Distributed Wind

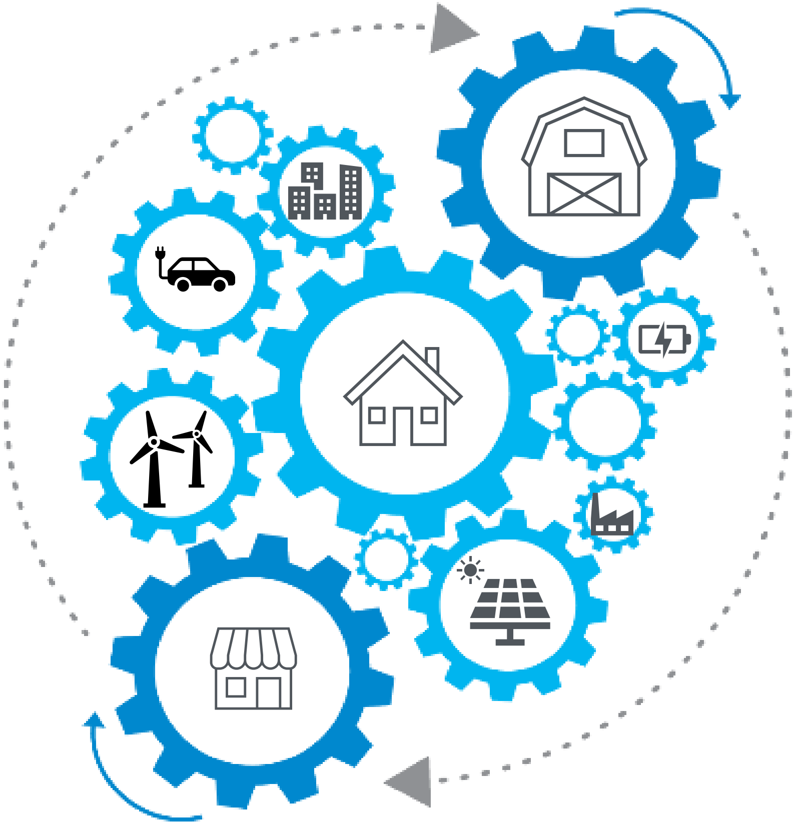
Supporting the Clean Energy Transition

National Challenge

The challenges are nothing short of monumental.

- National 2035 clean energy and low-carbon building goals.
- Need to provide economic development opportunities in communities that are disadvantaged or undergoing energy transition.
- Greatly undersized domestic renewable energy industry that needs to expand, with manufacturing and workforce implications.

