



U.S. – INDIA ENERGY MONITOR

THE WIND ISSUE

*A Quarterly Snapshot
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The U.S.-India Energy Monitor is a quarterly snapshot of climate and energy in the United States and India: two of the world's largest economies, largest consumers of energy, and largest emitters of greenhouse gas emissions responsible for climate change. Each quarter, the monitor provides a roundup of energy and climate news, followed by a detailed analysis of a topic relevant to energy and climate in both countries. The monitor provides readers timely, policy-relevant analysis on issues affecting the trajectories of two countries who will shape the world's energy and climate future.

LATEST DEVELOPMENTS

The Biden-Harris administration attempts to tame high gas prices

This quarter, the Biden-Harris administration attempted to tame high gas prices caused by Russia's war in Ukraine through a variety of ways. At the G7 summit, in response to rising Russian oil revenues despite various sanctions, President Biden proposed an "inverse OPEC", a coalition of oil buyers like the world's largest oil cartel. Biden envisions the coalition minimizing Russian oil revenues by enforcing a price cap on Russian oil without reducing global supplies which could trigger a recession.^{1,2} In addition, Biden called on the largest U.S. oil companies to increase refining capacity and lower pump prices for consumers, accusing them of aggravating consumer pain by earning profits off high energy prices.³ There is little room for more domestic refining as U.S. crude oil refining capacity has decreased to its lowest level since 2014. U.S. refineries have shut down from storm damage and reduced demand for gasoline during the pandemic.⁴ The administration also announced through the U.S. Department of Energy the sale of 45 million barrels of crude oil from the Strategic Petroleum Reserve which may help stabilize volatile American energy

prices.⁵ Lastly, Biden also proposed a three-month federal fuel tax holiday.⁶ However, this will yield little relief for American consumers, as it subsidizes demand by reducing prices and raises revenue to producers like Russia.⁷

India attempts to reduce risks from rising oil prices by buying discounted Russian oil

To protect consumers from rising energy costs and to reduce its import bill, India is negotiating with Russia to purchase oil at reduced prices.⁸ This comes in the wake of the Ukrainian crisis when many countries, led by the United States and European Union, have cut Russian crude imports. India cannot import from several other major oil producers like Iran and Venezuela because Western countries have sanctioned them. In the past, India has not relied heavily on Russian supplies. However, March 2022 marked the beginning of increased imports. Indian oil imports from Russia came in second after Iraq in May.⁹ China and India's imports of more Russian oil than the United States had anticipated may be alleviating a supply shortage on the world and reducing volatile oil prices.¹⁰

WIND: A VITAL SECTOR TO DECARBONIZE THE UNITED STATES AND INDIA

The focus of this issue is the wind sector in the United States and India. As a clean energy source vital to mitigating climate change and realizing a net-zero future, wind energy's current position and future trajectory in the energy mix is critical for both countries. The United States and India are global leaders in deploying wind for electricity generation, and both countries have started exploring increased deployment of offshore wind technology off their respective coastlines. This issue provides an overview of the current state of the wind sector and opportunities for the future.



WIND IN THE UNITED STATES

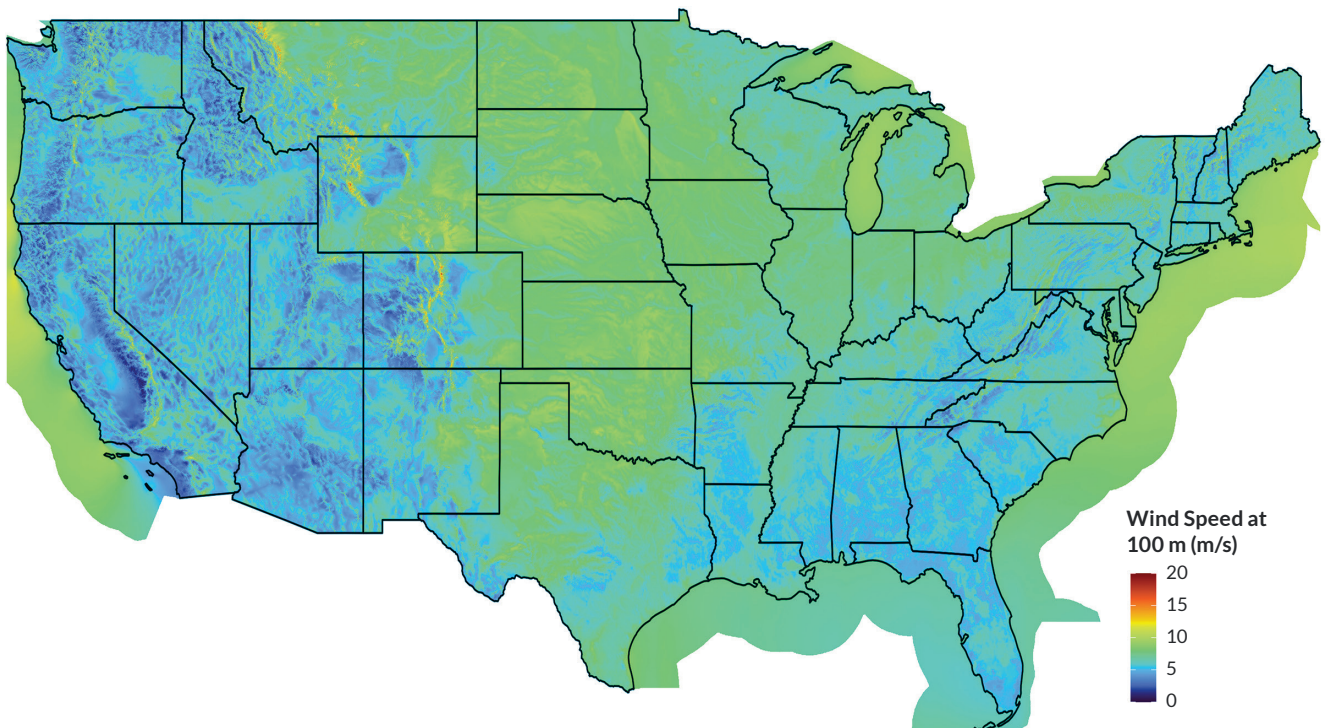
The United States ranks among the top countries in the world for wind power generation potential, the maximum amount of wind electricity a country can generate given its land and wind speeds.^{11,12} The country has the potential to generate approximately 32,000 terawatt-hours (TWh) of electricity from wind power in 2020, which dwarfs total U.S. electricity demand in 2020 of 3,860 TWh.¹³ However, due to economic and land constraints, the country will never exploit all this potential. The impact on the workforce is also notable. In the United States the wind industry employed approximately 120,000 people in 2021.¹⁴

The distribution of wind power across the United States varies regionally. Wind speed, elevation, and topography generally determine the potential of an area to generate wind electricity. Areas with higher wind speeds generally are better suited for wind energy. Moreover, wind turbines at higher heights produce more electricity because wind speeds increase with elevation. In the continental United States, areas best suited for wind electricity include the central United States in the Great Plains, the east and west coasts, and parts of the Gulf of Mexico near Texas (Figure 1).

