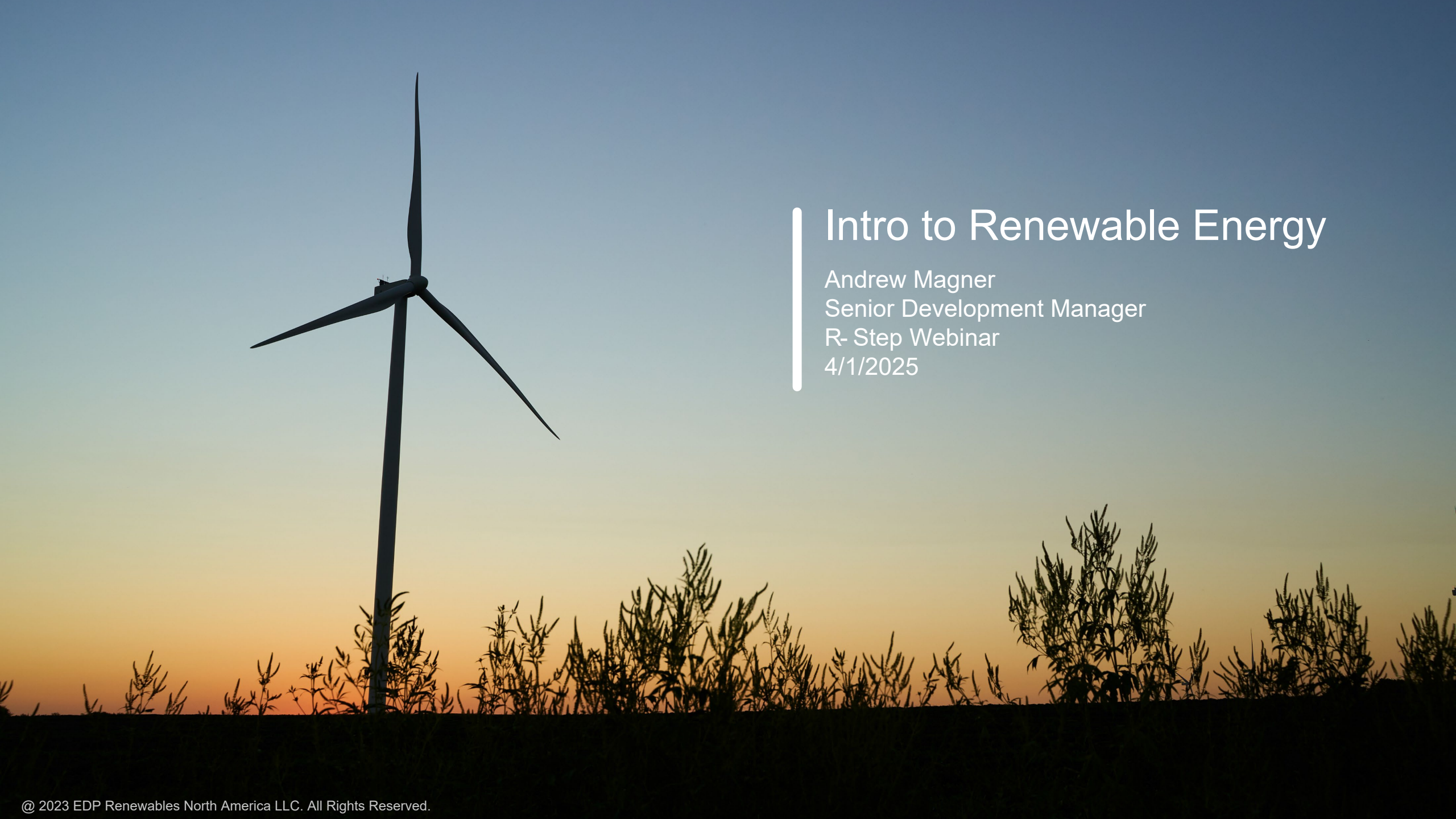

Intro to Renewable Energy

Andrew Magner
Senior Development Manager
R- Step Webinar
4/1/2025

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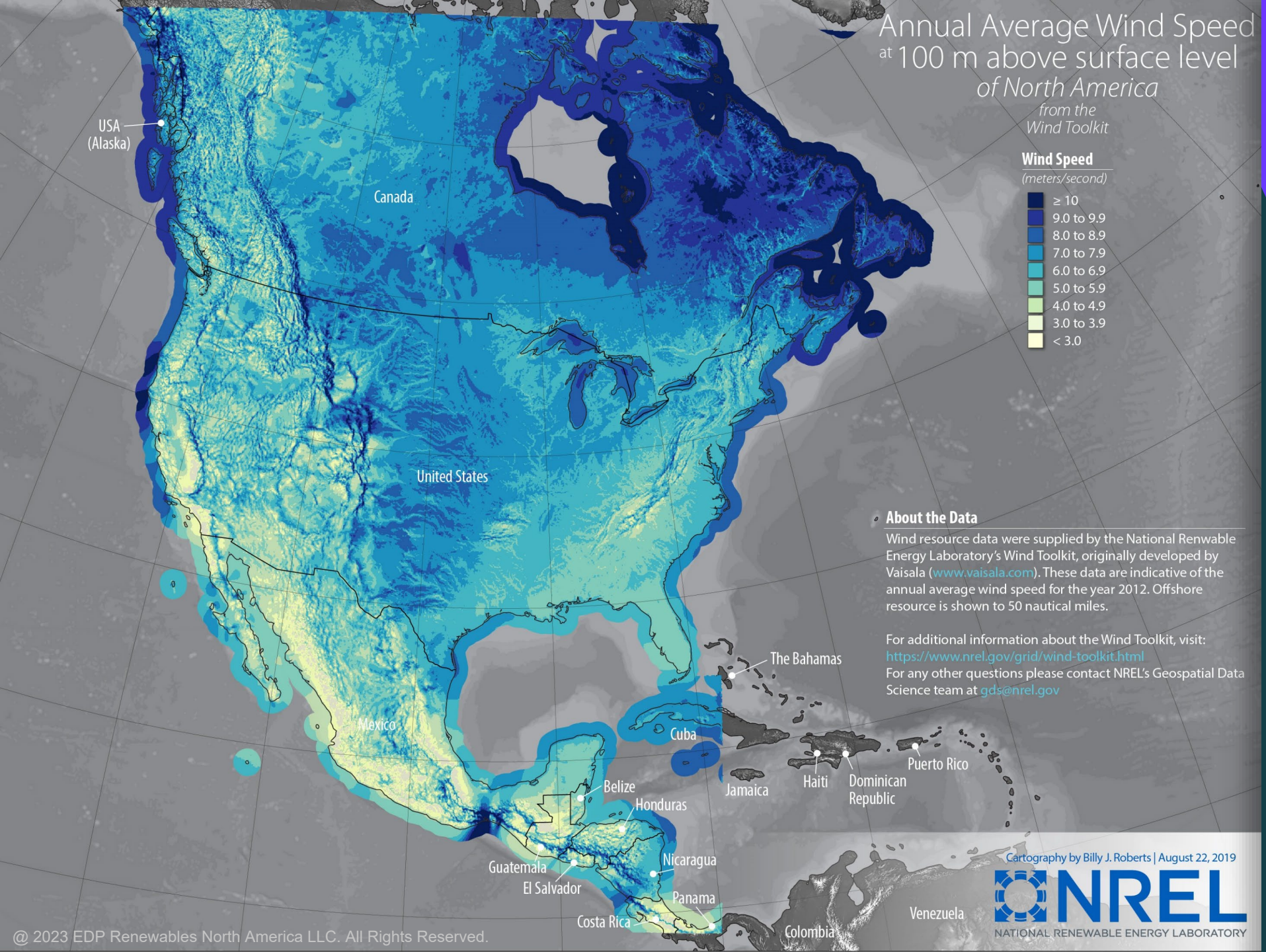
01

Wind resource in the U.S.



Wind is the largest source of renewable electricity generation in the United States, providing 9.8% of the country's electricity and growing.

Source: American Clean Power Association, 2022

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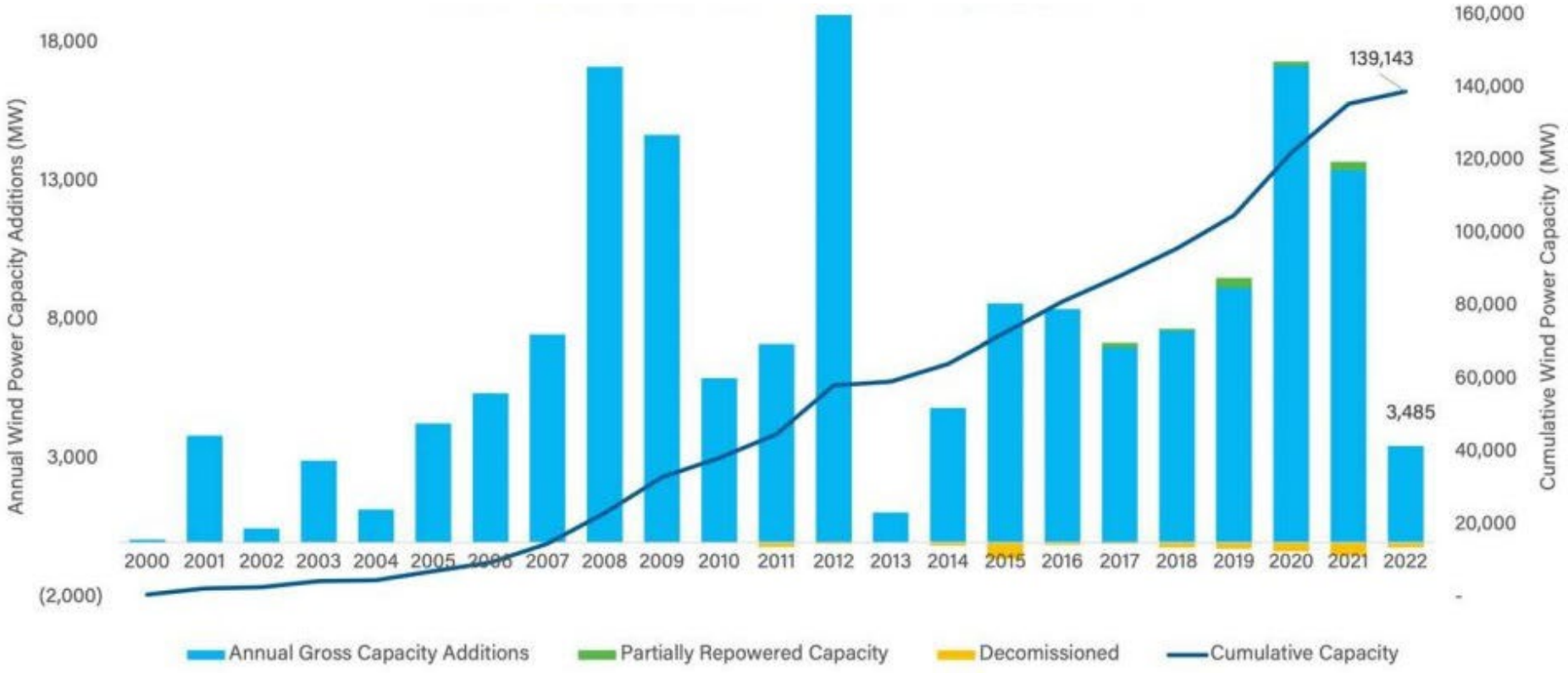
U.S. annual and cumulative wind power capacity growth



13.4 GW

of land-based wind power added to the grid in 2021.