Set in an international context…



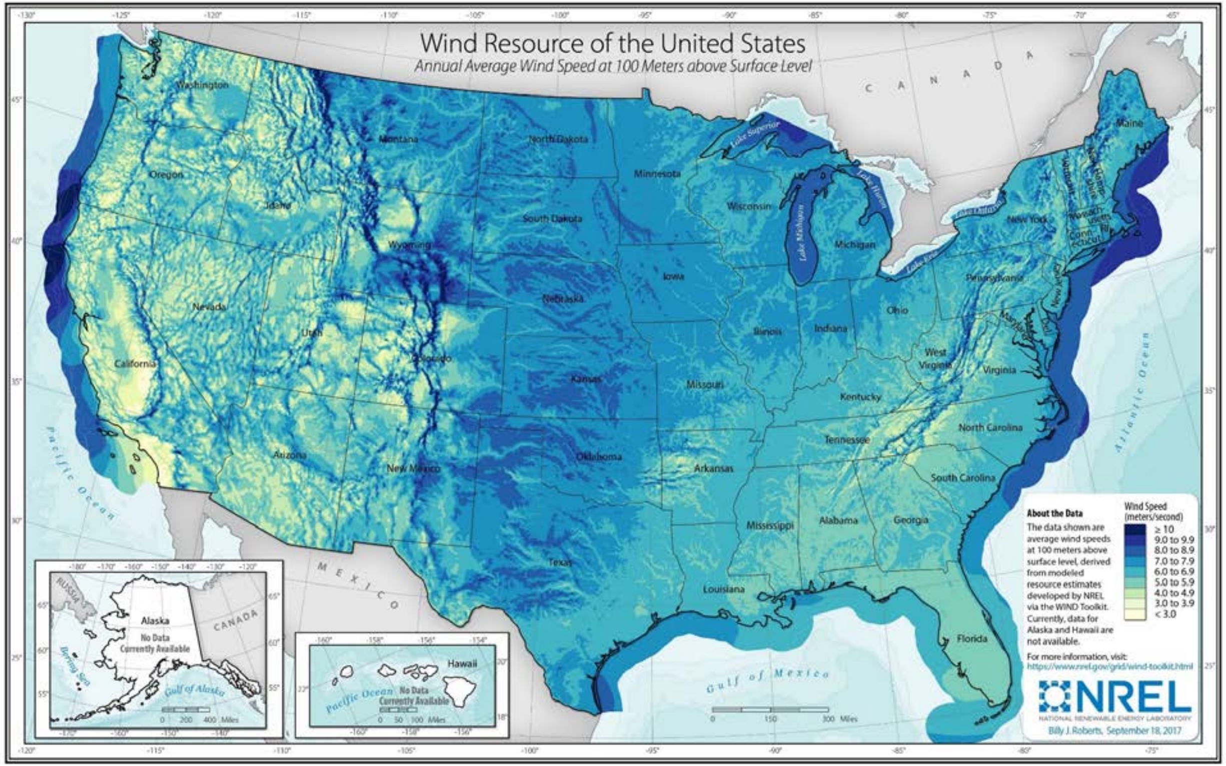
What the Future Can Look Like

- Communities that are generating energy locally, improving the energy system, and enhancing community resilience in collaboration with local governments and utilities.
- Expanded distributed energy development, which provides local jobs and keeps energy expenditures circulating within the communities.
- Opportunities provided to disadvantaged and transitioning communities through manufacturing of new distributed energy technology for domestic or international markets.

Wind Applications and Potential

Technical Potential for the U.S. is 9,800 GW

(current deployment is 120 GW)



Wind Resource Is HUGE

Wind energy technical resource is:

7x the current national demand (2019)

6x the projected national demand (2035)*

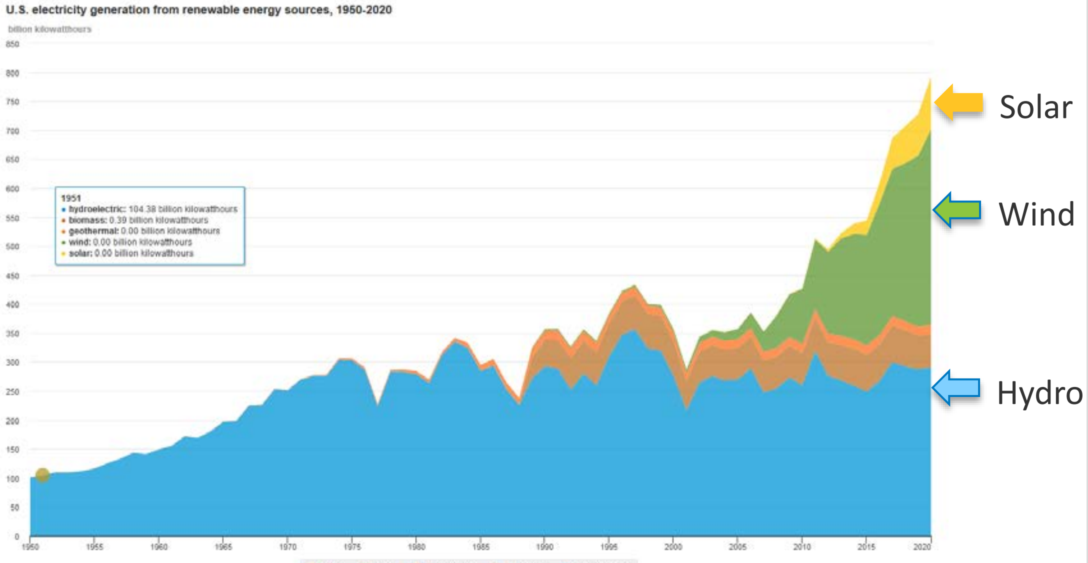
**assumes future energy system with adequate storage and transmission*

Lopez, Anthony, Trieu Mai, Eric Lantz, Dylan Harrison-Atlas, Travis Williams, and Galen Maclaurin. 2021. “Land Use and Turbine Technology Influences on Wind Potential in the United States,” *Energy* 223: 120044. https://doi.org/10.1016/j.energy.2021.120044.