FIGURE 1.

Average onshore and offshore wind speed at 100 m height in the United States.

Source: Global Wind Atlas 3.0¹⁵



The United States ranks among the top countries in the world for wind power generation potential

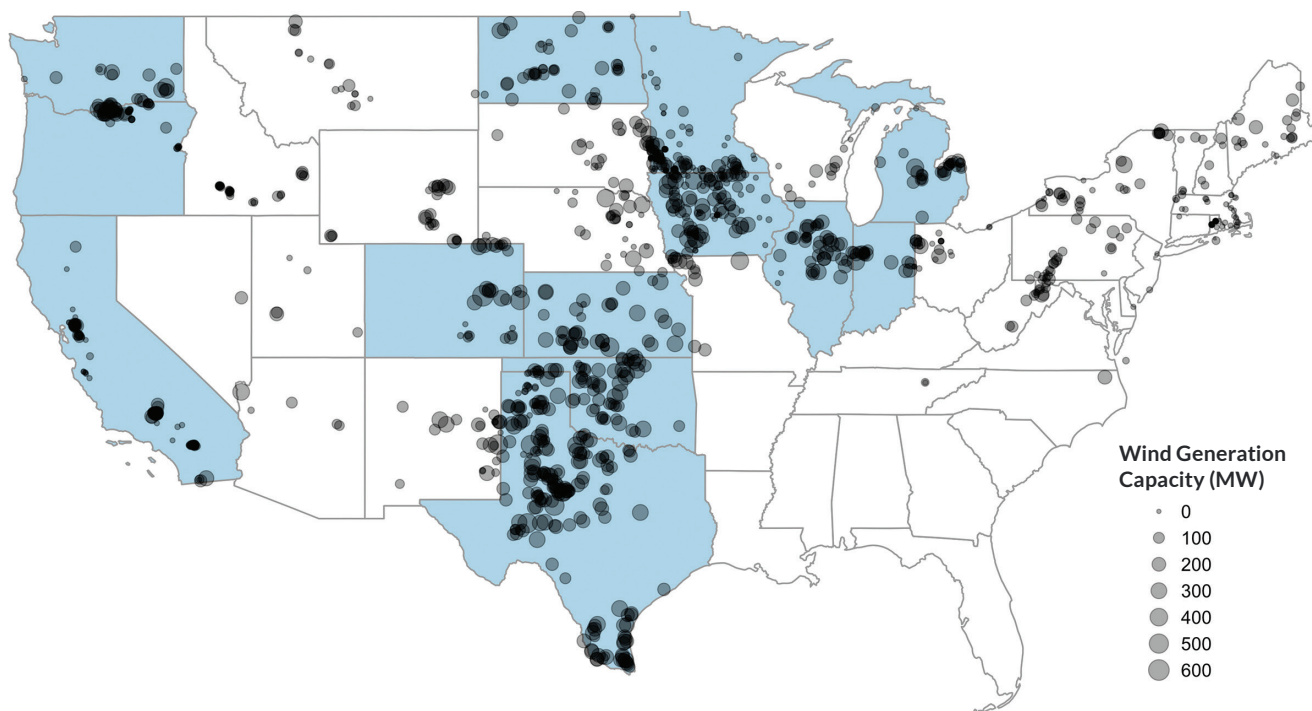
Wind electricity generating capacity in the United States ranks second in the world standing at about 130,000 megawatts (MW), or 130 gigawatts (GW), which formed about 11% of all generating capacity.¹⁶ Almost all wind power in the United States is onshore, but offshore development in places like the New England coast is in nascent stages.¹⁷ Due to geographic variability in wind

speeds, most wind generating capacity sits in 13 states which collectively house 80% of the nation's capacity: Texas (26%), Iowa (9%), Oklahoma (8%), Kansas (6%), Illinois (5%), California (5%), Colorado (4%), Minnesota (4%), North Dakota (3%), Oregon (3%), Washington (3%), Michigan (3%), and Indiana (2%) (Figure 2).

FIGURE 2.

Wind electricity generating capacity throughout the United States.