Wind energy provides 25% of the electricity produced in eight states.

Source: American Clean Power Association | Clean Power Quarterly 2022 Q2 .

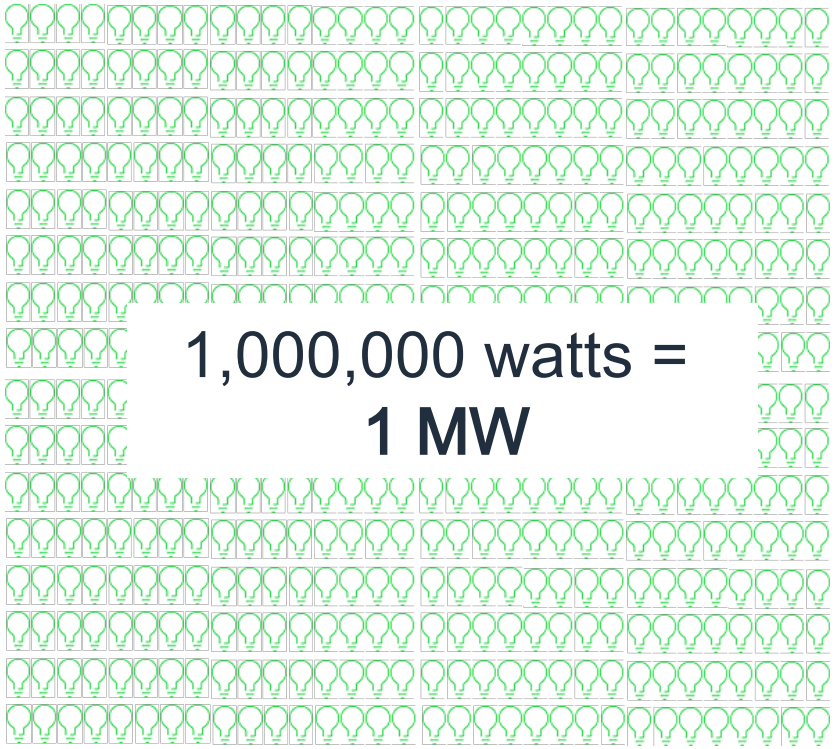
02

Utility- scale wind: How it works

Measuring wind power

1 Average Wind Turbine = 2.9 MW

1 Average Lightbulb = **60 watts**



Source: American Clean Power Association | Annual Market Report, 2021.

1 turbine produces enough energy to power more than 900 homes.

Wind farm sizes and applications

Small
(≤100 kW)
- Homes
- Farms
- Remote applications (water pumping, telecom sites, ice making)

Mid-scale
(100-1,000 kW)
- Village power
- Hybrid systems
- Distributed power

Large, land-based
(1-5+ MW)
- Utility-scale wind farms
- Large, distributed power

Large, offshore
(7-15 MW)
- Utility-scale wind farms in shallow coastal waters
- 30 MW wind farm installed off the southern coast of Rhode Island

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Parts of a Wind Turbine

Turbine technology

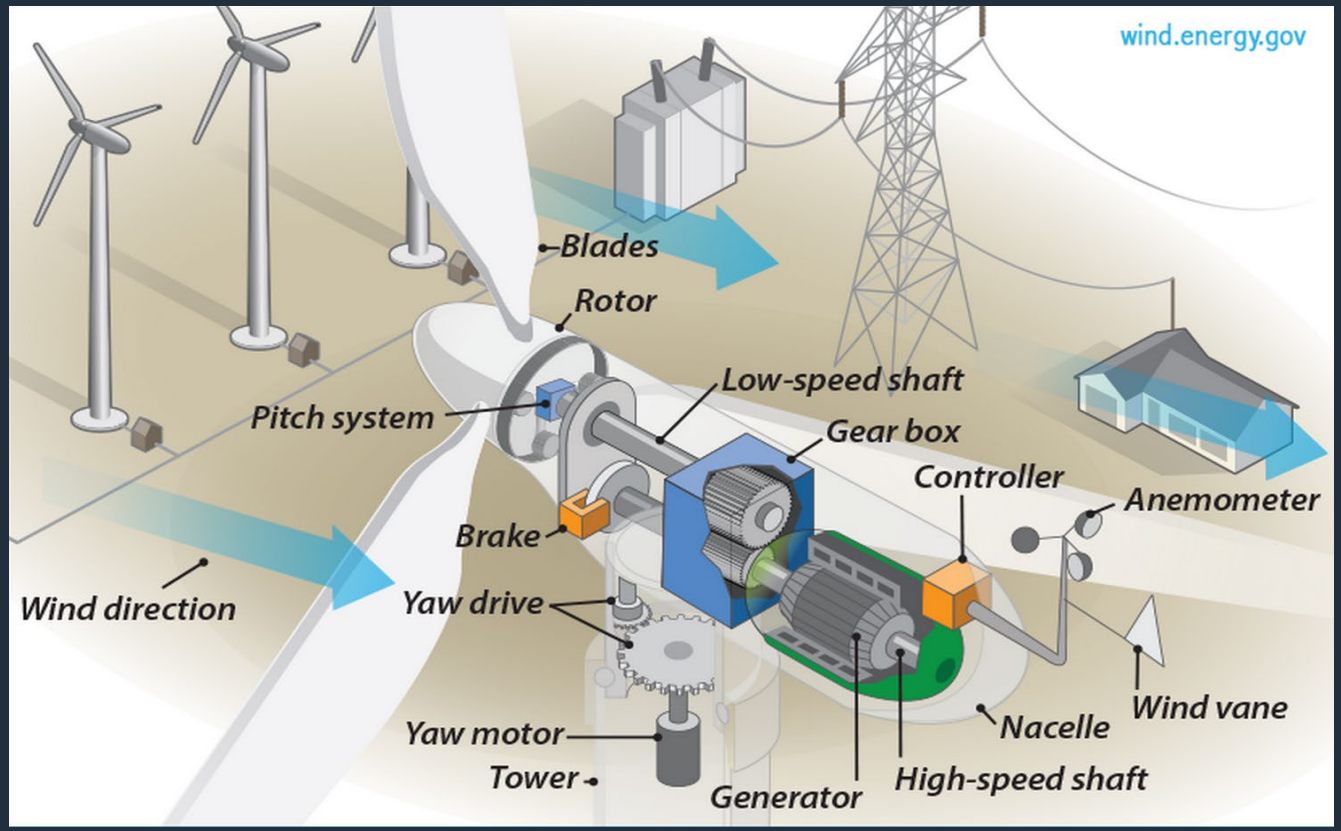
Generating electricity from wind: Inside a turbine

Blades - Wind pushes against the blades, causing them to spin. Blades turn the low-speed shaft which is connected to the gearbox.

Tower - A tubular steel tower supports a hub with three attached blades and a nacelle, which houses the shaft, gearbox, generator, and controls.

Gear Box - The gears in the box increase the rate of revolution to a high-speed shaft for the generator. The generator changes the motion from the high-speed shaft into electricity.

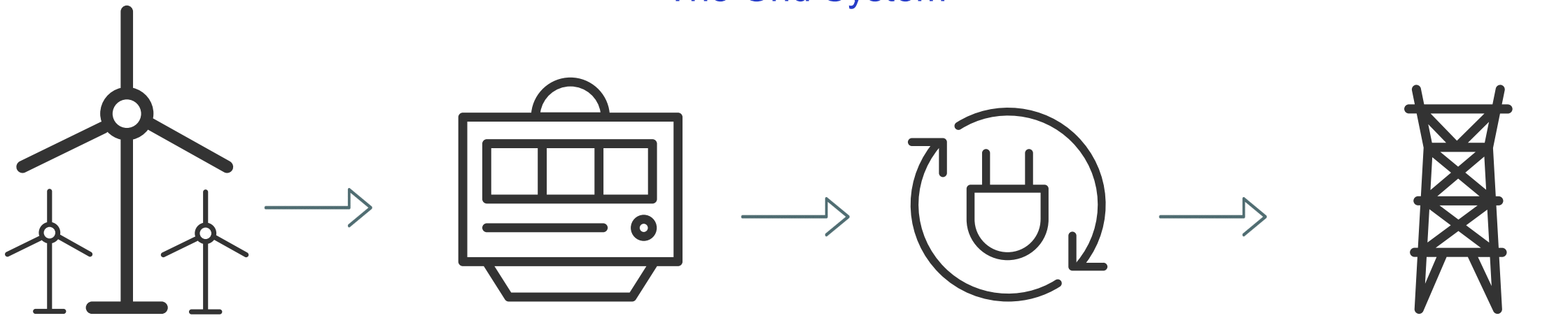
Pitch - Wind measurements are collected to automatically rotate the turbine to face the strongest wind and angle, or “pitch,” its blades to optimize the energy captured.



Turbines convert kinetic energy into electrical energy.

Generating electricity from wind

The Grid System



Wind Turbines

MV Switchgear

Power Transformer

Overhead Line

Measuring wind power

Capacity Factor

Capacity Factor
is a measure of how much energy is produced by a plant compared with its maximum output.