Musial, Walt, Donna Heimiller, Philipp Beiter, George Scott, and Caroline Draxl. 2016. *2016 Offshore Wind Energy Resource Assessment for the United States.* Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-66599.

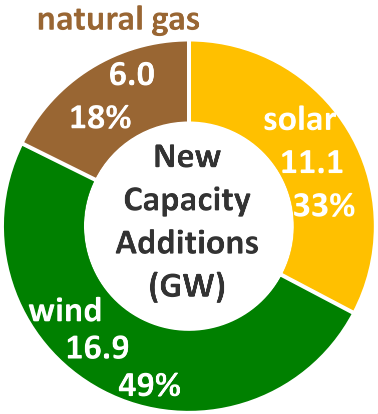
Wind Leads the Way as Renewables Dominate New Electricity Generation

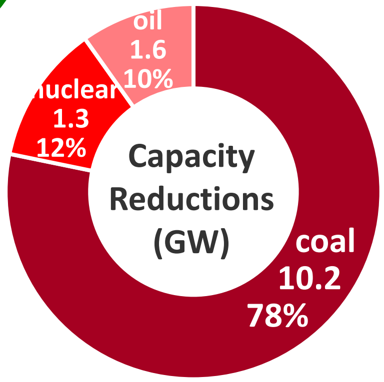
Renewables Through 2020



ote: Electricity generation from utility-scale facilities. Hydroelectric is conventional hydropower.
ource: U.S. Energy Information Administration, *Monthly Energy Review*, Table 7.2a, January 2021 and *Electric Power Monthly*, February 2021, preliminary data for 2020

2020 Utility-Scale Power





Electric Power Monthly
February 2021

ACP Market Report
Fourth Quarter 2020

Wind Turbine Sizes

Photo from Bergey Windpower Co. Inc., NREL

Small (≤100 kW)

- Homes
- Farms
- Remote applications (e.g., water pumping, telecom sites, ice making)

Photo from Tjaden Farms, NREL 13764

Mid-scale (100–1,000 kW)

- Village and hybrid power
- Community and distributed power
- Small commercial and industrial applications

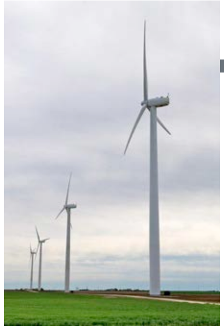


Photo from Native Energy Inc., NREL 7593

Large, land-based (1–3 MW)

- Large commercial and industrial deployments
- Large distributed power
- Utility-scale wind farms

Photo from HC Sorensen, NREL 17855

Large, offshore (3–7 MW)

- Utility-scale wind farms, shallow coastal waters with transition to deep water

There are four main applications for distributed wind deployments.

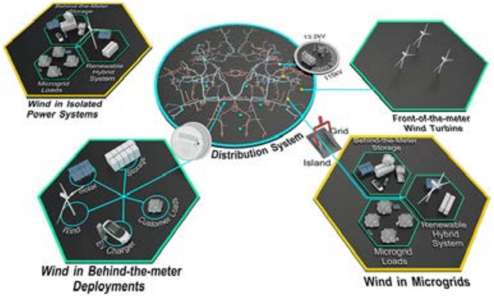
These applications have different technical needs as well as different economic and value considerations.

Photo Credit: Northern Power Systems

Isolated or islanded power that is not connected to a larger power system.
Toksook Bay, Alaska, USA

Credit: Hand Doster, One Energy Enterprise LLC

Behind-the-meter installations to provide local energy services.
Ball Corporation, Findlay, Ohio, USA