Source: U.S. Energy Information Administration¹⁸



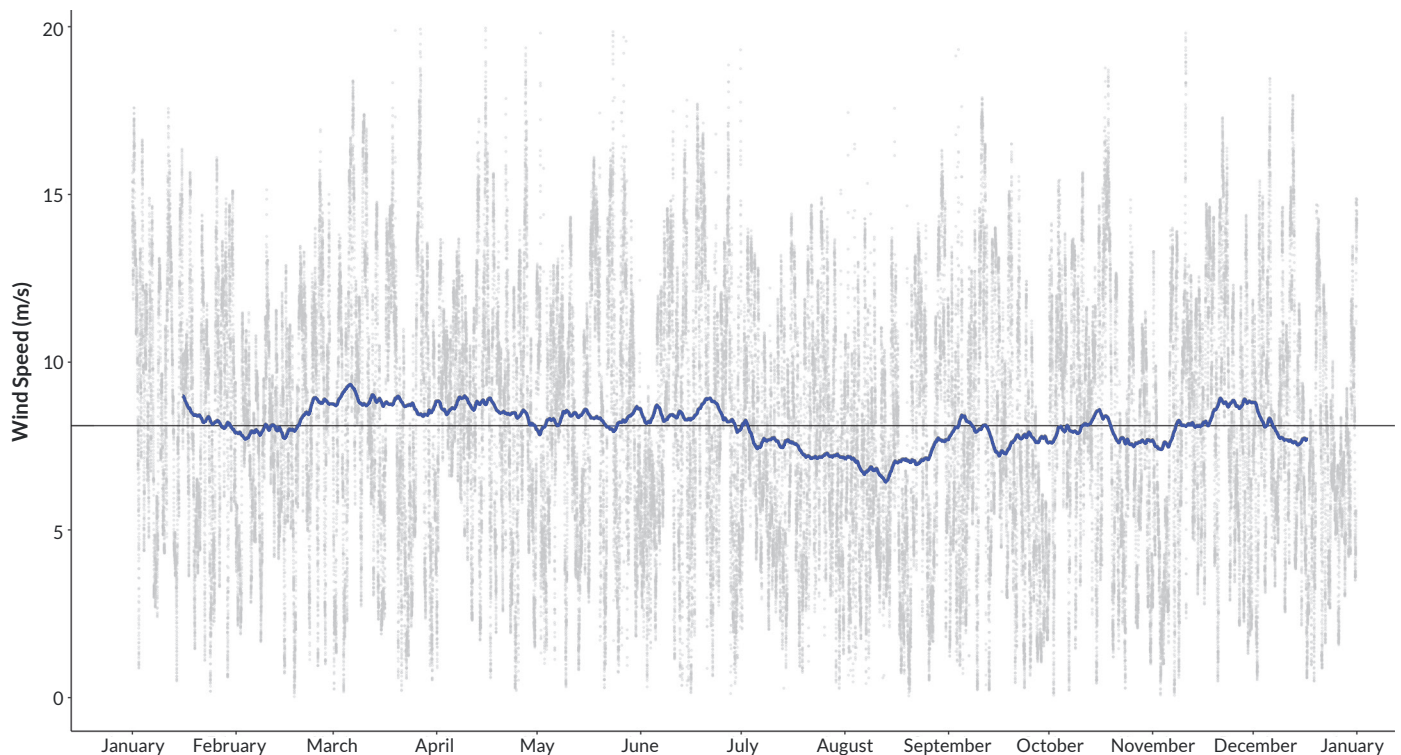
13 states collectively house
80% of the nation's wind
generating capacity

Wind energy is an intermittent source of electricity, varying by time-of-day and season. On average annually, the amount of capacity available in the United States only generates 30-35% of the time, but recent projects with newer turbines generate upwards of 40% of the time.^{19,20} Wind speeds from a representative site in Iowa (Figure 3), which has strong wind resources, show how

wind electricity varies not only every few minutes, but also seasonally: above average speeds during the winter and spring and below average speeds during the summer. This pattern holds for most of the United States, except western states like California, Oregon, and Washington where wind energy peaks in the summer.²¹

FIGURE 3.

Annual wind speeds from a representative site in Iowa show seasonal differences. Horizontal line is the annual average speed, the dark line is a rolling monthly average, and points are speeds at five-minute intervals. Source: Draxl et al (2015)²²



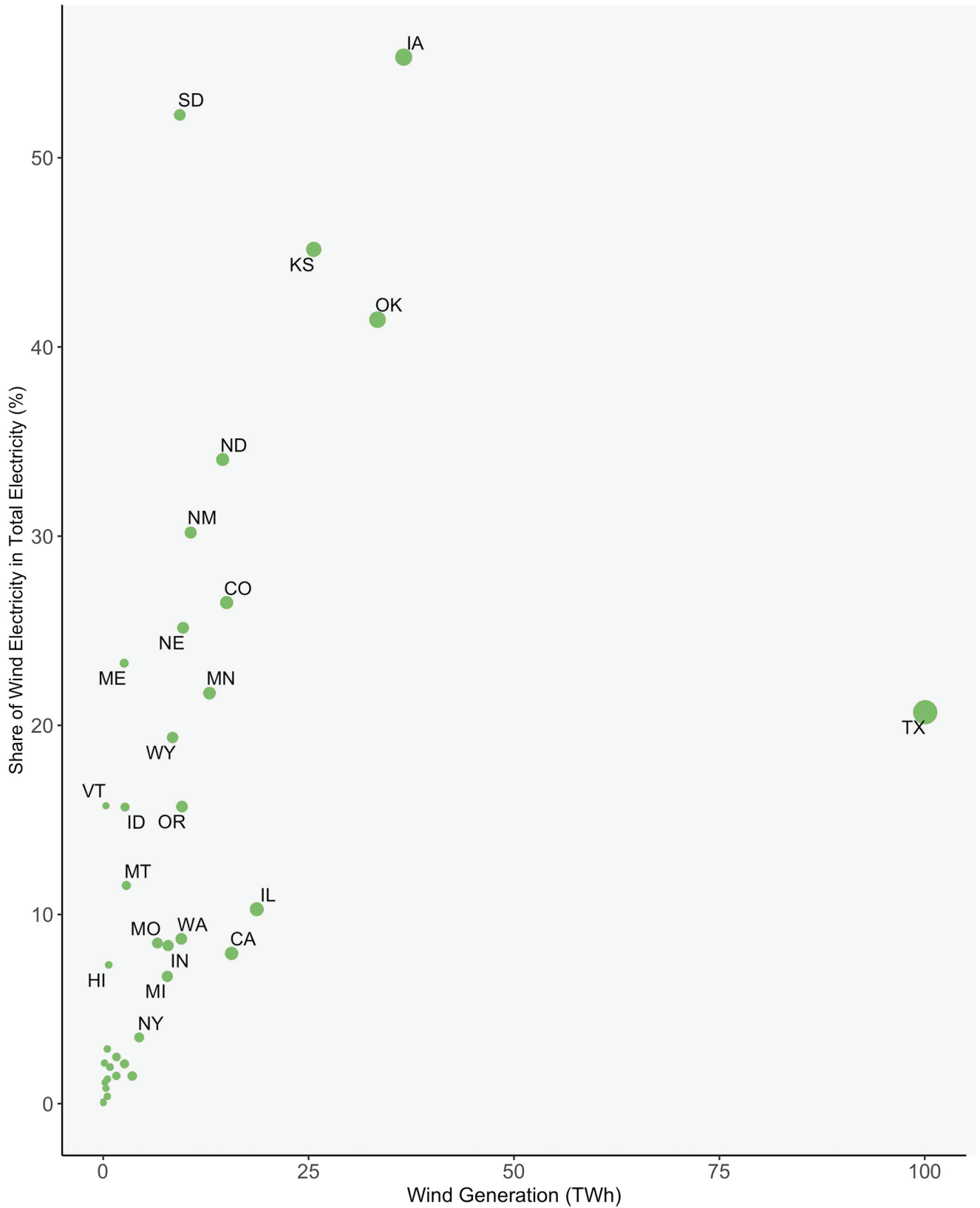
Despite its intermittency, wind generation in the United States stood at 380 TWh in 2021, second largest in the world.^{16,23}

