

RENEWABLES, LAND USE, AND LOCAL OPPOSITION IN THE UNITED STATES

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EXECUTIVE SUMMARY

Decreasing greenhouse gas emissions in the electricity sector is crucial to avoiding the worst impacts of climate change. The American public overwhelmingly favors renewable power and the costs of wind and solar power have declined rapidly in recent years. However, inherent attributes of wind and solar generation make conflicts over land use and project siting more likely. Power plants and transmission lines will be located in areas not accustomed to industrial development, potentially creating opposition.

Wind and solar generation require at least 10 times as much land per unit of power produced than coal- or natural gas-fired power plants, including land disturbed to produce and transport the fossil fuels. Additionally, wind and solar generation are located where the resource availability is best instead of where is most convenient for people and infrastructure, since their “fuel” can’t be transported like fossil fuels. Siting of wind facilities is especially challenging. Modern wind turbines are huge; most new turbines being installed in the United States today are the height of a 35-story building. Wind resources are best in open plains and on ridgetops, locations where the turbines can be seen for long distances.

Even though people like wind and solar power in the abstract, some object to large projects near their homes, especially if they don’t financially benefit from the project. Transmission for renewable power can also be unpopular, and even more difficult to site when the power is just passing through an area, rather than directly benefiting local residents. This is an issue today building transmission to move wind power from the Great Plains and Upper Midwest states to cities in the east.

Technological and policy solutions can lessen the land use impact of renewable power and the resulting public opposition. Offshore wind eliminates land use, but it raises opposition among those concerned with the impact on the environment and scenic views. Building on previously disturbed land and combining renewable power with other land uses, like agriculture or building solar on rooftops, can minimize land use conflicts. Community involvement in project planning and regulations for land use and zoning can help to alleviate concerns. Nevertheless, there is no perfect way to produce electricity on an industrial scale. Policymakers must recognize these challenges and face them head-on as the nation transitions to a lower-carbon energy system.

INTRODUCTION

A renewable electricity system sounds like an environmental utopia, relying on the sun and wind to meet our energy needs. However, as more solar and wind power generation is built, we are beginning to see some of the negative impacts of these energy sources come to the fore.

Production of fossil fuels for electricity generation, mainly coal and natural gas, generally happens away from population centers. The fuel is then transported to generation plants that tend to be large facilities located away from most of the population. The environmental justice issues and local pollution near fuel production and electricity generation are often borne by the poor and those with less political power. Few of us see the industrial facilities that generate our electricity; many people view their electricity as coming from the outlet in the wall and don't think beyond that.

Renewable sources of electricity raise different challenges. Air pollution is not an issue, but wind and solar generation are more land-intensive than their fossil fuel counterparts. Fossil fuels are very concentrated forms of energy, while renewable sources are abundant, but much more diffuse.¹ In an electricity system based on renewables, the fuel can't be transported. Instead, wind and solar generation must be located in areas with good resources, where they may come into conflict with wildlife, recreation, or scenic views.² By their nature, renewable electricity systems will be more widely-distributed geographically, with an extensive transmission system to move power to where it is needed.³ The expanding land needs of a renewable energy system raise concerns about "energy sprawl."

For these reasons, an energy system based on renewables will have a different shape than the fossil fuel-based system Americans are accustomed to. Production facilities will cover more land in areas that are not accustomed to energy infrastructure. Trillions of dollars of infrastructure will be needed to achieve a renewable power system, for construction of generation and transmission capacity.⁴

Most people say that they are in favor of renewable energy, in the abstract. But we are beginning to see a backlash against the land use implications of renewable energy in the United States, especially in wealthy, politically-active communities. Wind projects have encountered opposition from people concerned about the turbines' noise, impact on scenic views,⁵ and harm to birds.⁶ Solar projects in the desert have faced concern about habitat loss for rare plants and animals.⁷ Renewables are not an environmental panacea, but often raise concerns of their own, just like every other form of energy.

Policymakers have come to expect opposition to many "undesirable" forms of land use, from low-income housing to industrial facilities and oil and gas production. However, the general public's favorable opinion toward renewable energy is shifting attention away from the strong local opposition arising in some areas as wind and solar generation expands. Recognizing these challenges and facing them head-on will be an important part of moving toward a deeply decarbonized energy system.