U.S. utility- scale wind operated at an average

17% capacity factor in 2022.

Capacity Factor =

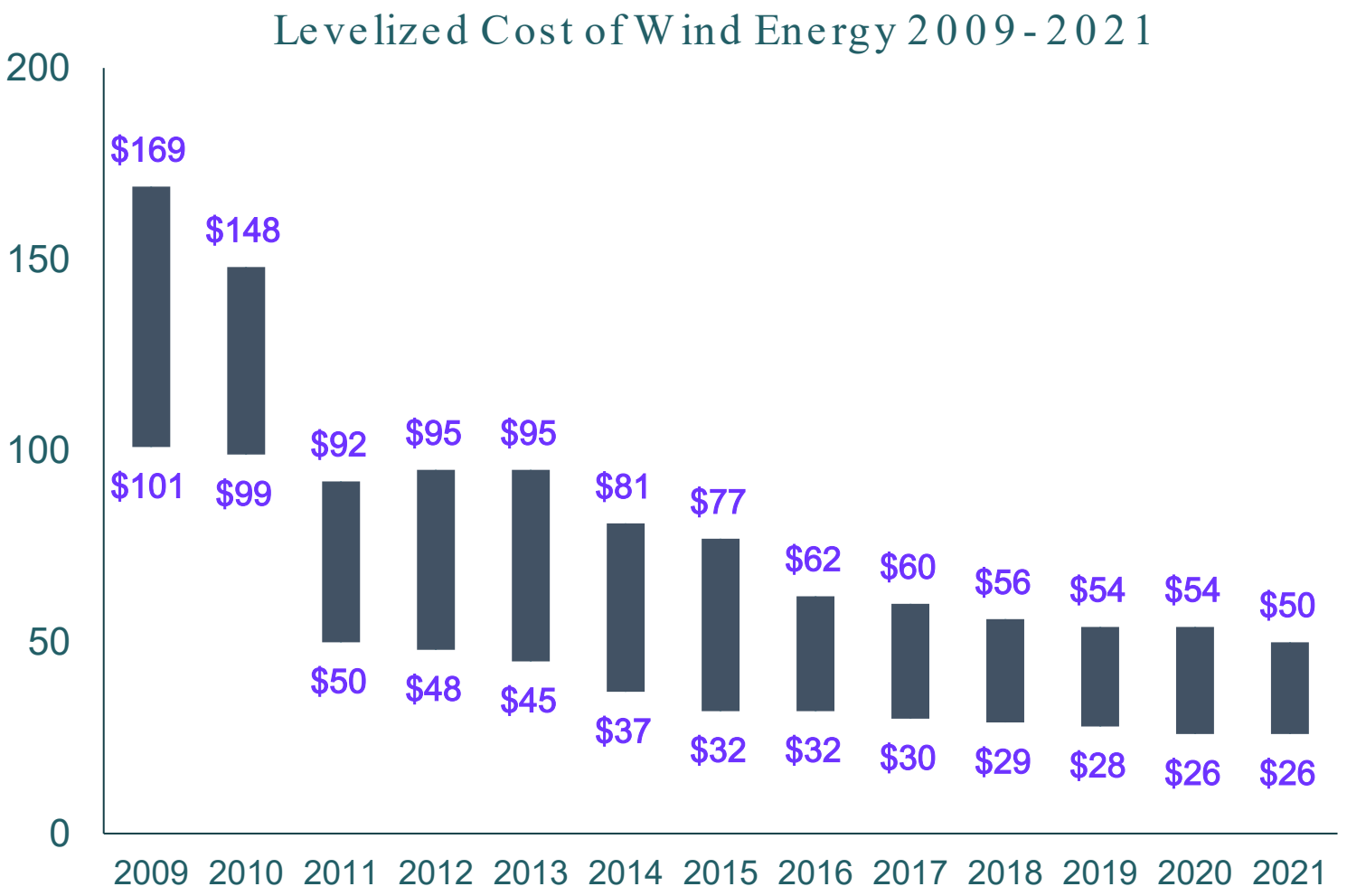
$$\frac{\text{TOTAL ENERGY PRODUCED}}{\text{MAXIMUM OUTPUT}}$$

Wind farms are variable energy resources with output dependent upon the time of day, season, and weather patterns .

Source: Energy Information Administration, 2022.

03

Demand for wind power



The cost of wind energy has fallen

47% in the last 10 years.

Source: American Clean Power | Annual Market Report 2021.

Indiana's Renewable Energy Outlook

Currently 4,179 MW of operating wind, solar and energy storage capacity across Indiana

- 3,468 MW in wind generation online
- 673 MW in solar generation online
- 38 MW in storage online
- 14th highest generation across the country

Approximately 41 projects, **8,248 MW** of generation and storage under development

- 5 projects, 980 MW in wind generation
- 31 projects, 6,928 MW in solar generation
- 5 projects, 340 MW in energy storage capacity

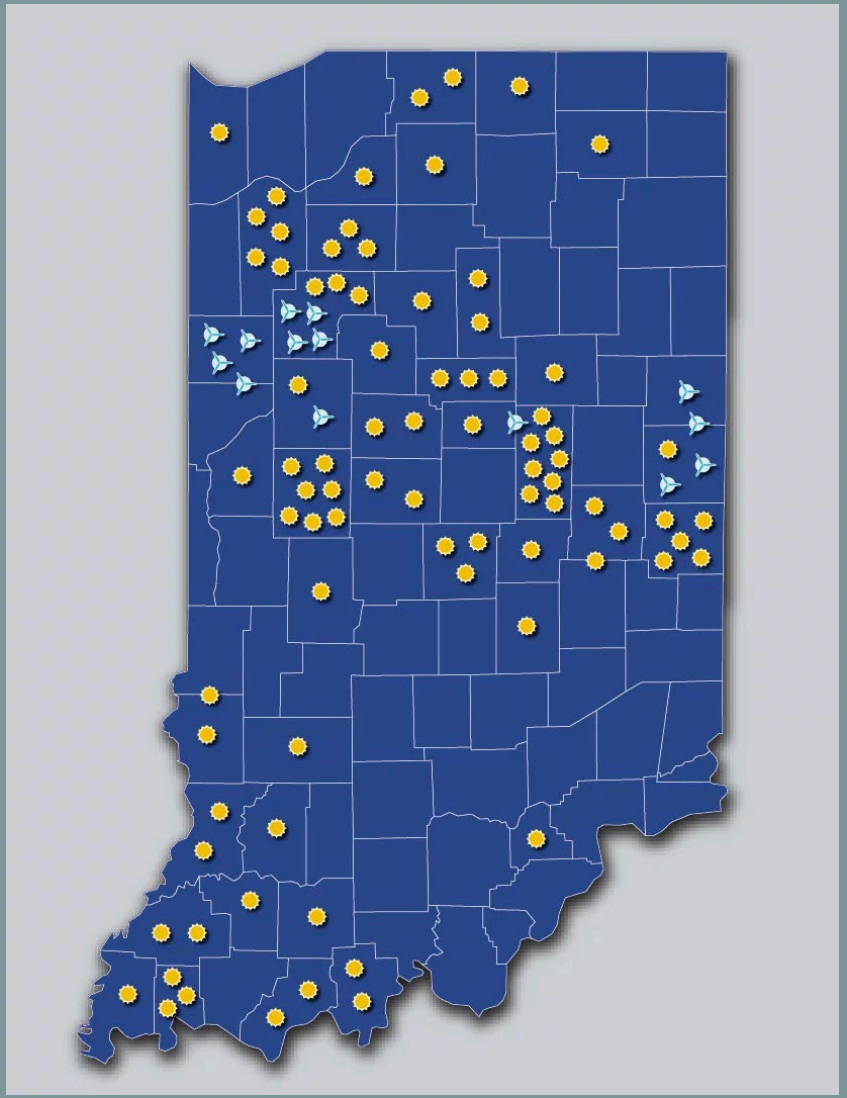
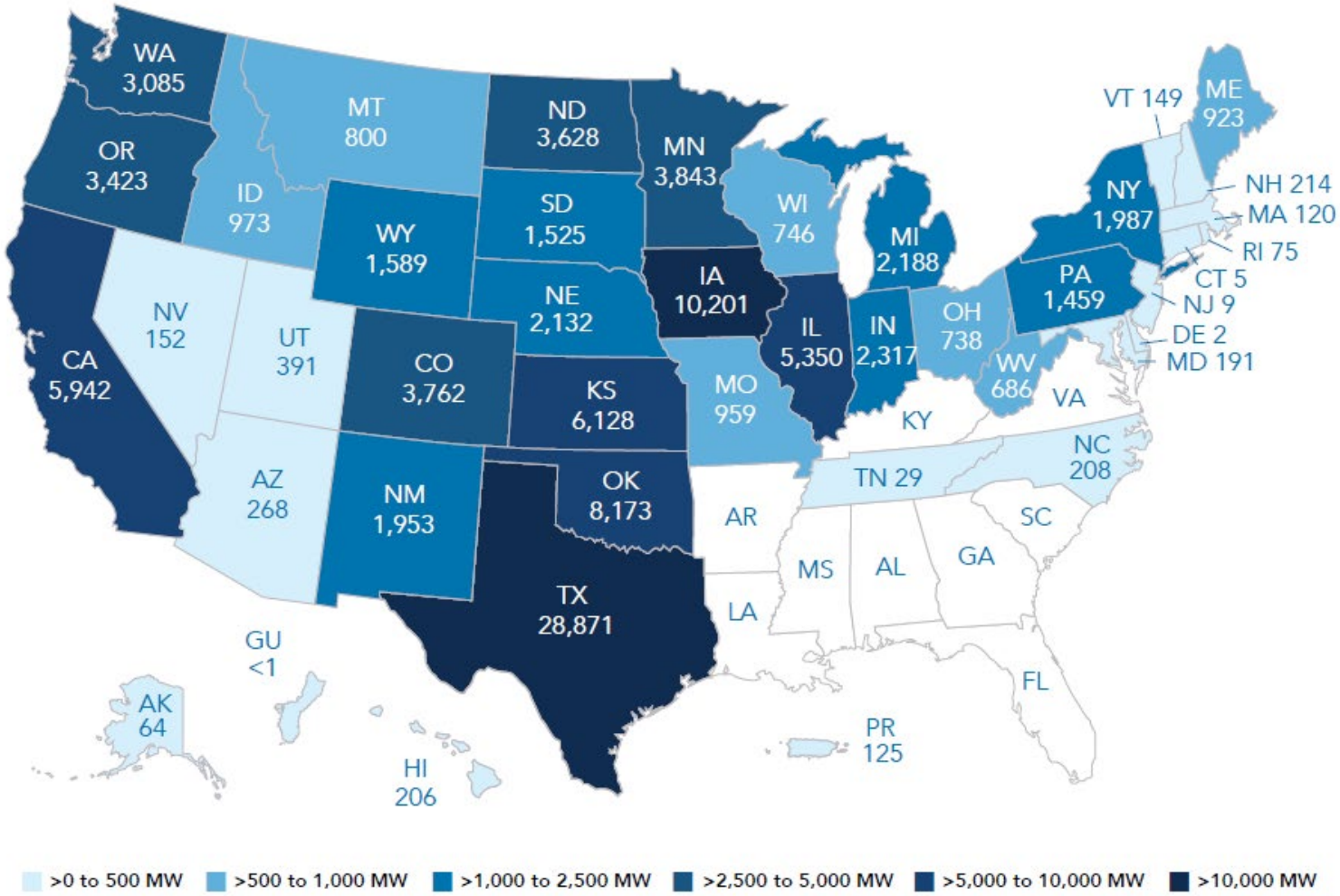