This was enough to meet the electricity consumption of about 35 million U.S. households and was 9% of all U.S. electricity demand in 2021.^{23,24} Texas leads the nation in wind generation, forming about 30% of nationwide wind generation. Wind also forms a sizable portion of electricity produced in many states with amounts exceeding 40% of all electricity generation in states like Iowa, South Dakota, Kansas, and Oklahoma (Figure 4).

FIGURE 4.

Share of wind generation and total wind generation in 2021 in the United States.

Source: U.S. Energy Information Administration^{25,26}



Wind is a zero-carbon source of energy with minimal environmental impacts. Greenhouse gas emissions of wind power plants on a life cycle basis remain 99% lower than coal power plants.²⁷ Moreover, the climate, air quality, and electrical grid benefits of wind power outweigh its costs.^{20,28,29} While there are documented cases of wind turbine collisions with birds and wildlife, the National Audubon Society cites greater threats to wildlife from climate change to support wind energy.³⁰

Since the 1990s, wind energy in the United States has enjoyed several policies at the federal and state levels to increase its development.³¹ Federally, there have been ongoing tax credits for both production (based on electricity generation) and investment (to offset capital costs for new projects).³²⁻³⁴ Crucially, states such as Texas also developed “Renewable Energy Zones” to direct electricity transmission projects to connect high-wind areas in the panhandle of Texas to cities with the highest electricity demands like Houston and Dallas.^{35,36} Other states have adopted “renewable energy portfolio” standards that mandate a certain portion of electricity consumed in the state be renewable.³⁷ Most recently, the Biden-Harris administration announced a target of 30 GW of offshore wind capacity.³⁸

With high resource potential, government incentives, and decreases in the costs of wind turbines by more than 50%, the cost of wind energy has decreased approximately 40% since 2009-2010 in the United States. While costs have declined nationwide, costs differ by location with the cheapest installed plants in Texas and the most expensive in California and New England.²⁰ Currently, onshore wind faces competition from solar and natural gas.²⁰

Under current policies, the U.S. Energy Information Administration projects wind to form at most 15% of new nationwide electricity capacity additions through 2050, with the greatest additions coming from solar and natural gas generating capacity.³⁹ Under scenarios of coherent federal climate policy in the United States such as clean energy tax credits in Build Back Better, analyses suggest capacity of wind could increase about fivefold by 2035 relative to current policies. However, solar and natural gas capacity would still dwarf wind capacity under these scenarios.⁴⁰

Wind is a zero-carbon source of energy with minimal environmental impacts.



WIND IN INDIA

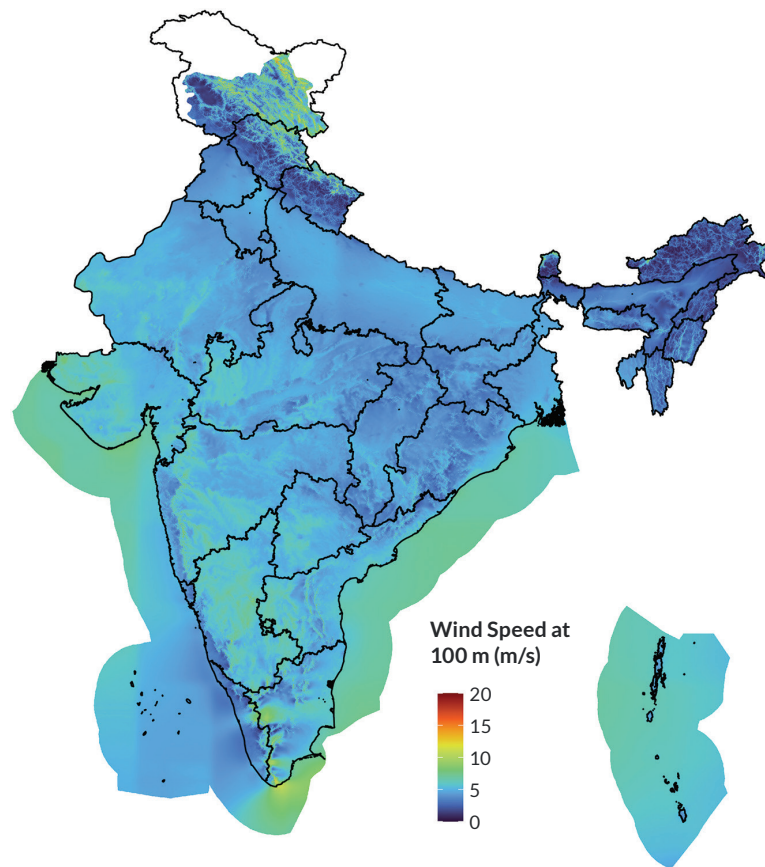
Like the United States, India also ranks high among the world's wind energy potentials, but wind resources are lower and are more geographically concentrated.⁴¹ The country has the potential to site approximately 300,000 MW of wind energy given conservative estimates of land constraints and wind speeds.⁴¹ This is much lower than the United States, and translates to roughly 500-800 TWh of wind generation assuming average intermittency.^{41,42} Other analyses peg this number to be two to three times

higher with relaxed assumptions of land available for development.⁴²⁻⁴⁴ Wind power employment in India corresponds with the lower wind resources available. In India, approximately 26,000 people worked in the wind industry in 2021.⁴⁵

In India, the best wind speeds and resources sit in southern and western India and in the highest elevations of the Himalayas (Figure 5). Likewise, the highest wind speeds for offshore wind development lie off the far western and southern coasts.

FIGURE 5.