RENEWABLE ELECTRICITY USES MORE LAND THAN THE FOSSIL FUEL SYSTEM

To understand the land implications of different forms of energy, a few terms will be helpful. Energy density is the amount of energy contained in a fuel by volume or weight. Coal and oil have a very high energy density, meaning that they pack a great deal of energy into a small space. Natural gas is not energy dense by volume but is certainly energy dense in terms of weight. Energy dense fuels are easily moved from place to place, a useful quality in today's energy system.

Power density is the land surface area needed to produce a given amount of energy. Power density is often used to describe renewable sources of energy, calculating how much land area must be covered by solar panels or wind turbines to produce energy. Several factors weigh into the overall power density, including the average intensity and duration

of sunshine or wind over time, and the conversion efficiency of the solar panel or wind turbine.

Although power density is easiest to understand in terms of renewable forms of energy, the concept can also be applied to natural gas- and coal-fired power to consider how the land use of a power system based on renewables might compare to today's fossil-based system. Calculating the power density for power generated from these fuels involves adding up the land area disturbed to produce and process the gas or coal, transport it to the power plant, and generate electricity.

We tend to think of fossil fuel production as environmentally destructive. This is sometimes true, but the high energy density of fossil fuels means that the overall land area disturbed per unit of energy produced can be quite low for very high-quality fossil resources. Clearly, mountaintop removal for thin coal seams results in much greater land disturbed per unit of energy produced than an efficient mine of a thick coal seam near the surface, or a very productive natural gas well. Land use at fossil fuel power plants tends to be very low per unit of power produced, although coal plants need more space to store fuel while natural gas arrives on a just-in-time basis via pipeline.

Despite the wide range in possible power densities for fossil fuel electricity production, we only need order-of-magnitude estimates of power density for the discussion here. Additionally, the lowest power density resources tend to be uneconomic to produce, narrowing the range a bit. All in, the fossil fuel electricity system in the United States has a power density of less than 200 to nearly 1,000 watts (W) per square meter (W/m^2).⁸ This number is meaningless without some context. The average U.S. household uses an average of 10,400 kilowatt-hours (kWh) of electricity in a year which equals an average flow of 1,190 W of power.⁹ Understanding that power demand is not constant, let's assume that an average household needs to have 2,500 W of power generation capacity in place to keep the lights on consistently. This equates to around 2.5 to 12.5 square meters of disturbed area, or 27 to 135

square feet (a range from the average bathroom size to the average bedroom size in an American home).¹⁰ Clearly this disturbed area adds up when you consider every household in the United States, and fossil fuels have very important environmental impacts beyond their land footprint. Nonetheless, this is an important starting point as we consider the footprint of renewable power.