Image Source: Hoosiers for Renewables, https://www.hoosiersforrenewables.com/indiana-renewable-energy-map
Data Source: Americans for Clean Power (Last Updated Apr. 10, 2023)



Annual and Cumulative Wind Power Capacity:

13,400 MW

installed in 2021, which brings the cumulative year - end capacity to

135,843 MW

Source: American Clean Power Association | Annual Market Report 2021.

Intro to Solar Power

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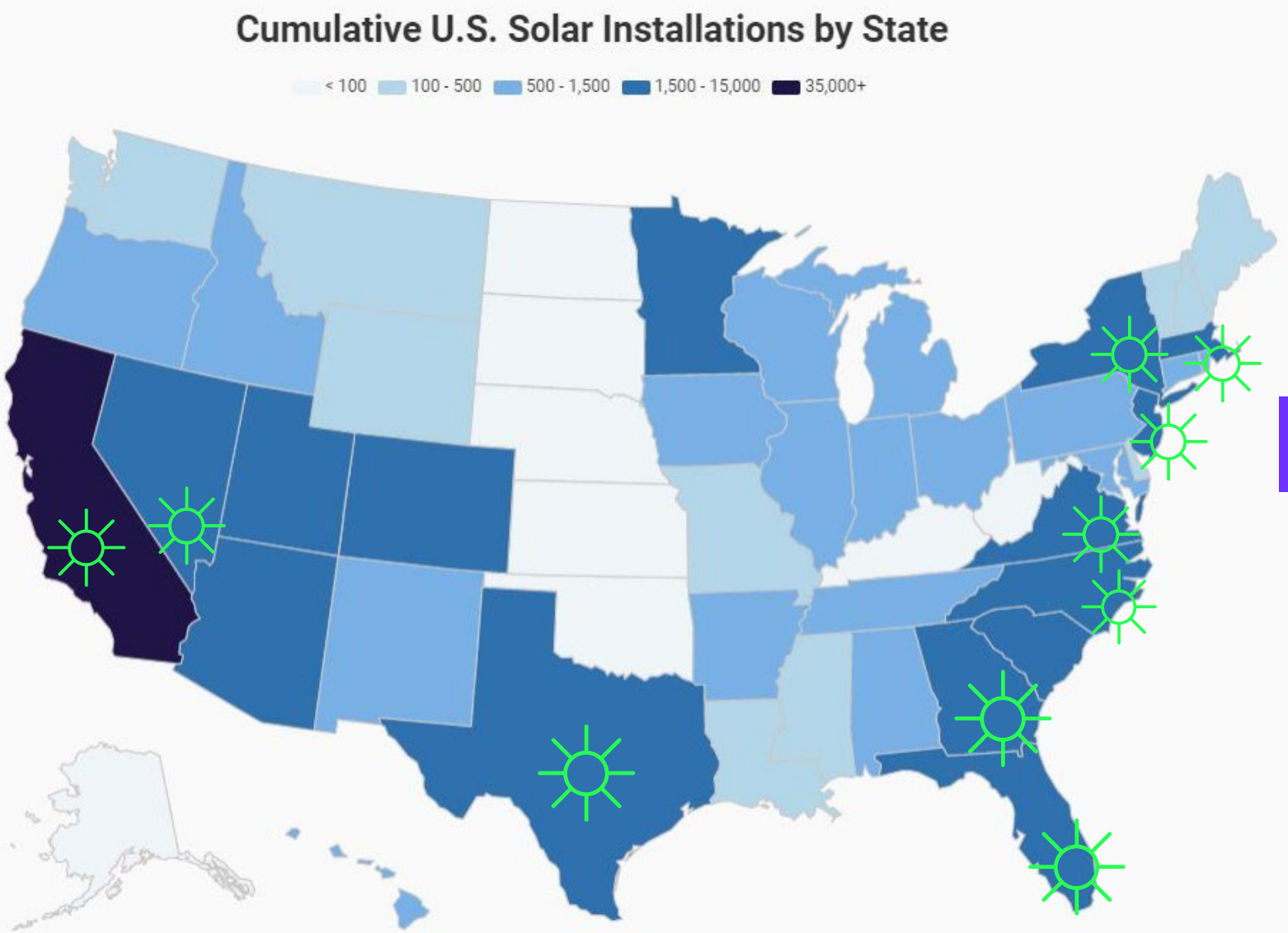
1. Solar capacity in the U.S.
2. Photovoltaic (PV) solar: How it works
3. Demand for solar power

01



121 GW

of solar capacity is installed nationwide, enough to power **23.3 million homes** .

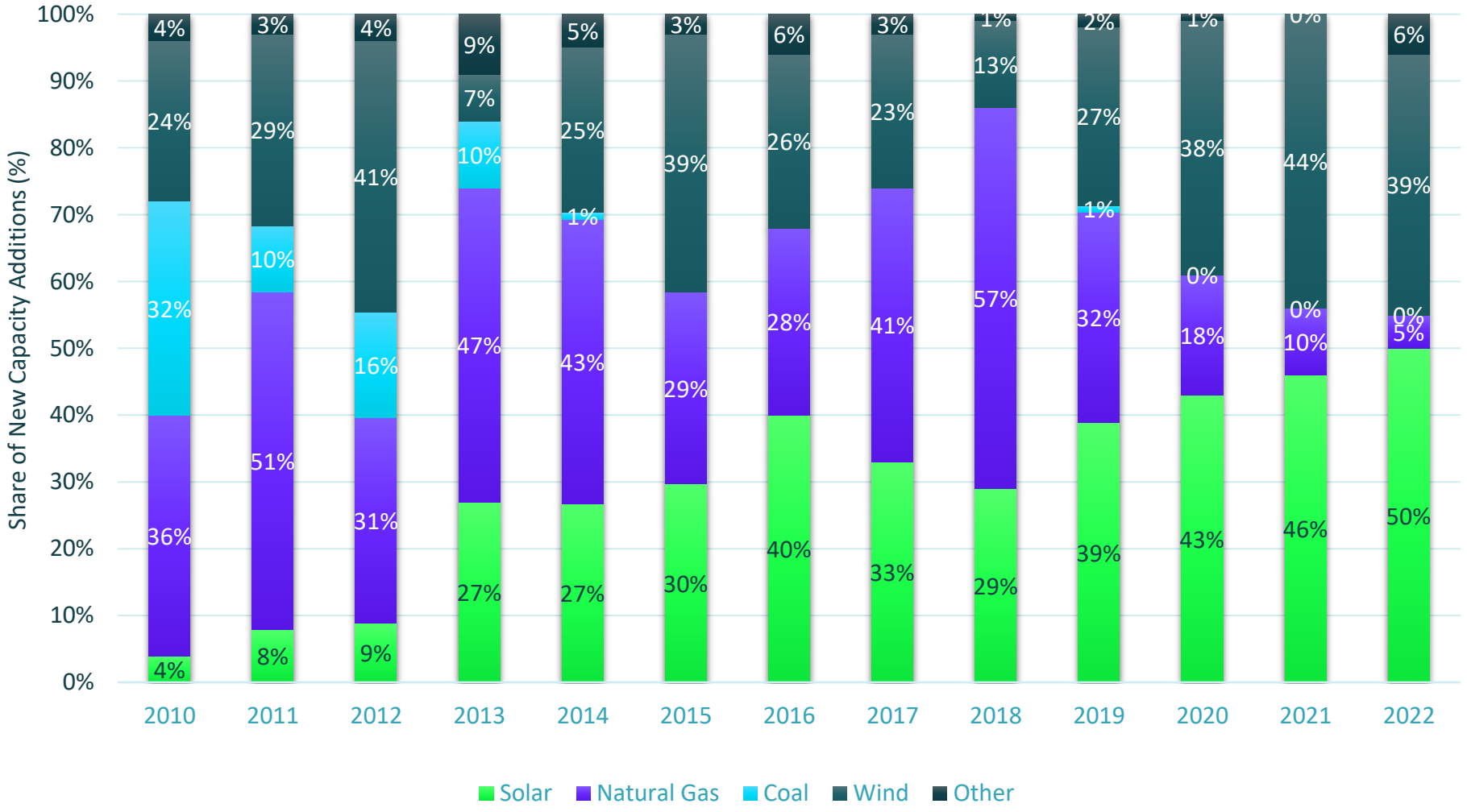
Top 10 Solar States by Installed Capacity

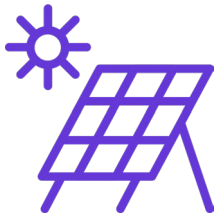
through 2021

1. **California** – 35,950 MW
2. **Texas** – 13,947 MW
3. **Florida** – 9,012 MW
4. **North Carolina** – 7,935 MW
5. **Arizona** – 5,743 MW
6. **Nevada** – 4,967 MW
7. **Georgia** – 4,299 MW
8. **New Jersey** – 3,927 MW
9. **Massachusetts** – 3,927 MW
10. **Virginia** – 3,790 MW

Source: SEIA/Wood Mackenzie Power & Renewables U.S. Solar Market Insight Q2 2022 .

