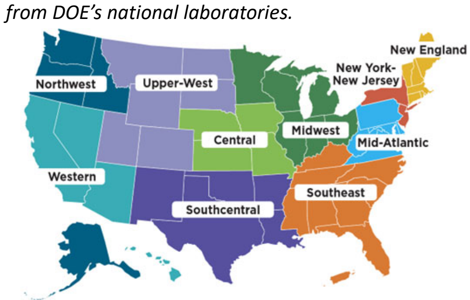
https://www.nrel.gov/docs/fy21osti/79094.pdf

Onsite Energy Technical Assistance Partnerships (TAPs)

Technical Assistance

The Onsite Energy Technical Assistance Partnerships (TAPs) provide direct technical assistance to industrial facilities and other large energy users with identifying and implementing technology options for achieving site-specific energy objectives. Technical assistance for end users can include a broad range of services in support of onsite energy project deployment, from the earliest stages of screening for multi-technology solutions, to the end stages of post-installation operation. The Onsite Energy TAPs also conduct outreach and engage with policymakers, utilities, and other key stakeholders to accelerate pathways for integration of onsite energy technologies. Additional activities include developing public tools and resources, sharing best practices, and building partnerships that drive efficiency across the U.S. industrial sector.

Each of the 10 Onsite Energy TAPs represents a multi-state area and brings specialized, regional knowledge to advise on economic, environmental, regulatory, and other issues impacting the adoption of onsite energy technologies. The Onsite Energy TAPs have expertise to advise on a variety of distributed energy technologies suitable for the industrial sector and are backed by world-class support from DOE's national laboratories.



https://betterbuildingssolutioncenter.energy.gov/onsite-energy/taps

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Onsite Energy

Technologies include:

- Battery Storage
- Combined Heat and Power
- District Energy
- Fuel Cells
- Geothermal
- Industrial Heat Pumps
- Renewable Fuels (biodiesel, ethanol, hydrogen, biogas, renewable natural gas, renewable diesel)
- Solar Photovoltaics
- Solar Thermal
- Thermal Storage
- Waste Heat to Power
- Wind Power

https://betterbuildingssolutioncenter.energy.gov/onsite-energy/taps

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Case Study: CHP at Freres Engineered Wood

Facility produces wood veneer and plywood, and operates a lumber mill and engineered mass timber facility.

Installed 10MW CHP plant that uses waste wood to operate steam boilers, which in turn provide steam and heat to processes and generate power for the plant and nearby residences. Energy is also used to make biochar for sale.

Project At-A-Glance

- SITE
  - **Location:** Lyons, Oregon
  - **Sector:** Forest Products
  - **Facility Size:** Total square feet of 700,000 at 3 plant sites
  - **Property Size:** Over 17,000 acres of forest under ownership
- TECHNOLOGY SOLUTIONS
  - **CHP System:**
    - Steam Boiler: Wellons, 100,000 PPH at 850 psi (875°F) steam boiler
    - Prime Mover: GE 10 MW double-extraction condensing turbine
    - Generator: GE 22,500 KVA, 13.8 KV synchronous generator
- IMPACT
  - **Annual CO_2 Avoided Onsite:** Over 23 million lbs.
  - **Annual Cost Savings:** ~$500,000
  - **Simple Payback Period:** 7 years
  - **Resilience:** Powering 5,000 nearby residences
  - **Biochar:** Producing 2,000 lbs./year, creating 3,500 Carbon Offset Credits
  - **Incentives:**
    - $11,965,075 - Oregon Department of Energy BETC (Business Energy Tax Credit)
    - ~$30,000 - Energy Trust of Oregon Production Efficiency Incentive for fuel storage buildings
    - ~$400,000/year - Federal Production Tax Credit ($.012/kWh)

https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Freres%20Engineered%20Wood%20Combined%20Heat%20and%20Power%20and%20Biochar%20Case%20Study.pdf

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Case Study: CHP at Computing Facility & Data Center

First National Bank of Omaha experienced interruptions with power for their data center which cost them millions of dollars. Installed 400kW natural gas fuel cell CHP system that provides power as well as heating. During winter, the building can rely on the system for 30% of its heating needs and for outdoor snow-melt purposes. In the summer, heat is used in the reheat system used to help dehumidify the space.

Quick Facts

LOCATION: Omaha, Nebraska
MARKET SECTOR: Computing Facility / Data Center
TOTAL CHP GENERATING CAPACITY: 400 kW
PRIME MOVER TYPE: Clear Edge PureCell 400 kW Fuel Cell
HEAT RECOVERY RATE: 1 MMBtu/hr hot water
FUEL TYPE: Natural Gas
CHP INSTALLATION COSTS: $3 million
BEGAN OPERATION: Replacement system commissioned November 2013 [original system installed 1999]
FACILITY RELIABILITY FACTOR: 99.9999%
NUMBER OF POWER INTERRUPTIONS: No unscheduled downtime since June 1999