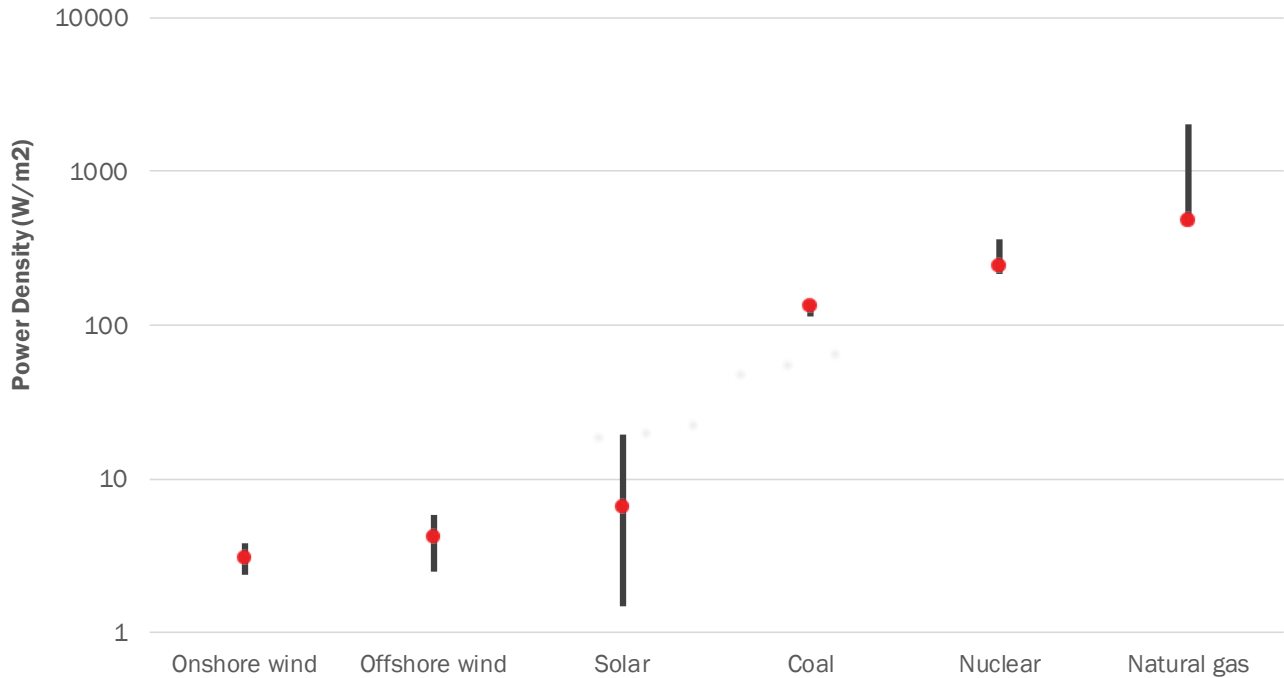
The power density of renewable power is one to two orders of magnitude lower than that for fossil fuel power, meaning that renewable power requires at least ten times more land area per unit of power produced.¹¹ Solar photovoltaic cells have a power density of about $10 W/m^2$ in sunny locations and wind's power density is around 1 to $2 W/m^2$ in the United States.¹² These power density values are averages over time, taking into account that wind and sun are intermittent sources of energy. Maximum instantaneous power density values would be much larger. These values also include all the land area of a solar or wind facility, including access roads and the spacing required between wind turbines for optimum operation. The space between wind turbines can be used for other purposes, like agriculture or grazing;¹³ considering only the area of turbines and required infrastructure gives a figure of about $10 W/m^2$. The correct figure to use depends on the question being asked — total impacted land area or area unavailable for another use.

Understanding the power density numbers for renewables also requires context (see Figure 1). Fossil fuel power is generally available whenever needed, while wind and solar power depend on wind or sun conditions. Siting renewable resources over a wide area makes their production less correlated — for example, if the wind is not blowing in one place, it may be windy somewhere else. Additionally, electricity storage will become a more important part of a renewable power system over time, allowing renewable power to meet the varying demand of customers.¹⁴ Finally, power systems based on renewables may have some fossil fuel backup for times when geographic diversity and

storage still do not meet demand. Without knowing the nature of a renewables-based system, one can't make assumptions about the generation capacity needed to meet demand. However, considering the 2,500 W of capacity per household assumed for a fossil system and counting only land unavailable for other uses (10 W/m² power density for both wind

and solar) means that 250 square meters or 2,700 square feet of space would be needed, roughly the average floor area of a new single-family home in the United States.¹⁵ A system with more fossil backup would be closer to this number, while a system reliant on energy storage could be much larger to deal with variability.

FIGURE 1: POWER DENSITY OF SELECTED SOURCES OF ELECTRICITY



The bars represent the range of values and the dot represents the median value.

Source: John van Zalk and Paul Behrens, "The spatial extent of renewable and non-renewable power generation."¹⁶

These calculations for land use in fossil and renewable systems are indicative, meant to help in visualizing differences in power density. Extrapolating them to the overall power system would create a host of problems, related to the variable power production of renewables and the need for ongoing production of fossil fuels. But clearly a difference in power density of as much as one to 100 makes an important difference in the land use implications of a power system with ever more renewable power. Renewable power production will take place in areas that have not seen energy development before.

Despite the order-of-magnitude difference in power density, renewables have an important land use advantage over fossil fuels. Renewable energy can be sustained indefinitely on the same land base, while energy production from fossil fuels requires that new resources are continually exploited to meet demand. Anne Trainor, Robert McDonald, and Joseph Fargione introduce the concept of time-to-land-use equivalency, meaning the amount of time it takes for fossil resources to catch up with renewable forms of energy in terms of land disturbed to produce a given cumulative amount of energy.¹⁷ Considering the direct footprint of renewables (land unavailable for other uses) rather than the overall land disturbed leads to interesting results, especially for wind. In 1.4 to 6.9 years, electricity production from natural gas reaches the same level of land use as wind, if the land around the turbines is considered available for other

use. This time extends to as much as 44 years if one considers the entire footprint of a wind farm, including the area between the turbines. Solar photovoltaic power takes longer to reach equivalent land use with natural gas, from 15.8 to 78.5 years. The wide range depends on the efficiency and resource quality of the renewable energy systems, along with the productivity and life of the natural gas wells.¹⁸ Importantly, these calculations consider land disturbed for fossil production as permanently disturbed. Producers in the United States generally must restore lands after fossil fuel production ends, although restoration cannot necessarily return land to its previous state.