U.S. Annual Additions of New Electric Generating Capacity





Solar accounted for nearly

46 percent

of all new U.S. electric capacity installed in 2021.

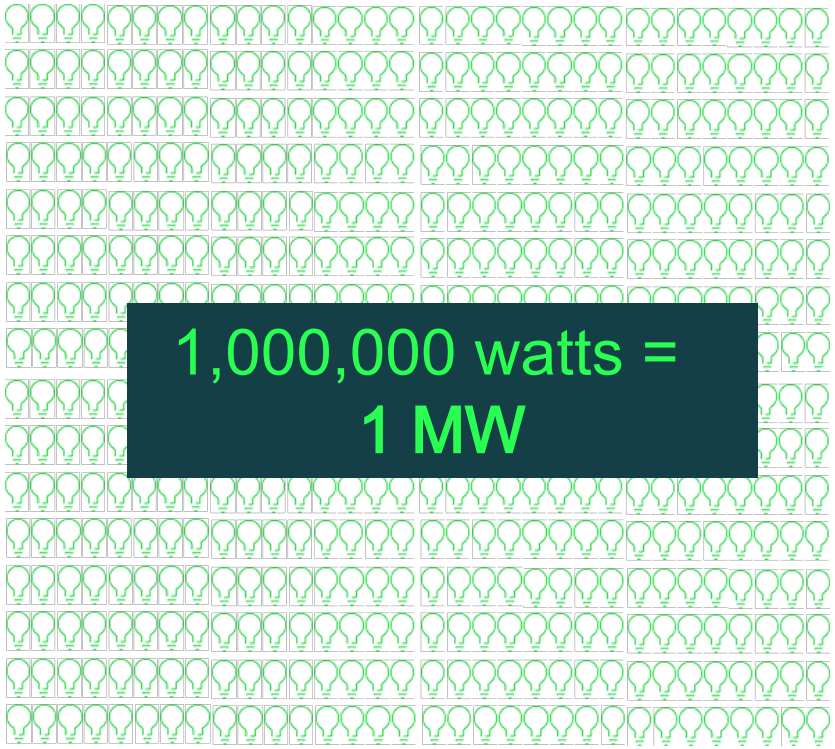
Source: SEIA/Wood Mackenzie Power & Renewables U.S. Solar Market Insight Q2 2022.

02

Measuring solar power

Solar is a critical and rapidly growing part of America's electric grid, producing enough energy to power more than 16.1 million homes nationwide and counting.

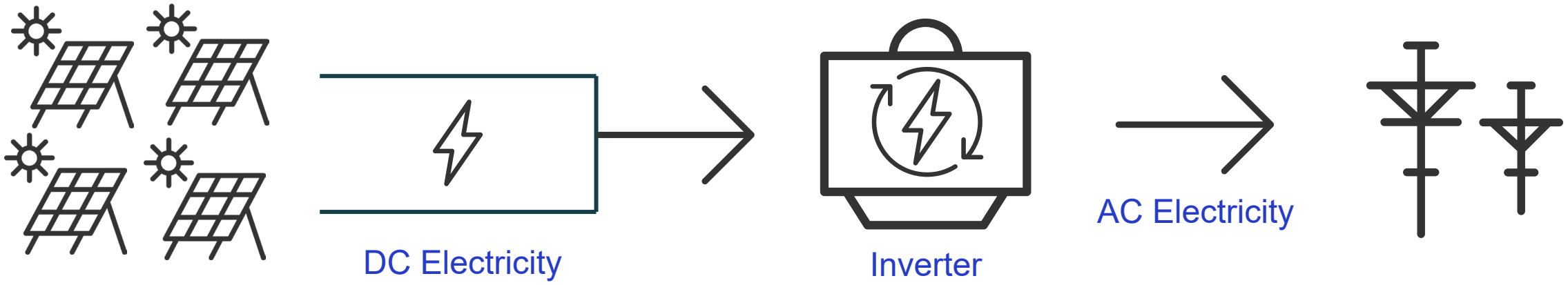
1 Average Lightbulb = **60 watts**



Source: Solar Energy Industries Association, 2019.

Generating electricity from solar

The Grid System



The solar panels absorb sunlight and generate DC electricity. Many have trackers installed to tilt toward the sun as it moves across the sky.

The electricity goes through an inverter, converting it to AC electricity.

Then it flows into the grid, supporting the region's energy needs.

Solar array size and applications

Residential Solar

- 1 to 15 KW
- Rooftops, single family homes
- $2.84/watt

Commercial/Industrial Solar

- 1 to 5,000 KW
- Roof or ground-mounted on commercial or industrial properties
- $1.39/watt

Utility-Scale Solar

- 1+ MW
- Ground-mounted installations on open land
- $0.83/watt (fixed tilt)

Source: Solar Energy Industries Association, 2019.

Measuring solar power

Capacity Factor

Capacity Factor
is a measure of how much energy is produced by a plant compared with its maximum output.

Solar PV accounted for 50% of all new electricity-generating capacity additions in the first quarter of 2022.

Capacity Factor =

TOTAL ENERGY PRODUCED

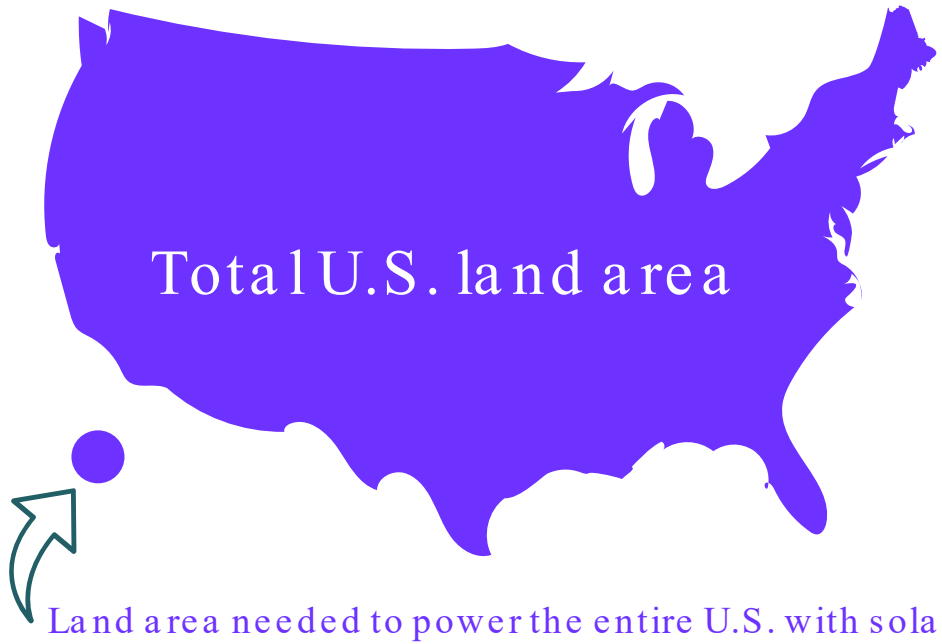
MAXIMUM OUTPUT

Solar PV systems are variable energy resources with output dependent upon the time of day, season, and weather patterns.

Source: NREL: Solar Energy and Capacity Value, Energy Information Administration.

Solar parks and land use

Compared to other power generating sources, solar energy has a relatively small footprint per megawatt.

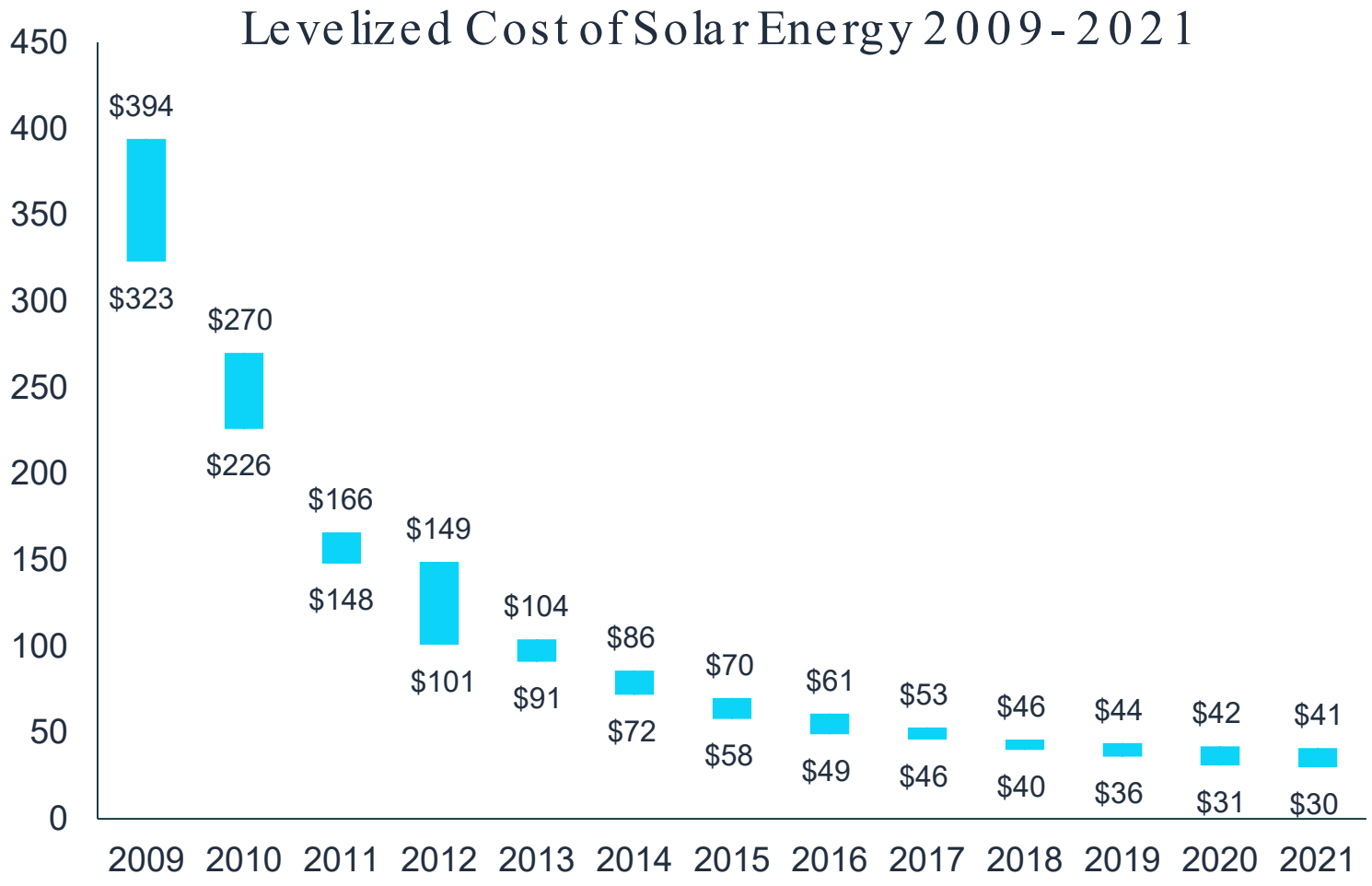


Land area needed to power the entire U.S. with solar PV

The entire United States could be powered by solar energy with just 0.6% of the nation's land.