Average onshore and offshore wind speed at 100 m height in India. Source: Global Wind Atlas 3.0¹⁵



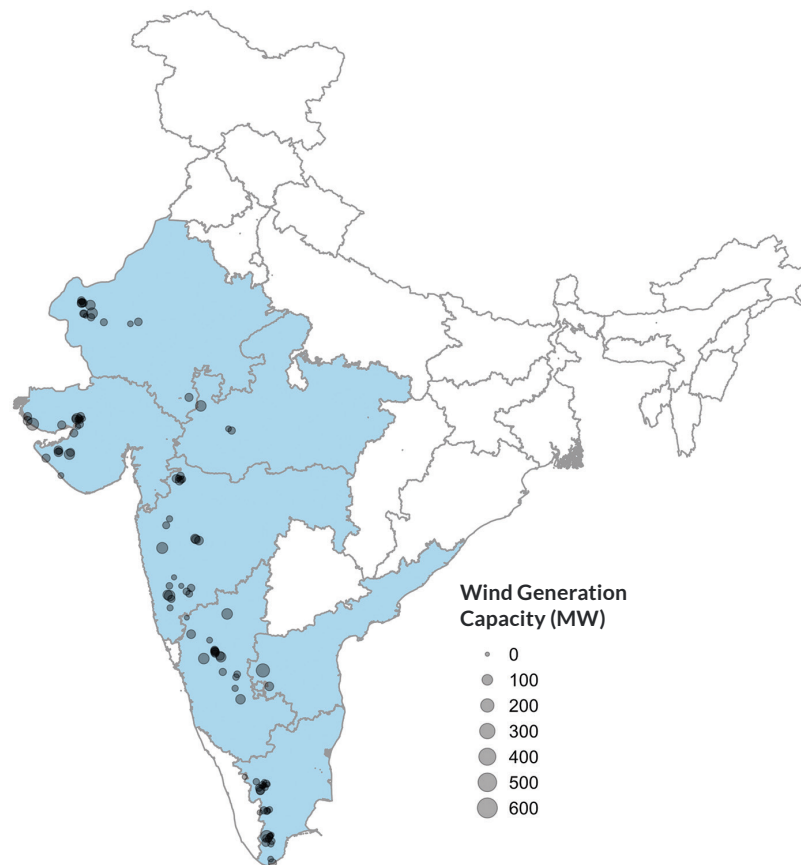
Like the United States, India also ranks high among the world's wind energy potentials.

In 2021, total wind generating capacity in India stood at approximately 40,000 MW (40 GW), ranking fourth in the world.¹⁶ Wind formed about 10% of all generating capacity in the country.⁴⁶ Like the United States, wind generating capacity in India is disproportionately concentrated in a

handful of states due to geographic variability in wind speeds (Figure 6). Just seven states housed all wind capacity: Tamil Nadu (25%), Gujarat (23%), Karnataka (13%), Maharashtra (13%), Rajasthan (11%), Andhra Pradesh (10%), and Madhya Pradesh (6%).

FIGURE 6.

Wind electricity generating capacity in India. Source: World Resources Institute⁴⁷



Wind generating capacity in India is disproportionately concentrated in a handful of states due to geographic variability in wind speeds

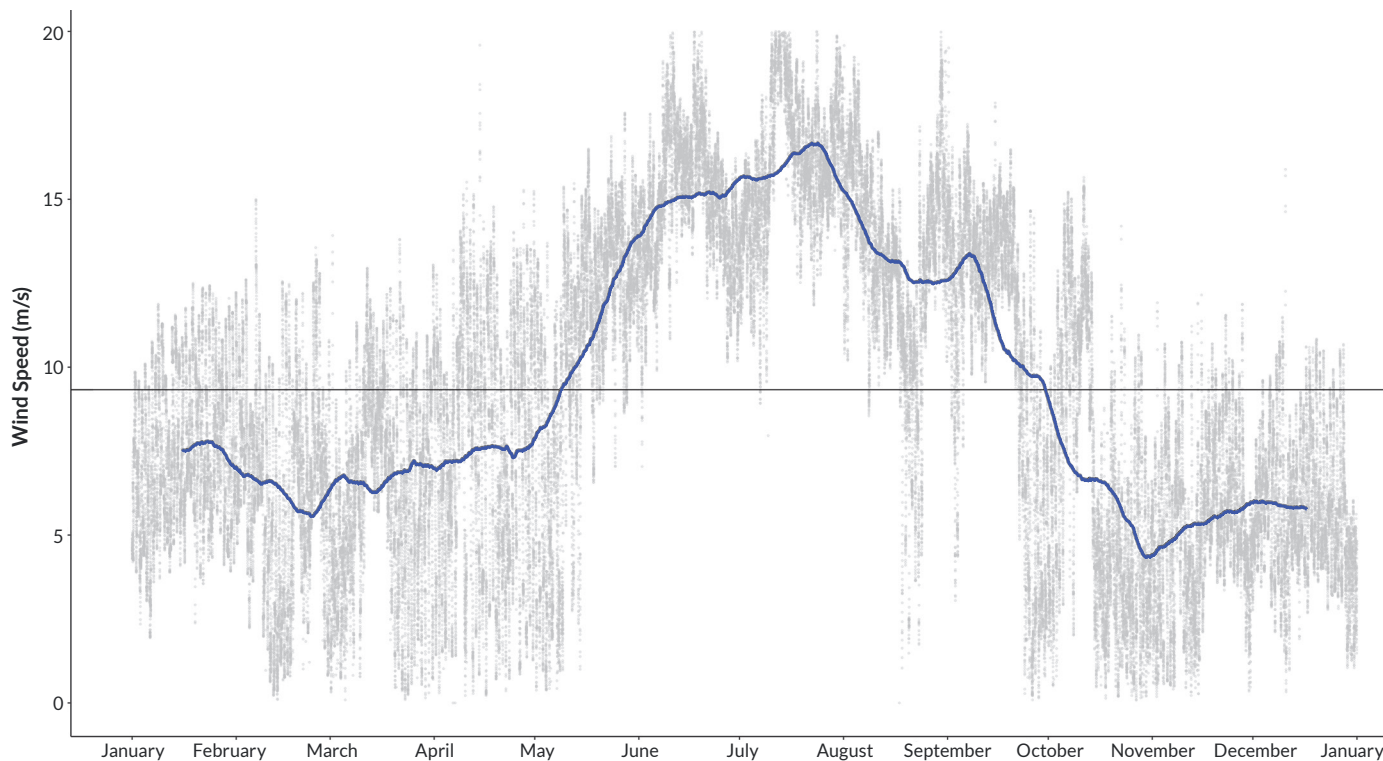
Wind energy in India is even more seasonal than wind energy in the United States. The strongest wind speeds in India occur during the rainy, summer monsoon from June to September. For example, at a representative site from Tamil Nadu, which has strong wind resource potential in India, average wind speeds during the monsoon can be 50% higher than annual averages while speeds

during dryer months can be up to 50% lower (Figure 7). During the monsoon, turbines can run on average as high as 40% of the time, but that frequency decreases to as low as 10% during dry months. Consequently, over the year, wind only generates about 20% of the time in India because of this strong seasonality, lower than the 30% on average across the United States.^{48,49}

Wind energy in India is even more seasonal than wind energy in the United States.