CONCENTRATED FOSSIL SYSTEM MEANS FEWER PEOPLE INTERACT WITH ENERGY PRODUCTION

A key feature of the current fossil-based energy system is how little land it occupies, given its central role in our economy. Estimates from 2010 and 2015 show that the fossil fuel, nuclear power, and hydroelectric system occupies 0.5% of U.S. land area.¹⁹ This area is divided in roughly equal proportions among fossil fuel production and use, hydroelectric reservoir area, and rights-of-way for fuel transportation.²⁰ Approximately 7,300 square miles were involved in fossil fuel production in 2010, roughly the size of New Jersey. U.S. fossil fuel production is concentrated in the southern Plains states, Appalachia, and the Mountain West, as shown in Figure 2.

FIGURE 2: U.S. OIL AND GAS WELLS AND COAL MINES



Brown dots represent oil and/or gas wells and black triangles represent coal mines.

Source: U.S. Energy Information Administration²¹

The limited land area means that relatively few people live near fossil fuel production, although these residents are concentrated in certain states. An estimated 17.6 million people, 5% of the U.S. population, lived within one mile of an operating oil and gas well in 2014.²² This number is likely an overestimate of today's level, since 2014 had the highest number of operating wells in recent years.²³ Data on populations living near coal mines is harder to find, but the nearby population is certainly much smaller, given that coal mining is more geographically-concentrated than oil and gas production.

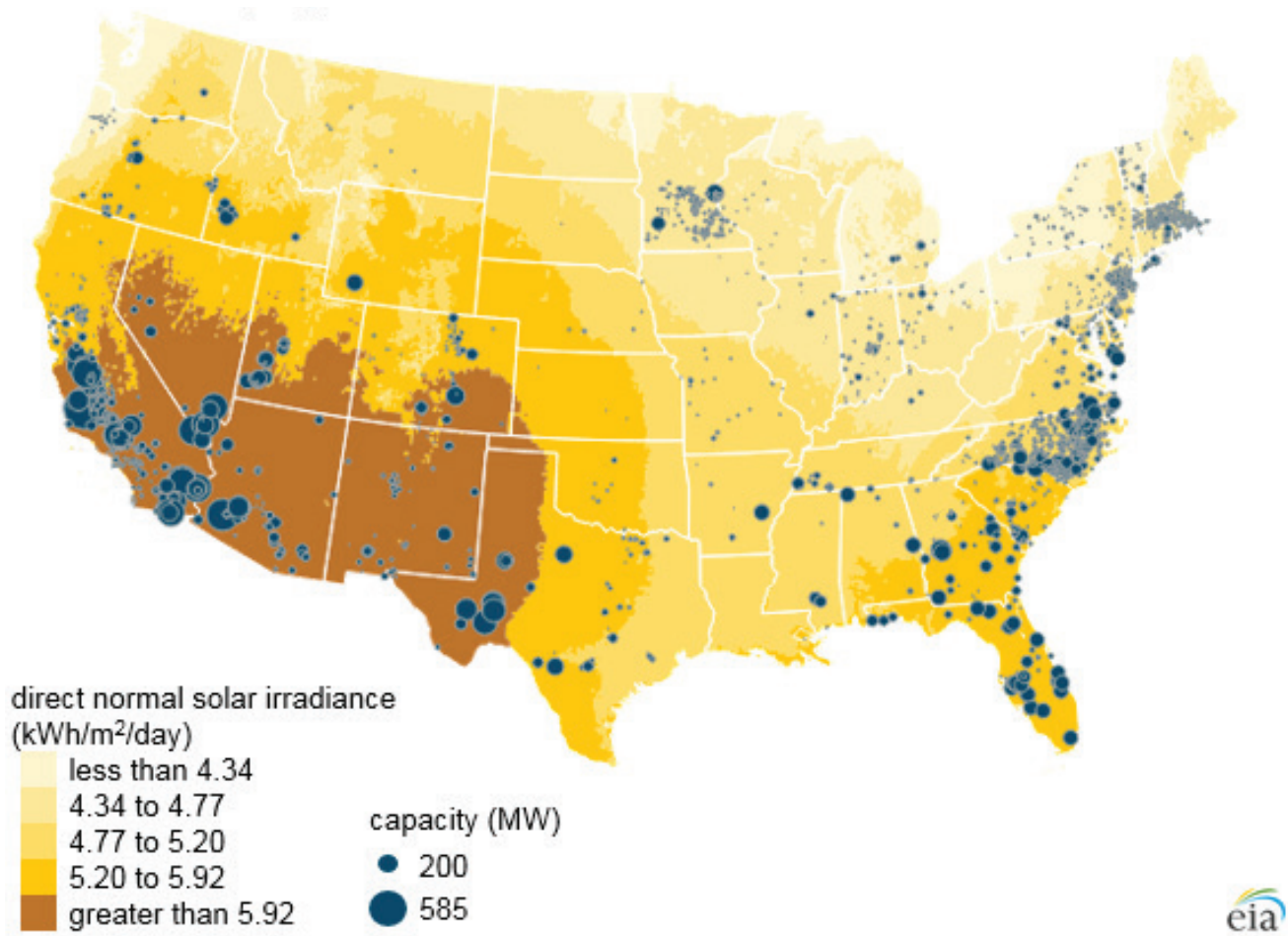
Fossil fuel production and electricity generation negatively impact local communities, through local air pollution, disturbed landscapes, and issues related to aesthetics like lower property values.²⁴ This is an environmental justice issue for those living closest to energy facilities, frequently the poor and minorities with less political power. This relatively