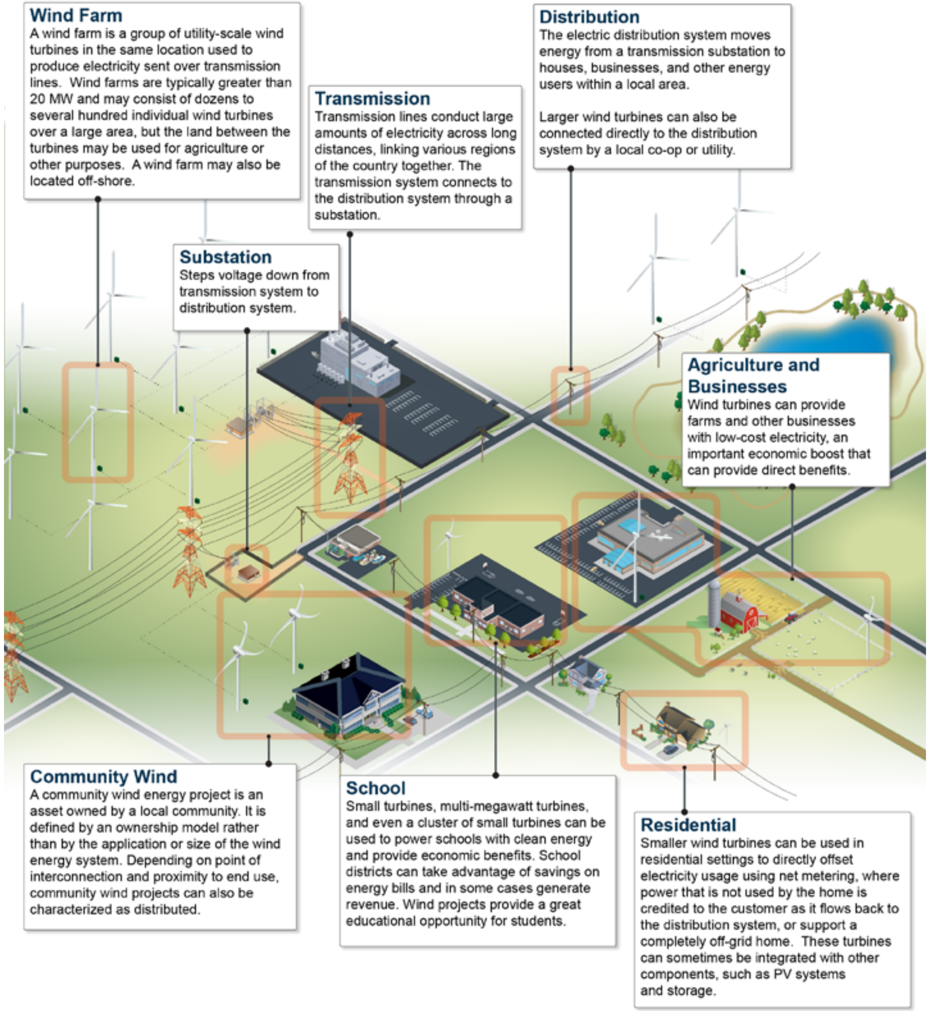
Integrating wind with diverse technologies creates a larger system that provides a range of benefits, including improved resiliency and flexibility. Graphic by Joshua Bauer, NREL

NREL: 57714

Utility-owned and operated distributed wind farms installed in front of the meter.
Kaupuni Village, Hawaii, USA

A multitude of ways to use distributed wind in current markets.

There is no one-size-fits-all solution; we need renewables deployment in many applications to meet current and future needs.