FIGURE 7.

Annual wind speeds from a representative site in Tamil Nadu show stronger seasonal differences than the United States. Horizontal line is the annual average speed, the dark line is a rolling monthly average, and points are speeds at five-minute intervals. Source: Palchak et al. (2017a, 2017b)^{50,51}



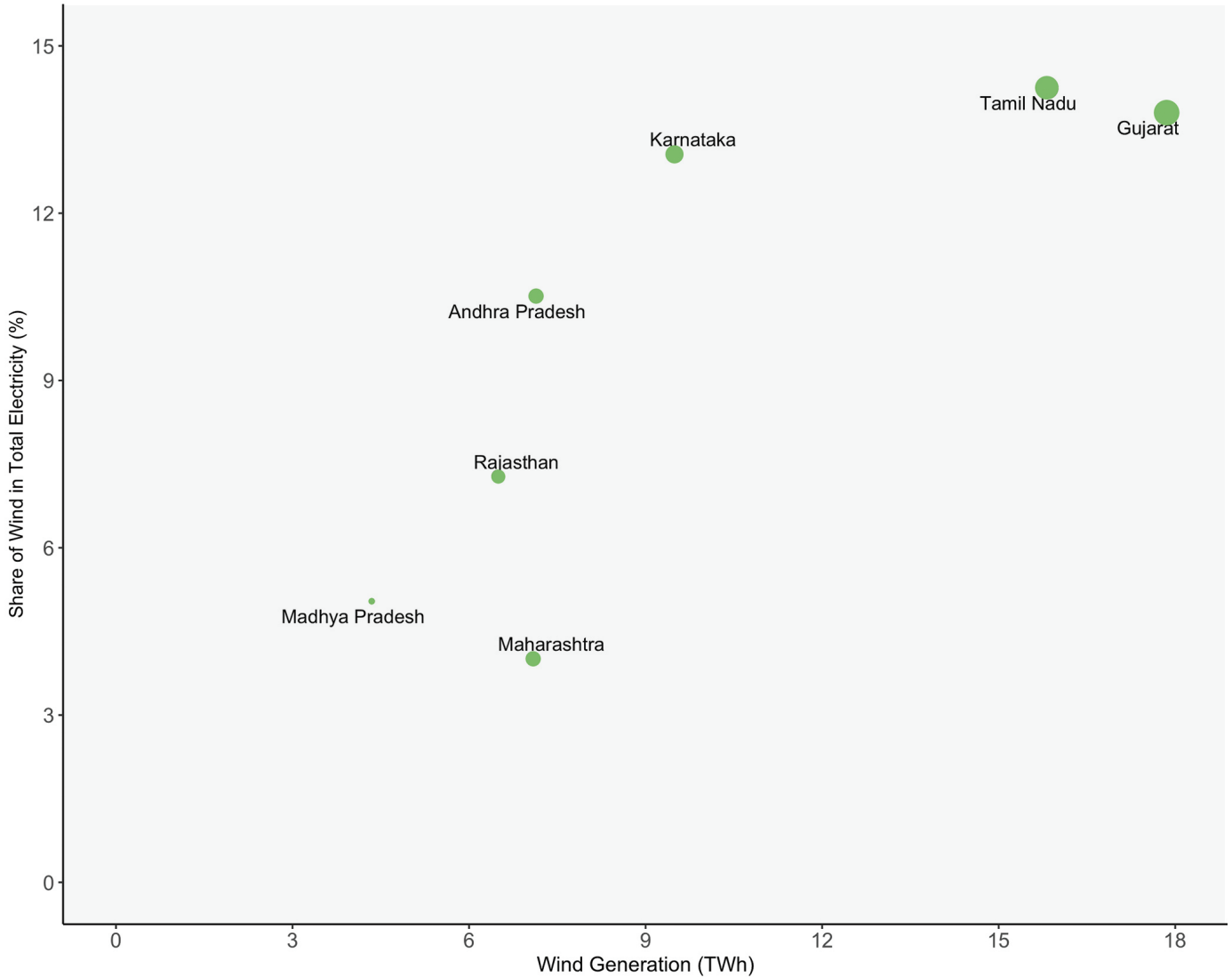
Wind generation in the India stood at 70 TWh in 2021, fifth largest in the world.^{16,52}

This formed about 5% of all electricity generation in India.⁴⁶ Among the seven states where wind generates electricity, Tamil Nadu and Gujarat generated the most wind electricity, and amounts

of wind generation exceeded 13% of their electricity shares (Figure 8). Overall, the amounts and shares of wind electricity in India are lower than the United States. This is consistent with the differences in geographic variability and seasonality of wind energy between the two countries.

FIGURE 8.