small immediately-affected population bears much of the brunt of the current fossil fuel system. (Air pollution from fossil facilities can also be much more widely dispersed, but the conversation here focuses on those closest to the facilities that bear the worst of pollution and other negative impacts.)

LAND USE REQUIREMENTS MAKE SITING RENEWABLES A CHALLENGE

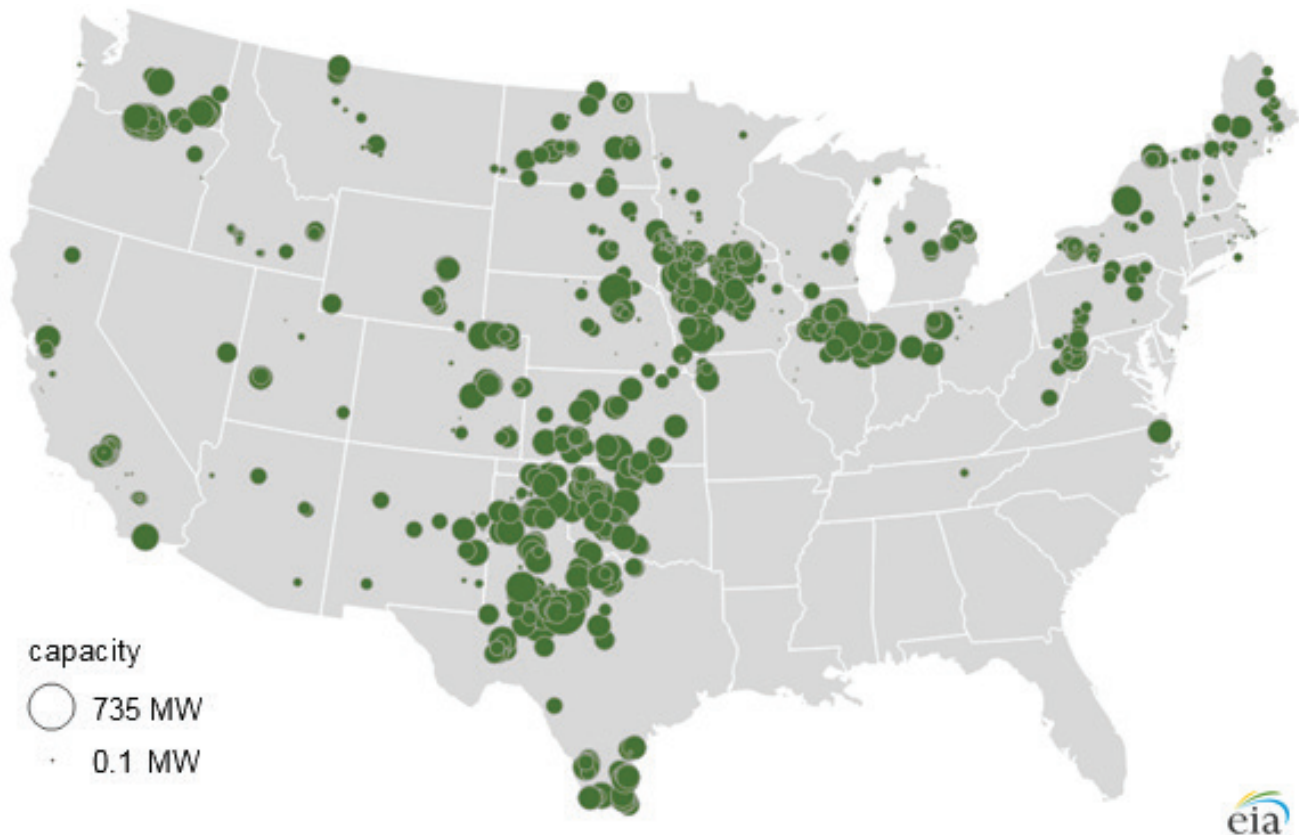
Wind and solar resources, and thus generation capacity, are distributed differently than oil and gas resources. Solar resources are best in the Sun Belt of the Southwest, although the southeastern United States also has strong resources, as shown in Figure 3. Wind resources and development are strongest in the Great Plains states and Texas along with the Upper Midwest, as shown in Figure 4. Wind and solar generation is being built in some areas unaccustomed to large-scale industrial energy development.