Source: Solar Energy Industries Association, 2021.

03



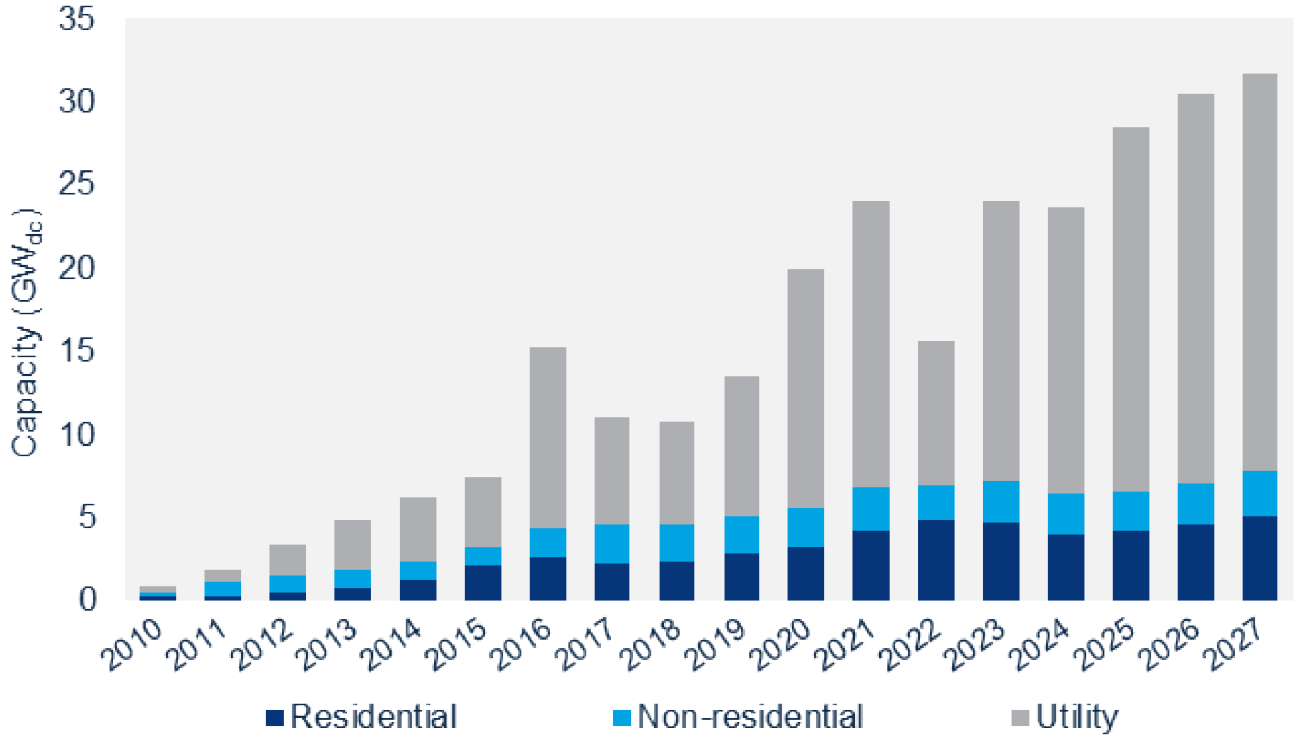
The cost of solar energy has fallen

71% in 10 years.

Source: American Clean Power | Annual Market Report 2021.

U.S. PV solar deployment forecast

U.S. PV installation historical data and forecast, 2010-2027



SEIA Solar Energy Industries Association® | Wood Mackenzie A Verisk Business

Source: Solar Market Insight Report, Q2 2022

> 112 GW

of new utility - scale PV solar will be added from 2022 to 2027, nearly doubling the amount installed in the last decade.

Source: U.S. Solar Market Insight 2022.

Intro to energy storage

edp Renewables

edp Renewables

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01

A wide array of storage technologies have been developed so that the grid can meet everyday energy needs.

Batteries

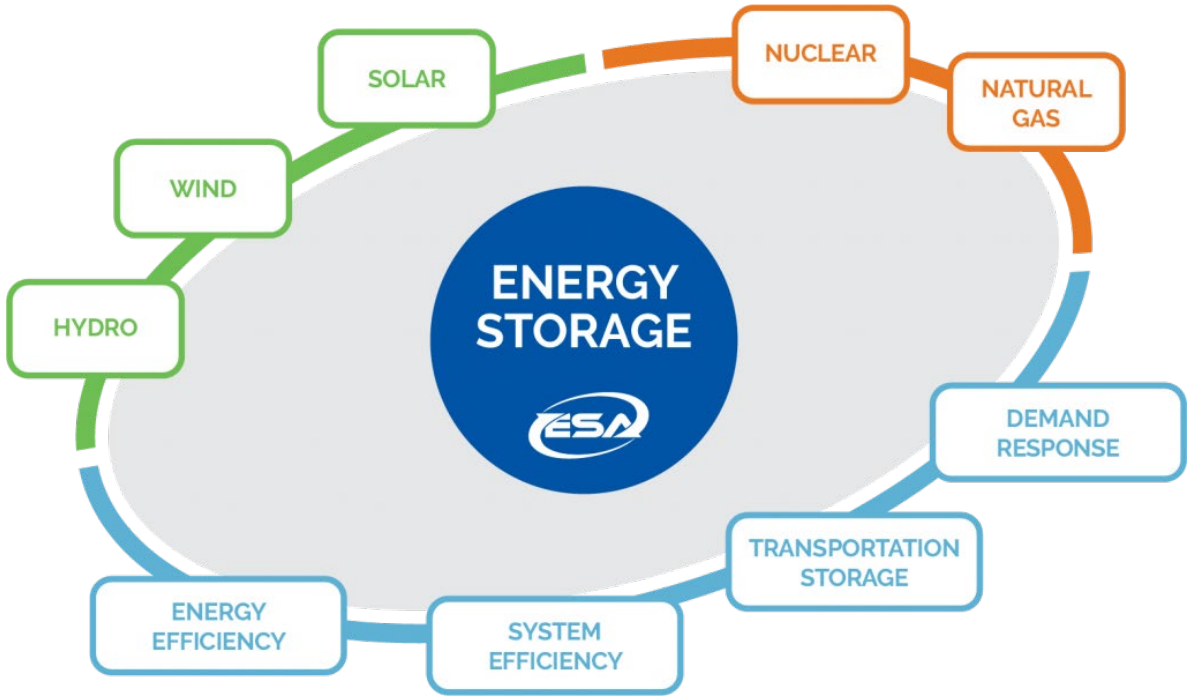
Thermal

Mechanical Storage

Hydrogen

Pumped Hydropower

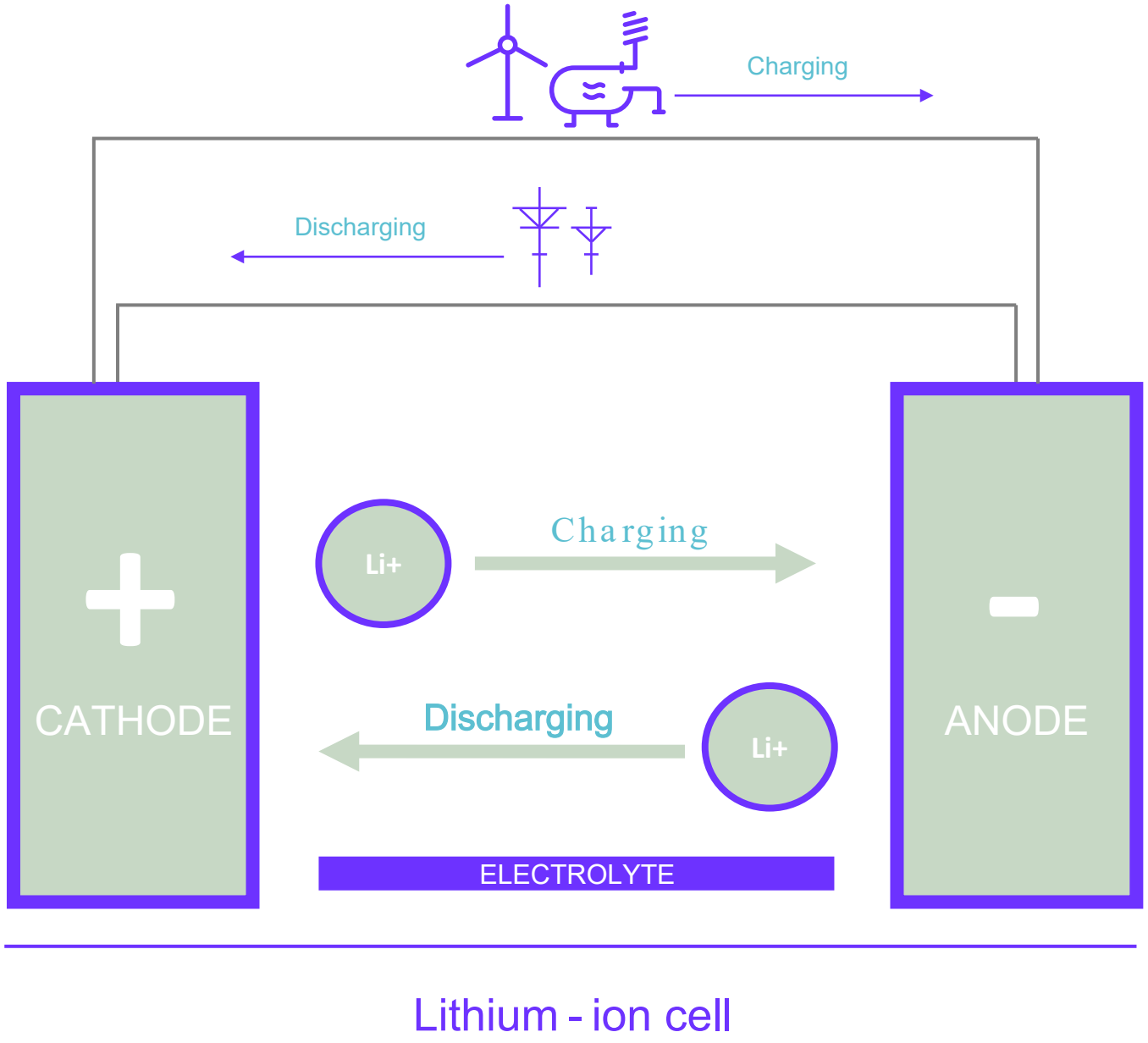
Source: American Clean Power Association, 2022.