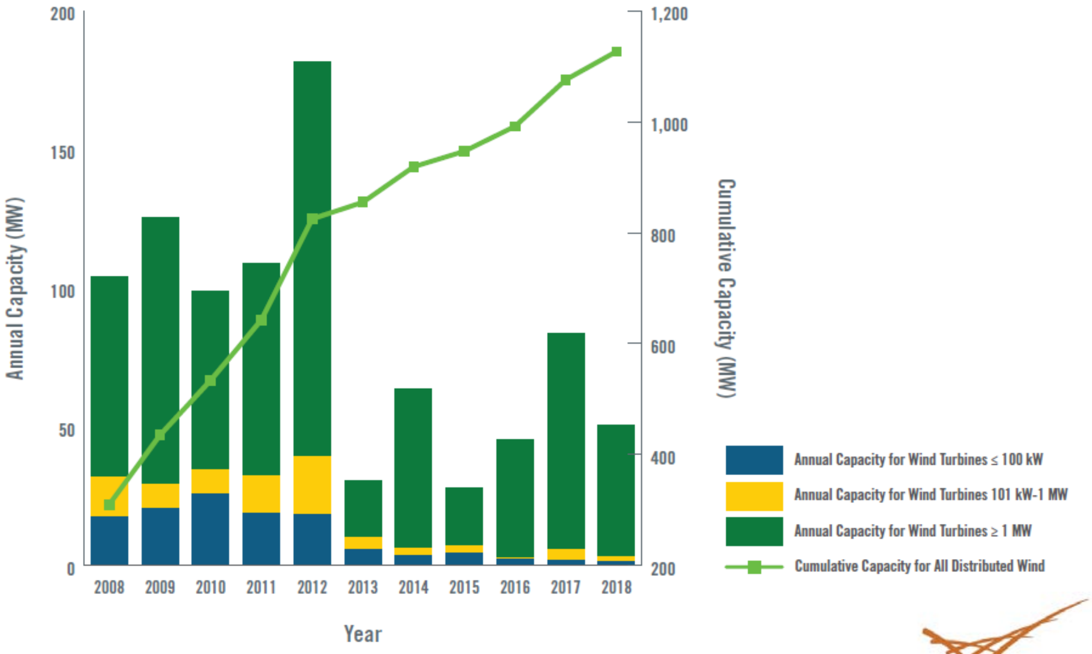


Distributed Wind Markets

Fair policy has huge impact on development—and thus on the industry.

Currently, the market is driven by large turbines installed in distributed applications because they can take advantage of the Production Tax Credit (PTC)

Distributed wind deployments have been anemic since changes in the Investment Tax Credit (ITC) left out distributed wind

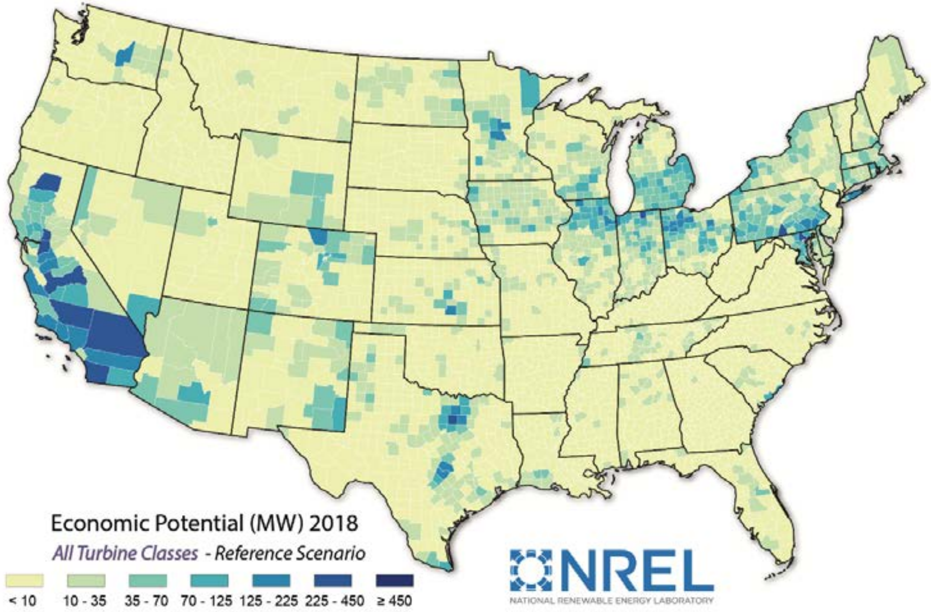


Distributed Wind Market Report: 2021 Edition. U.S. Department of Energy. available at: https://www.energy.gov/sites/default/files/2022-01/distributed-wind-market-report-2021-full-report-v2.pdf

Pacific Northwest NATIONAL LABORATORY

How much distributed wind development is viable?

Based on existing technology, there are wide areas of the country where behind-the-meter applications are economically viable. As costs continue to decrease, more markets become available.