FIGURE 3: U.S. SOLAR PV CAPACITY AND SOLAR IRRADIANCE



Source: U.S. Energy Information Administration²⁵

FIGURE 4: GEOGRAPHIC DISTRIBUTION OF U.S. WIND POWER GENERATION



Source: U.S. Energy Information Administration²⁶

With power density as much as 100 times less than fossil fuels, one might be concerned about running out of appropriate land as the electricity system becomes more reliant on renewable sources. However, a real zero-carbon power system will not take up nearly as much land as its power density might suggest. Such a system is likely to include more power dense sources, such as nuclear power and gas-fired power with carbon capture and storage to deal with intermittency. Wind and solar technologies will become more efficient over time, reducing the space required per unit of power produced. Land disturbed for fossil fuel production adds up, whereas the land used for renewable production is only disturbed once. Finally, renewable power can also be co-located with other land uses, such as solar generation on city rooftops²⁷ and wind and solar facilities sharing land with agriculture.²⁸

Nonetheless, densely-populated states may face challenges in siting enough renewable energy to meet their in-state goals. For example, meeting New York's goal of 50% renewable generation by 2030 will require approximately 6,800 megawatts (MW) of solar photovoltaics and 3,500 MW of onshore wind, which would require an estimated 136 square kilometers and 700 square kilometers, respectively.²⁹ Together these amount to only 0.5% of the state's land area, but more than half of New York state is occupied by forest and woodland, and farmland accounts for nearly one quarter of the total land area.³⁰

The greater challenge will be siting renewable facilities in ways that minimize public opposition and conflicts with existing land use. For renewable electricity, the site "chooses" the project, rather than the other way around.³¹ This lack of flexibility in

site selection raises challenges. The areas with the best sunlight or wind resources are not necessarily located near demand centers or existing energy infrastructure, such as high voltage transmission lines.³² There are often trade-offs between the best sites for power generation and the costs of accessing infrastructure. Transmission infrastructure is also often inflexible in its siting; avoiding sensitive areas or areas of public opposition can be difficult.

Power infrastructure will also extend into areas where local citizens are not accustomed to seeing it. In the United States today, wind and solar make up only 8.7% of power generation and 11.1% of generation capacity, yet these land use challenges are already coming to a head in some areas.³³ At the end of 2015, nearly 1.4 million homes in the United States were within five miles of a utility-scale wind project.³⁴

Local opposition to projects

Public opinion toward renewable energy is generally positive in industrialized countries, including the United States.³⁵ Political attitudes toward renewable energy in the United States are less polarized than those toward climate change, and several states that vote Republican are leaders in renewable energy, including Texas, Oklahoma, and North Carolina.³⁶ Nationally, 82% of Americans would support tax rebates for energy-efficient vehicles or solar panels. However, public perception can turn negative, even among those generally in favor of renewable energy, when people believe that a renewable development will cause them economic or health problems or when they dislike the aesthetics of the project.