The need for energy storage

Energy storage is a critical hub for the entire grid, augmenting resources from wind, solar, and hydro, to nuclear and fossil fuels, to demand side resources and system efficiency assets.

Source: American Clean Power Association, 2022.



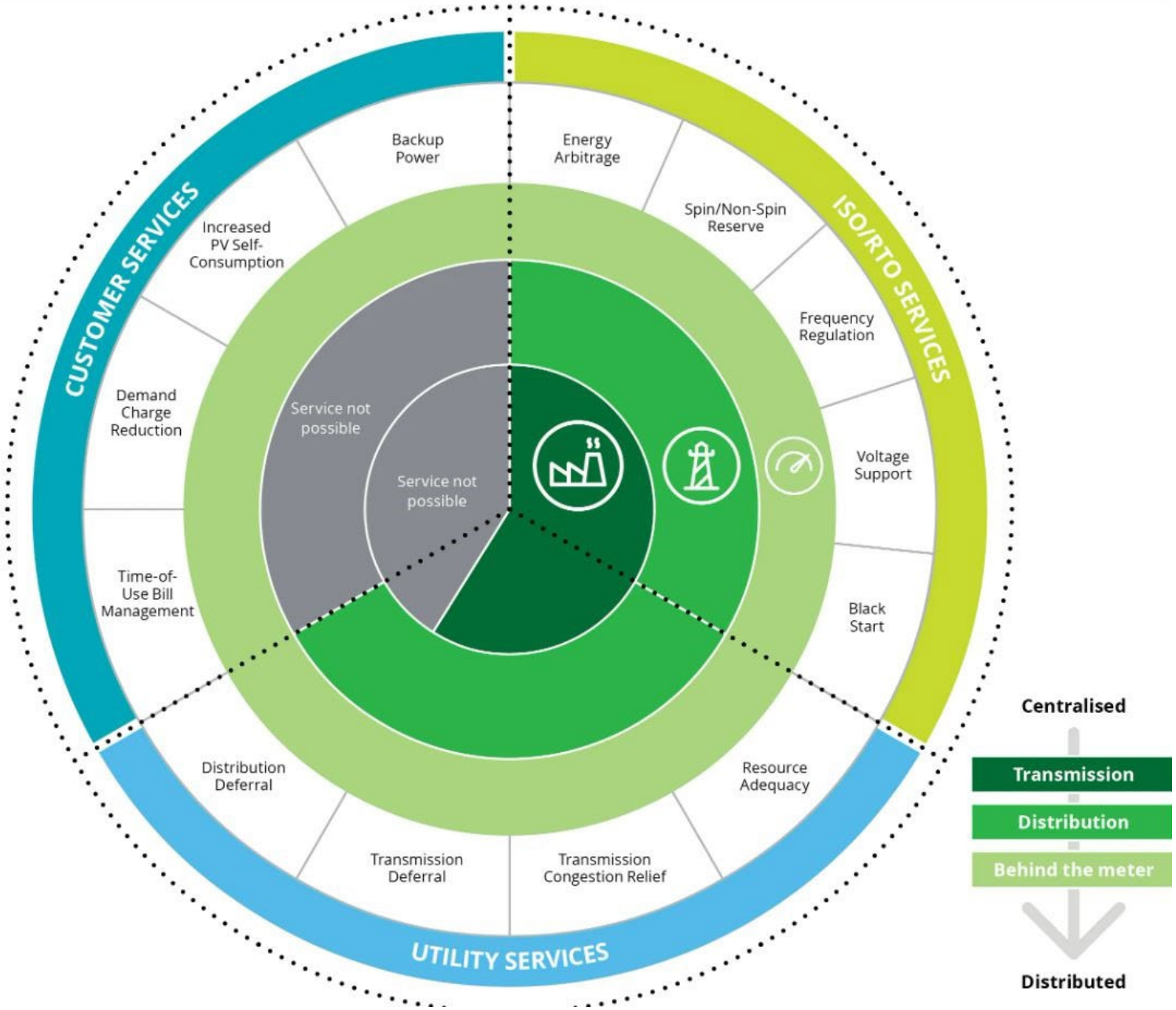
Lithium - ion cell

How a lithium-ion cell works

Powered by growth in the electric vehicle market, lithium-ion battery manufacturing is rapidly growing.

Lithium ion battery cells take many form factors:

Source: University of Michigan Center For Sustainable Systems, 2017.



Energy storage applications and value streams

Source: Rocky Mountain Institute, "The Economics of Battery Energy Storage," 2019.

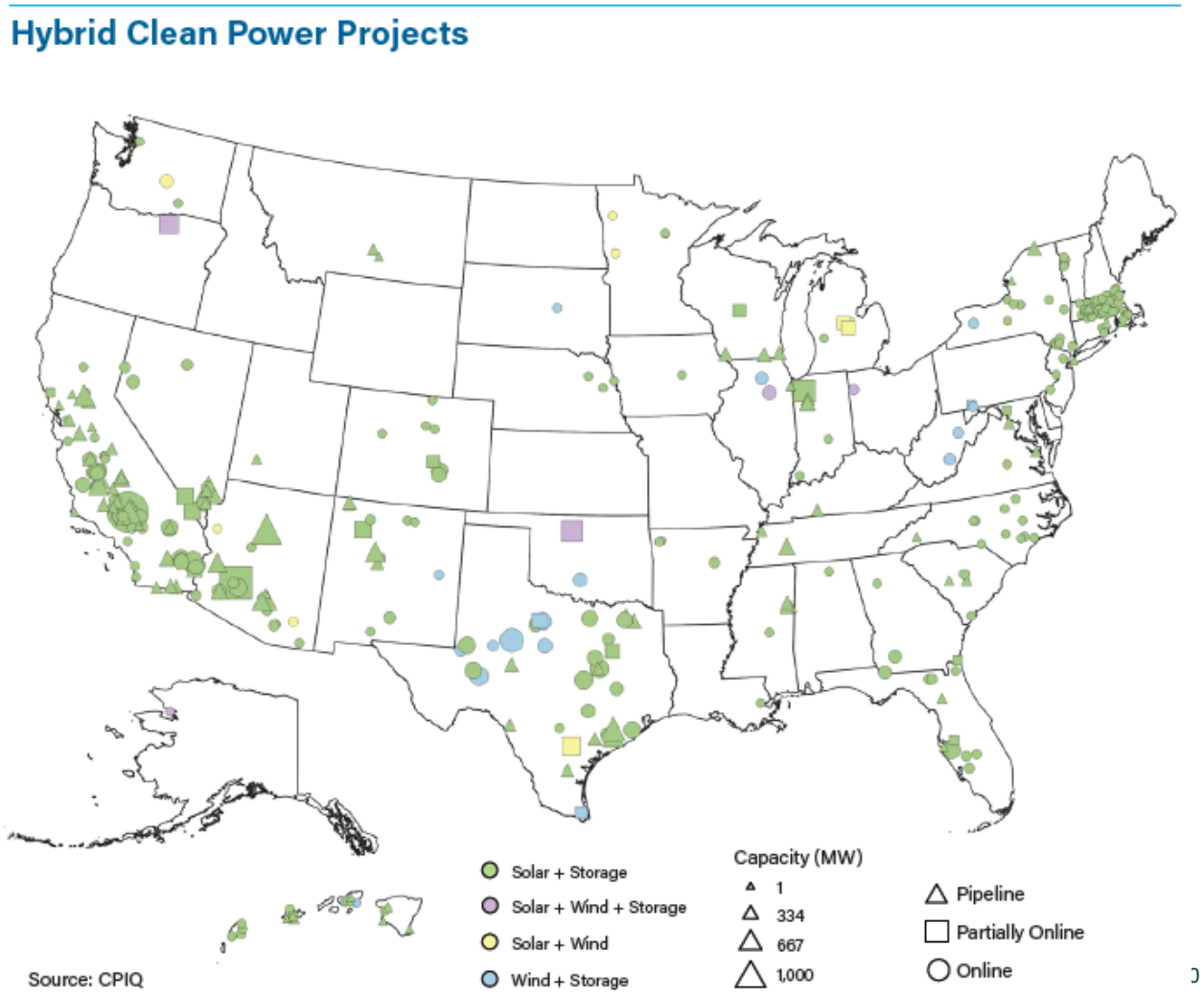
02

Energy storage in the U.S.

In 2023, over 11GW of new hybrid project capacity came online, 95% of which is comprised of solar + storage projects. 2023 hybrid installations were 90% higher than 2022, setting a new record in the hybrid space.