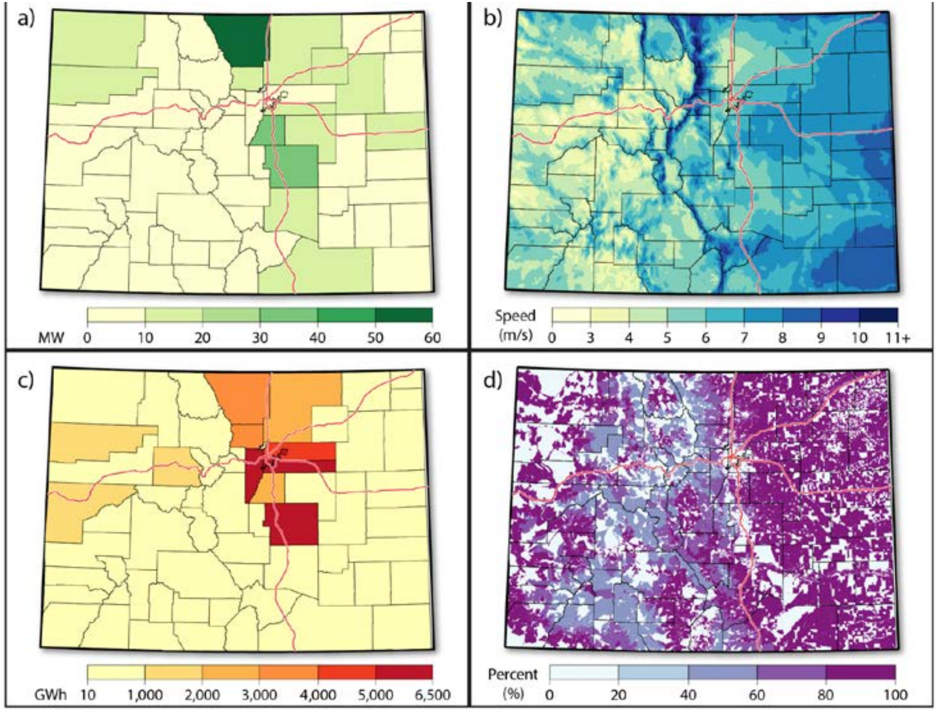


- **49.5 million residential, commercial and industrial sites** with technically feasible behind-the-meter development
- Potential capacity for turbines <1 MW is **3 terawatts (TW)**
- Larger turbines could provide additional **5.1 TW** of capacity in distributed applications.

Lantz, Eric, et al. 2016. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-67337. https://www.nrel.gov/docs/fy17osti/67337.pdf.

NREL-based modeling shows strong potential for wind development.

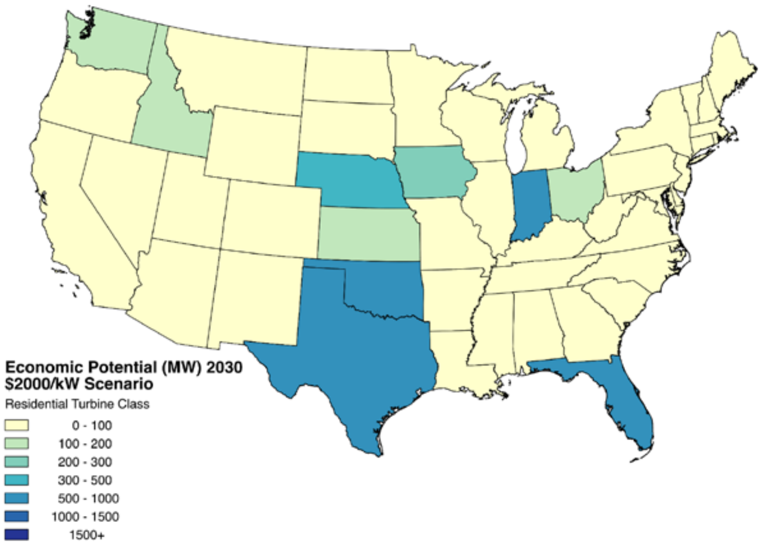
Areas with good wind resource outside of developed areas show very strong potential for behind-the-meter development.



You don't end up deploying in areas with the best wind resource! Potential behind-the-meter installations (upper left) are driven by wind resource (upper right), electricity costs (lower left), and lot size of potential users (lower right).