Large solar and wind farms and the infrastructure that serves them are often unpopular at the local level. People like clean energy in the abstract, but some object to large-scale projects near their homes. Renewable electricity requires more and different land area than today's fossil fuel system and thus often brings about opposition in areas not currently affected by energy development. Nearby residents are concerned about impact

on their property values.³⁷ Conflicts can arise between landowners that stand to profit from wind, solar, or power line development and those nearby who will be affected by the development without compensation. Renewable energy projects are not alone in generating public opposition, but the juxtaposition of strong general support for the technologies with sometimes strong local opposition to wind, solar, and transmission projects can catch policymakers unprepared.

Concerns about losing forest, agricultural lands,³⁸ or other important ecosystems³⁹ to renewable development are real, as are apprehensions about the water requirements of solar in water-constrained areas.⁴⁰ Studies have shown that the conservation value of lands has degraded following renewables development in fragile areas, such as the Mojave Desert.⁴¹

Wind projects generate particular opposition because of their size. Modern wind turbines are huge; two important factors make them so. Winds are more consistent at higher altitude, so a taller turbine means greater power generation. Additionally, larger and longer blades catch more wind and allow more power production from each turbine. Larger and taller turbines have been key factors in increasing wind efficiency in past years, made possible by stronger materials that can take the stress of high winds without flexing too much. Most new onshore wind turbines in the United States are just under 500 feet tall, or roughly the height of a 35-story building, to avoid additional regulations from the Federal Aviation Administration if they reach 500 feet.⁴² Offshore turbines are even larger. The only offshore wind project in operation in the United States, at Block Island, Rhode Island, has turbines 590 feet tall, while GE is designing an offshore turbine that will be more than 850 feet tall, with blades longer than a football field.⁴³

These huge turbines create turbulence around them, meaning that for maximum efficiency, turbines in a wind farm must be spaced far enough apart that they don't interfere with each other. Suggested spacing is generally 3 to 10 rotor

diameters. Assuming the average rotor diameter in the United States of 380 feet and 7 diameters of spacing, turbines would be more than half a mile apart.⁴⁴ A wind farm in a prime location can have hundreds of turbines; the largest wind farm in the United States is in Tehachapi Pass in Southern California, with more than 4,000 turbines and more than 1.5 gigawatts of generating capacity.⁴⁵ Additionally, since the turbines need unobstructed wind to produce power efficiently, they tend to be located in open plains or ridgetops, meaning that they can be seen over long distances. Their beauty is in the eye of the beholder (or not), but modern wind turbines can certainly take over a landscape.

Lawrence Berkeley National Laboratory conducted a survey of residents living within five miles of modern, utility-scale turbines, which they defined as those at least 354 feet tall and at least 1.5 MW in capacity.⁴⁶ Fifty-seven percent of those surveyed viewed their local wind project positively or very positively. Attitudes changed only slightly for those located within half a mile of the project, with 50% of respondents viewing the projects positively or very positively. Positive attitudes toward projects were correlated with residents being compensated for the projects' impacts and their perception that the planning process was fair.⁴⁷ On the other hand, projects that begin in secret and developers that are seen as aggressive or misleading toward landowners and community members foster opposition and mistrust.⁴⁸

Even though the majority of people in the vicinity of wind projects favor them, wind energy can still face significant challenges from local residents, especially those who will not receive direct financial benefits from the projects. Residents are concerned about noise and shadow flicker, potential declines in property values, and bird kills, and many believe that wind turbines are an eyesore.⁴⁹ Additionally, wind projects are often large enough to cross jurisdictional boundaries, meaning that opposition in one jurisdiction can stop an entire project.⁵⁰

Studies have found mixed results on the impact of wind turbines on property values. A large study in 2013 found no statistical evidence that wind development affects nearby home values.⁵¹ However, other studies have found significant decreases in property values near wind projects, of as much as 15% within one mile of a turbine.⁵² U.S. courts have generally not provided any recourse for decreasing property value due to wind development. For example, in *Wisconsin Realtors Association v. Public Service Commission of Wisconsin*, several building and real estate interests sued over the state's wind energy rules. The plaintiffs argued that the Public Service Commission failed to prepare a housing impact report for the Wisconsin Legislature, as required, when their new wind energy rules affected housing valuation in the state. The Wisconsin Supreme Court ultimately decided that there was no causal relationship between the siting of wind turbines and a measurable change in property values, and thus that the housing impact report was not required.⁵³