Share of wind generation and total wind generation in 2021 in India. Source: Government of India^{52,53}





The Government of India and state governments in India have supported wind energy through a variety of mechanisms. Chief among this is a national target to install 60 GW of wind energy by 2022.⁵⁴ While the country will likely miss this goal, the target has signaled long-term policy focus on growing wind energy in the country.⁵⁵ In June 2022, the Government of India also announced intentions to auction off shore areas for wind development.⁵⁶ In addition to the target and offshore auctions, the central government has “renewable purchase obligations”, like renewable purchase standards in the United States, mandating a certain portion of generation in each state come from renewable sources. It also waives transmission charges for wind power between states.⁵⁷ In the past, the central government provided tax incentives and credits for capital investments in the wind sector.^{58,59} Even now there is meaningful institutional protection on investment. The Solar Energy Corporation of India (SECI), a public sector company, serves as an intermediary between wind project developers and distribution companies that procure wholesale power. SECI reduces investment risks by providing payment guarantees to project developers in case

distribution companies fail to pay for the power they procure.⁵⁷ At the state level, several states have “feed-in tariffs” which guarantee a minimum price paid to wind power developers. In addition, some states also have a land bank for easily accessible land to developers.⁵⁹

With strong government incentives, costs for wind energy have decreased in India, and wind energy will form a sizable portion of India’s efforts to meet energy demand while decarbonizing its economy. Costs of wind energy in India since 2014 have decreased by approximately 60%.⁶⁰ They are currently comparable to those in the United States.⁶¹ Likewise India has pledged to have net-zero greenhouse gas emissions by 2070.⁶¹ The country has increased ambition by setting a non-fossil fuel electricity (nuclear, solar, wind, and hydro) capacity target to 500 GW by 2030. Wind will likely form about 140 GW of this target.⁶²⁻⁶⁴ Absent a net-zero target and climate emissions limits, wind capacity is projected to grow about sixfold by 2050 from current levels. Yet to meet more stringent limits like India’s 2070 net-zero target, India will require wind capacity to grow more than tenfold by 2050.⁶⁵

Wind energy in the United States and India is poised for growth in both countries to meet clean energy goals.

Both countries rank among the top in the world for wind energy, and similar policy mechanisms have supported development of the sector in India and the United States

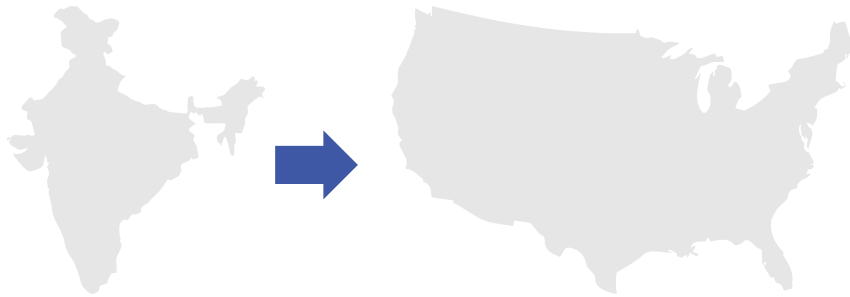
However, in both countries due to geographic variability, seasonality, and costs the sector faces competition from solar, whose capacity will likely dwarf that of wind. Wind energy in India will likely need greater policy support and focus than in the United States because of lower resource potential. India has lower wind speeds and less land available than the United States for wind energy development. In addition to policy, India will need technology that can exploit wind for electricity at higher elevations and lower speeds due to the constraints it faces.

To take advantage of wind, both countries will need greater efforts in areas such as more precise forecasting of wind speed under a warming climate, lowering of barriers to construct electricity transmission lines from wind projects to consumers, innovative financing mechanisms to fund new projects, and deployment of offshore wind which is nascent in both countries. Consequently, wind energy cooperation in areas of technology development, forecasting, and policy provide active areas of cooperation between the two countries. Current efforts include some of these areas. For example the National Renewable Energy Laboratory and the National Institute of Wind Energy collaborate on wind forecasting.⁶⁶ Overall wind will continue to be a pillar of energy ties between the two countries.

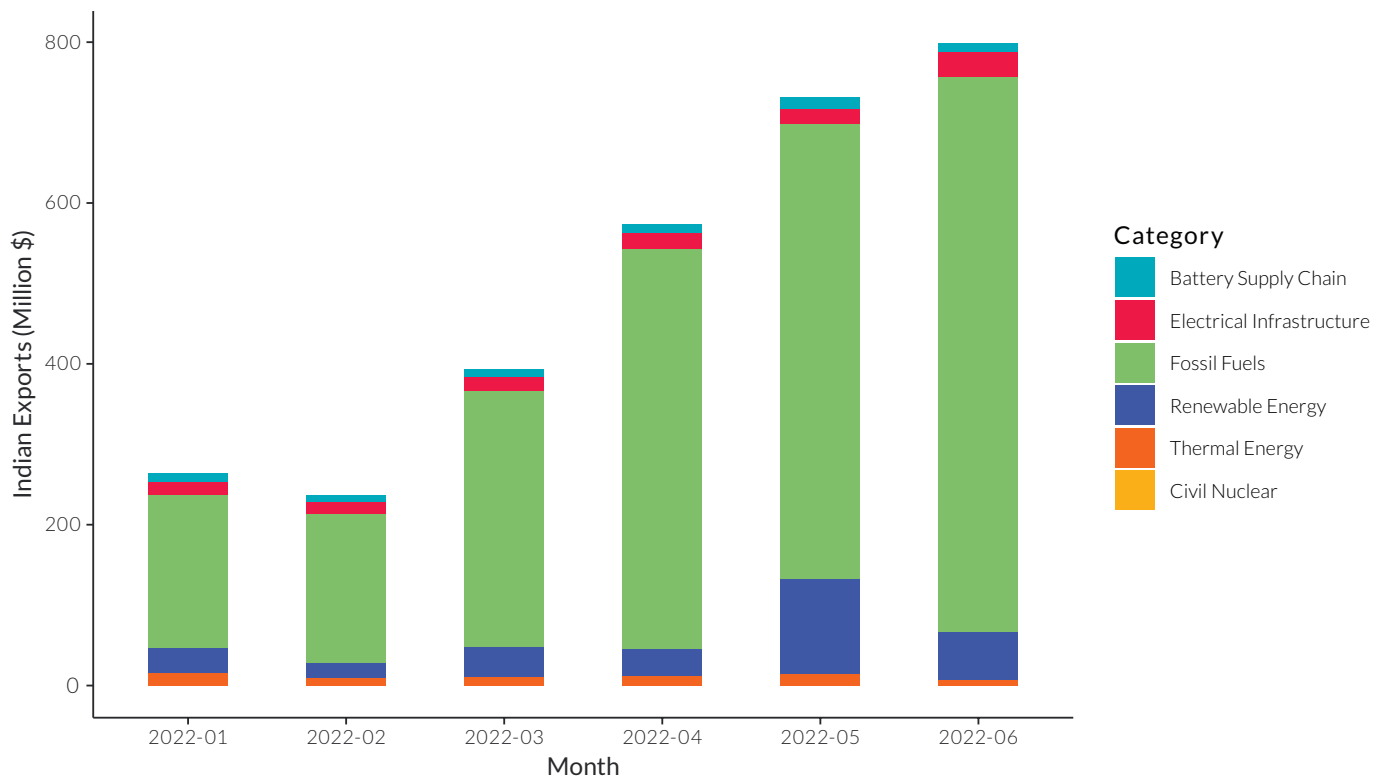


INDIA-U.S. ENERGY TRADE

INDIAN EXPORTS TO THE U.S. (MILLION \$)