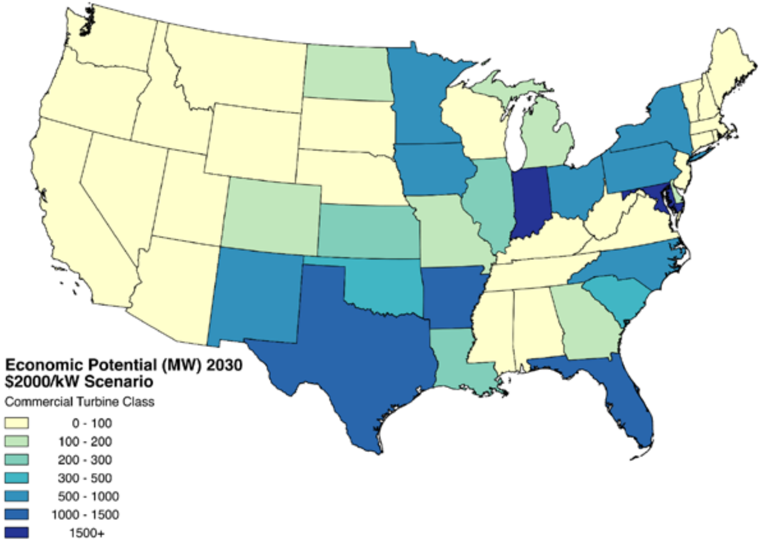
McCabe, Kevin, et al. 2018. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-70547. https://www.nrel.gov/docs/fy18osti/70547.pdf.

Spatial Trends of Economic Potential
for Residential and Commercial Distributed Wind Applications



Focusing on the residential and commercial-scale market segments, NREL examined the potential scale of distributed wind as a result of future cost reduction to $2,000/kW, about half of current generation costs.

Reaching a $2,000/kW cost point would result in 4.5 GW in the residential-scale development and 14.9 GW in the commercial-scale market potential with wide geographic dispersion by 2030.



Distributed wind technology is also seeing steady cost reductions.

DOE and NREL are working with multiple companies to develop a wide range of turbines with technologies from 300 W to 300 kW, all with unsubsidized costs between 40.0¢/kWh (for under 1kW) to 7.0¢/kWh for large turbines (300 kW).

Credit: Primus WindPower, / NREL 44229

Credit: Bill Schwankl, Alternative Energy Services

Credit: Dennis Schroeder / NREL 49381

Credit: QED Wind Power

Credit: Eocycle

Credit: Carter Wind Turbines

Cost of Power Comparison

- Rooftop residential solar 15.0¢/kWh
- Utility-scale solar 2.9¢/kWh
- Utility-scale wind 2.6¢/kWh.

(Lazard Market Report 2021)

Why should we be thinking about wind?

Outside of cost, wind has other values.

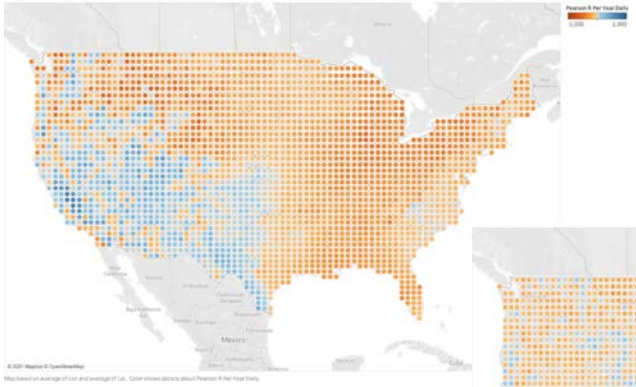
Distributed wind has additional values that will support a more impactful distributed energy market.

- Higher energy density, especially in areas with higher wind speed
- Small footprint, allowing for increased on-site generation
- Improved (or different) grid support capabilities as compared to solar photovoltaics (PV)
- Wind is complementary to solar; seasonal and daily variation will be important to achieve high renewable contributions while improving resilience
- High domestic content that can be produced in small, distributed factories.