https://chptap.ornl.gov/profile/79/FirstNationalBank-Project_Profile.pdf

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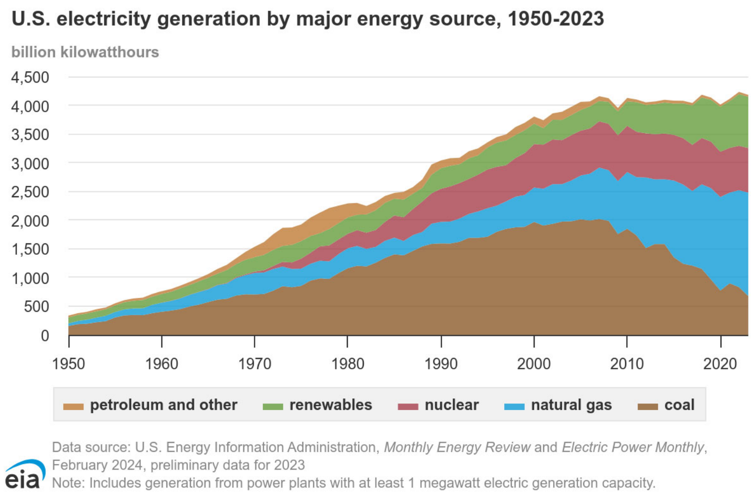
Role of Natural Gas

Natural Gas



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

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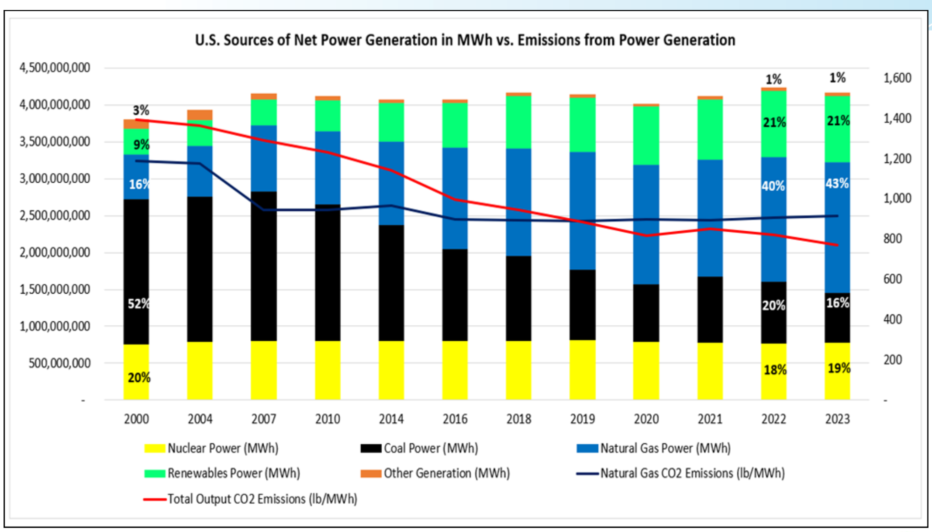
Natural Gas



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

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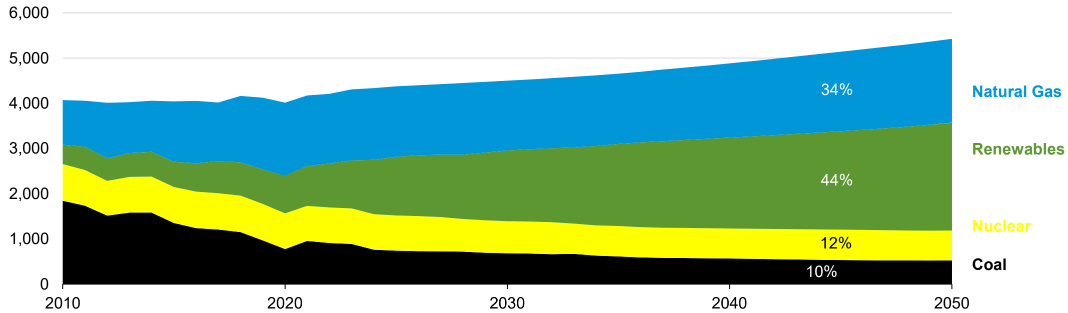
Natural Gas



Source: eGRID 2020

Natural Gas

Natural gas is expected to remain a critical part of the electricity grid and play a critical role in the transitional years to come.

- **Reduced emissions & higher efficiencies** – Natural gas with reduced emissions and higher efficiency potential in electricity generation is the fuel of choice for replacing more polluting energy sources such as coal and oil.
- **Scalability** – Natural gas can be implemented at both small and large scales, meeting the needs of individual businesses up through grid-scale generation.
- **Dispatchability** – Natural gas can be rapidly dispatched, meeting the fluctuating needs of the grid, especially during peak times.
- **Established infrastructure and domestic supply** – Natural gas benefits from a network of well-established infrastructure and domestic supply, reducing costs for new implementation across the states.
- **Flexibility** – Natural gas can be used both at small and large scale in different applications including traditional generation, CHP, and fuel cells.
- **Cost-effectiveness** – Technologies are mature, benefitting from reliability and economies of scale, and fuel costs remain relatively low.
- **Renewable energy transition support** – Natural gas generation is able to fill the gap between non-dispatchable renewables and grid dispatch needs. It also is able to step in during the transition period as traditional generation sources are retired and renewable implementation ramps up.
- **Energy storage** – Natural gas as a physical product can help meet grid energy storage and reserve needs.
- **Electrification support** – As electrification moves end-use customers away from natural gas, more demand is needed grid-side which can be supported with natural gas generation.

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Thank You

Consider taking the on-line test while course material is fresh in your mind

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