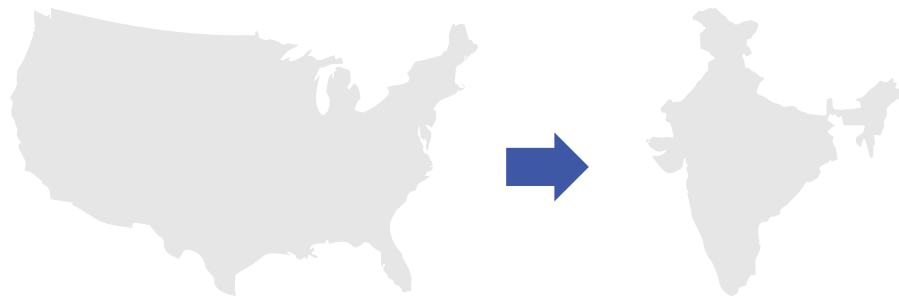
CATEGORY	JANUARY 2022	FEBRUARY 2022	MARCH 2022	APRIL 2022	MAY 2022	JUNE 2022
Fossil Energy	190	184	319	497	565	689
Renewable Energy	32	19	37	34	119	59
Electrical Infrastructure	17	16	17	20	19	32
Thermal Power	15	9	10	11	14	7
Battery Supply Chain	10	8	9	11	15	12
Civil Nuclear	-	-	-	-	-	-



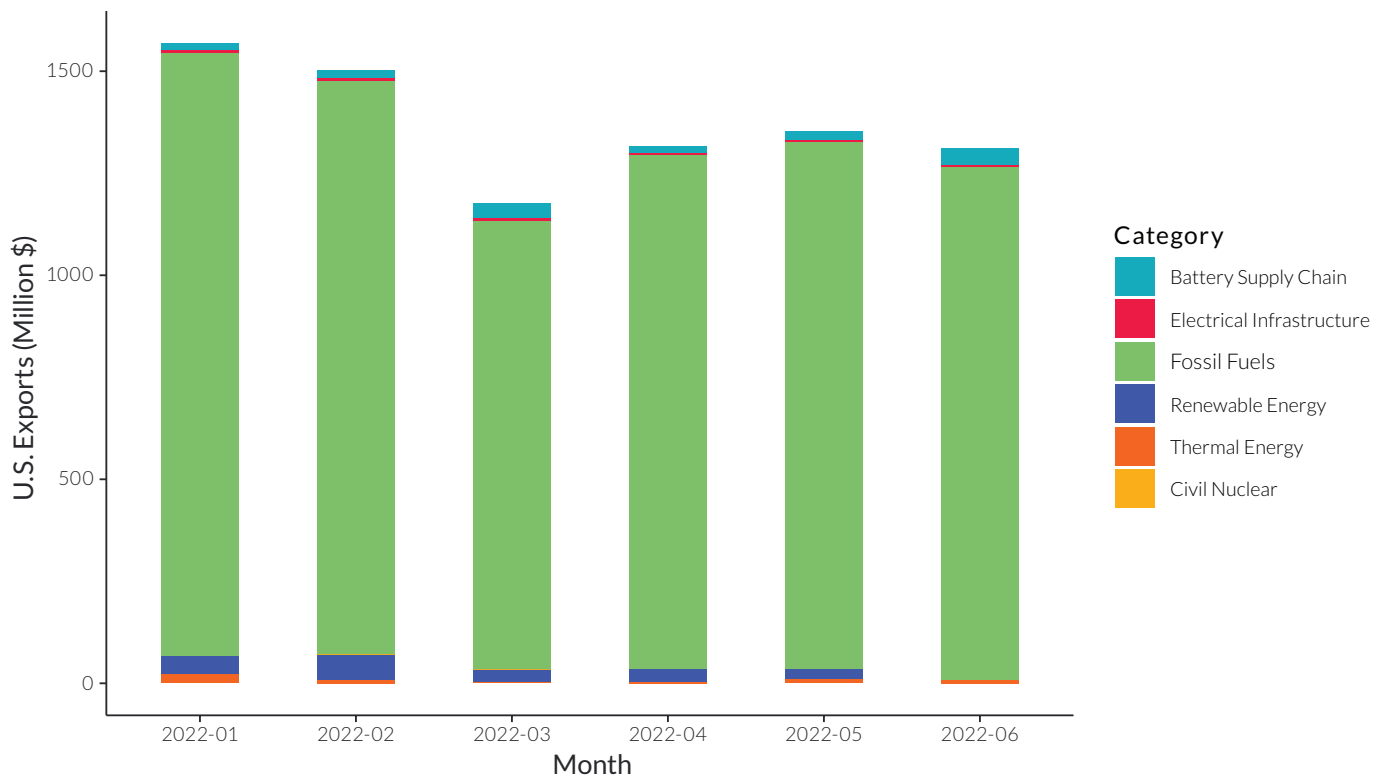
Source: U.S. Census Bureau⁶⁷, U.S. International Trade Administration⁶⁸

U.S.-INDIA ENERGY TRADE

U.S. EXPORTS TO INDIA (MILLION \$)



CATEGORY	JANUARY 2022	FEBRUARY 2022	MARCH 2022	APRIL 2022	MAY 2022	JUNE 2022
Fossil Energy	1,478	1,406	1,099	1,258	1,290	1,256
Renewable Energy	44	61	31	32	26	-
Electrical Infrastructure	8	7	7	6	7	7
Thermal Power	21	9	2	3	9	8
Battery Supply Chain	17	20	36	18	22	40
Civil Nuclear	0.03	0.06	0.04	0.09	0.02	0.03



Source: U.S. Census Bureau⁶⁷, U.S. International Trade Administration⁶⁸

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