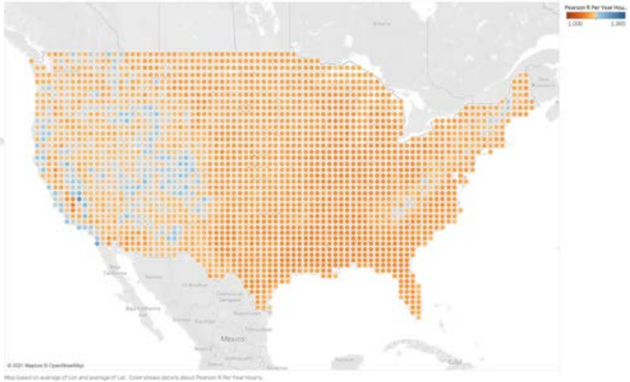
Complementarity between solar and wind is critical.

Considering higher renewable contributions, in many parts of the United States a combination of wind and solar (with storage) will be required.

Daily and hourly complementarity (red is good and blue is bad) will lower the costs and reduce the need for storage to meet higher renewable energy contributions.



Averaged across days



Averaged across hours

Clark, C., Barker, A., King, J., & Reilly, J. (2022). *Wind and Solar Hybrid Power Plants for Energy Resilience*. https://www.nrel.gov/docs/fy22osti/80415.pdf

Distributed energy will play a key role in addressing global energy needs.

International organizations focus almost completely on solar PV + storage as the only option for energy-access solutions.

IEA – *World Energy Outlook 2020*: Renewables meet 80% of the growth in global electricity demand to 2030. Hydropower remains the largest renewable source of electricity, but solar is the main driver of growth, as it sets new records for deployment each year after 2022, followed by land-based and offshore wind energy.

IEA. 2020. *World Energy Outlook 2020*. Paris, France: IEA. https://www.iea.org/reports/world-energy-outlook-2020.

World Bank – *Mini Grids for Half a Billion People*: To reach universal access by 2030, 490 million people served at lowest cost by 210,000 mini-grids, (third-generation mini-grid, mostly solar hybrids) requiring an investment of $220 billion.

ESMAP. 2019. *Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers*. Energy Sector Management Assistance Program (ESMAP) Technical Report 014/19. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/31926.

Sustainable Energy for All – *State of the Global Mini-Grids Market Report 2020*: The fastest-growing segment of the global mini-grids market is that of solar hybrid mini-grids. Anticipate 111 million households by 2030, a $72 billion investment.

Soni, Ruchi, et al. 2020. *State of the Global Mini-Grids Market Report 2020.* Bloomberg NEF and Sustainable Energy for All. https://minigrids.org/wp-content/uploads/2020/06/Mini-grids_Market_Report-20.pdf.

Understanding the challenges.

There are challenges that need to be overcome to support wide-scale development.

- Continued cost reduction and reliability improvements, especially around deployment costs, are exacerbated by slanted renewable energy policy
- Interconnection requirements and acceptance by rural utilities
- Lack of access to project financing, which is driven in large part by undemonstrated performance prediction
- Local zoning and permitting variances because of outdated height and setbacks
- Lack of information, knowledge, and consideration of distributed wind.

Research is underway to address distributed wind challenges.

DOE Wind Energy Technologies Office has launched research programs that are helping address many of the technical challenges.

Lowering technology costs, developing new markets, and improving turbine reliability

- Competitiveness Improvement Project
- Defense and Disaster Deployable Turbine (D3T)
- Turbine standards improvements

Improving integration and control

- Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad (MIRACL)
- Distributed Integrated Energy Laboratory (DIEL) development and implementation

Improving prediction of long-term output

- Tools Assessing Performance (TAP)

Understanding market dynamics

- Market modeling and analysis
- International research collaboration.

Conclusion

Distributed wind is a viable distributed energy resource on its own or in combination with on-site solar for a wide range of energy consumers.

To achieve a 100% clean power system and 50% decarbonization of buildings by 2035, distributed wind must be part of the solution.

Distributed wind, combined with other distributed technologies, can provide a path to support underserved communities and those undergoing energy transitions.

Although there are challenges to distributed wind, the progress in distributed solar over the last 10 years indicates that the challenges can be overcome with a combination of research, community-centric deployment assistance, and supportive, stable policy.

Thank You

www.nrel.gov

Ian Baring-Gould
Distributed Wind Platform Lead

NREL/PR-5000-82467

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

NREL Transforming ENERGY