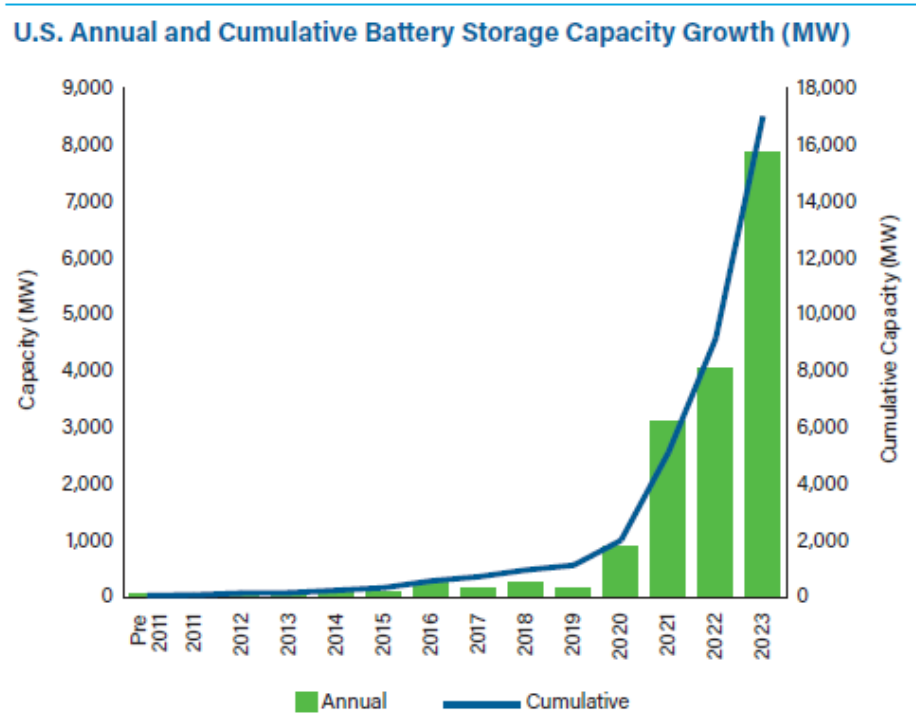
In total, over 30.7 GW of hybrid project capacity was operational in the U.S. Solar + storage projects have become dominant over the past five years and now account for 80% of operating capacity. Wind + storagemakes up 13% of operating hybrid capacity, wind + solar+ storage 3%, and wind + solar the remaining 3%.

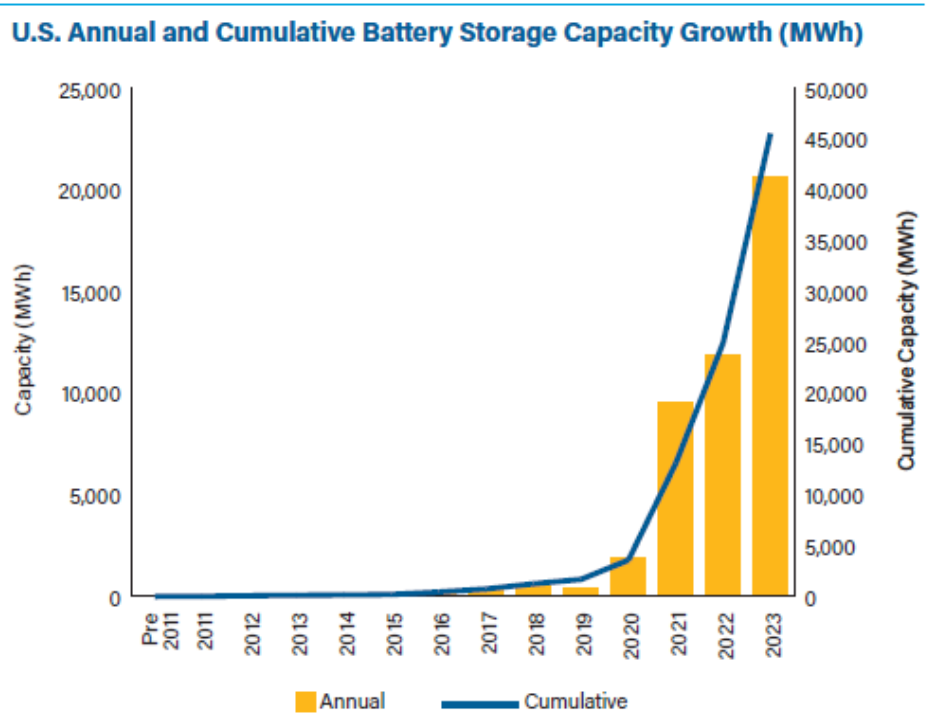
Sources: American Clean Power Association, Annual Market Report 2023.



Annual and cumulative energy storage power capacity

Battery storage installations in 2023 outpaced 2022, the previous record year, by 95%, a near doubling of capacity installed in MW terms.





Source: American Clean Power Association, Annual Market Report 2023.

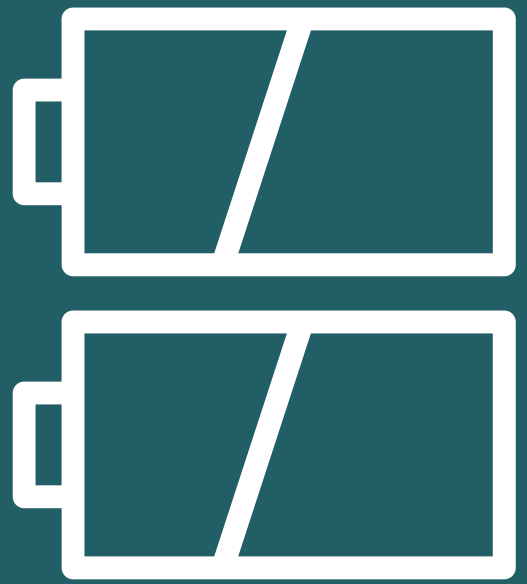
Energy storage growth

As of the end of 2023, there was 17,027 MW / 45,588 MWh of battery storage operating across the country.

Large-scale battery storage capacity is estimated to increase from 1GW in 2019 to 80 GW in 2030, according to the average forecast.

Source: American Clean Power Association, Annual Market Report 2023.

Lithium-ion battery pack prices have fallen 82% from more than $780/kWh in 2013 to $139/kWh in 2023.

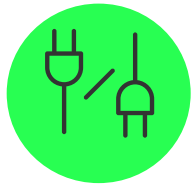


Source: American Clean Power Association, 2024.

03

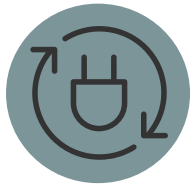
Benefits of energy storage

Enhancing reliability, reducing costs, and increasing grid resilience by:



Smoothing out variable energies

Protecting productivity



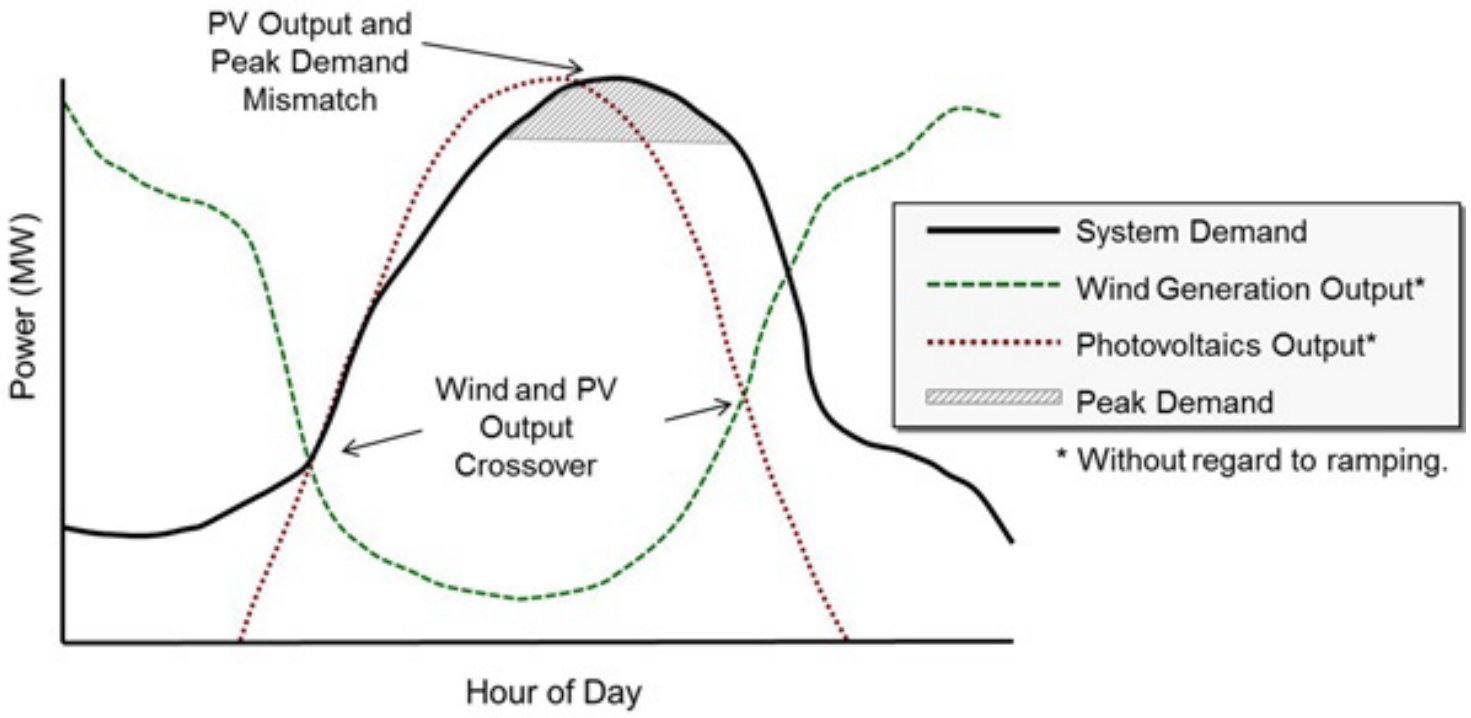
Higher energy density

Synchronizing the delivery of electricity to consumers and businesses.

Source: American Clean Power Association, Benefits of Clean Energy Storage, 2022.

Making clean energy more viable

Energy storage enables us to power the grid using renewables like solar and wind, even when the sun has set or the wind is not blowing.



Source: American Clean Power Association, Benefits of Clean Energy Storage, 2022.

Thank you!

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