A frequent complaint is that the power produced in these projects is not needed locally and will only benefit people in cities far away. However, given the distribution of wind resources, the sparsely populated Great Plains and Upper Midwest are key areas for U.S. wind development. Nonetheless, bills in Nebraska have proposed to exclude wind energy from the state's definition of renewable energy and to require new turbines to be at least three miles from homes.⁵⁴ Public opposition recently stopped a project in Kansas, the U.S. state that gets the highest proportion of its power from wind, at 36%.⁵⁵ A small wind project in Iowa was recently dismantled amid public opposition, when a court determined that the permits for the project were issued illegally.⁵⁶

Although solar energy does not produce noise and is only visible over short distances, solar development faces many of the same challenges as wind. California's San Bernardino County, the largest county in the United States by area, recently prohibited utility-oriented renewable energy

projects, defined as those where more than 50% of the electricity generated will be used outside the local area, in more than a dozen unincorporated areas and in rural living zones. Sparsely populated and sunny areas in San Bernardino County could be ideal for solar development. However, local residents argue that such projects disturb pristine desert, scenic views, and wildlife habitat. The prohibition eliminates more than one million acres of private land from development.⁵⁷ Nonetheless, the State of California requires utilities to get 60% of their electricity from renewable sources by 2030.⁵⁸

This sort of opposition is not unique to California. A 500 MW solar farm in Virginia that would be the largest solar facility east of the Rocky Mountains has attracted fierce opposition from locals concerned about the development reducing property values and ruining the rural character of the area.⁵⁹ Meanwhile, in 2018 the Virginia General Assembly passed legislation aiming to increase solar capacity in the state to 5,000 MW.⁶⁰

Transmission capacity also brings opposition

Building the infrastructure to move renewable energy to market is an additional challenge, in financing, policy, and public acceptance. Renewable power facilities generally produce less power at a single site than their fossil fuel counterparts and their electricity production is intermittent, meaning that lines will carry less power than those connected to fossil generation.⁶¹ Transmission lines to move renewable power follow different paths than many existing lines, from areas of good renewable resources toward areas of strong power demand, mostly cities. These factors can make financing transmission infrastructure for renewables more challenging and risky.⁶² The lack of transmission capacity can create a chicken-and-egg problem for renewable projects. Without adequate and accessible transmission capacity, renewable projects are less likely to be economically viable, but investments in renewable energy are needed to justify construction of new transmission.⁶³

The U.S. power transmission grid needs significant upgrading, in addition to the challenge of integrating renewables. Most U.S. high voltage transmission lines were built in 1950s and 1960s, with an expected lifespan of approximately 50 years. The grid is also congested, with many lines operating well beyond their design range.⁶⁴ The structure of the grid is currently fractured among regional entities and utilities, but greater interconnectivity would reduce the impact of intermittent generation, since wind speed is not correlated over large distances.

In the United States, federal and state governments can force property owners to sell land for public use, so long as the government offers the property owners just compensation, a power known as “eminent domain.” However, for transmission lines, the power of eminent domain lies with states and a single project often needs to get approvals from multiple state and local jurisdictions. States differ in their policy toward using eminent domain for power lines that are separate from incumbent utilities or that transfer power outside the state.⁶⁵ Some states encourage such development, believing that it encourages investment in their state. Others discourage it by forbidding the use of eminent domain in siting or through other polices.⁶⁶ Many states approve projects based on the benefits they provide to the state, which is minimal when the line is merely transiting the state, not providing local power.⁶⁷

Significant new transmission lines are particularly needed to move wind power from the Great Plains and Upper Midwest to load centers further east. However, some landowners in transit states are resisting these transmission projects, complaining that they are being forced to sell land for easements and deal with the visual impact of transmission projects that do not benefit them. For example, the Grain Belt Express transmission line is intended to bring wind power generated in Kansas through Missouri, Illinois, and Indiana, where it will connect into the eastern power grid. The line’s developers have met public and legal resistance

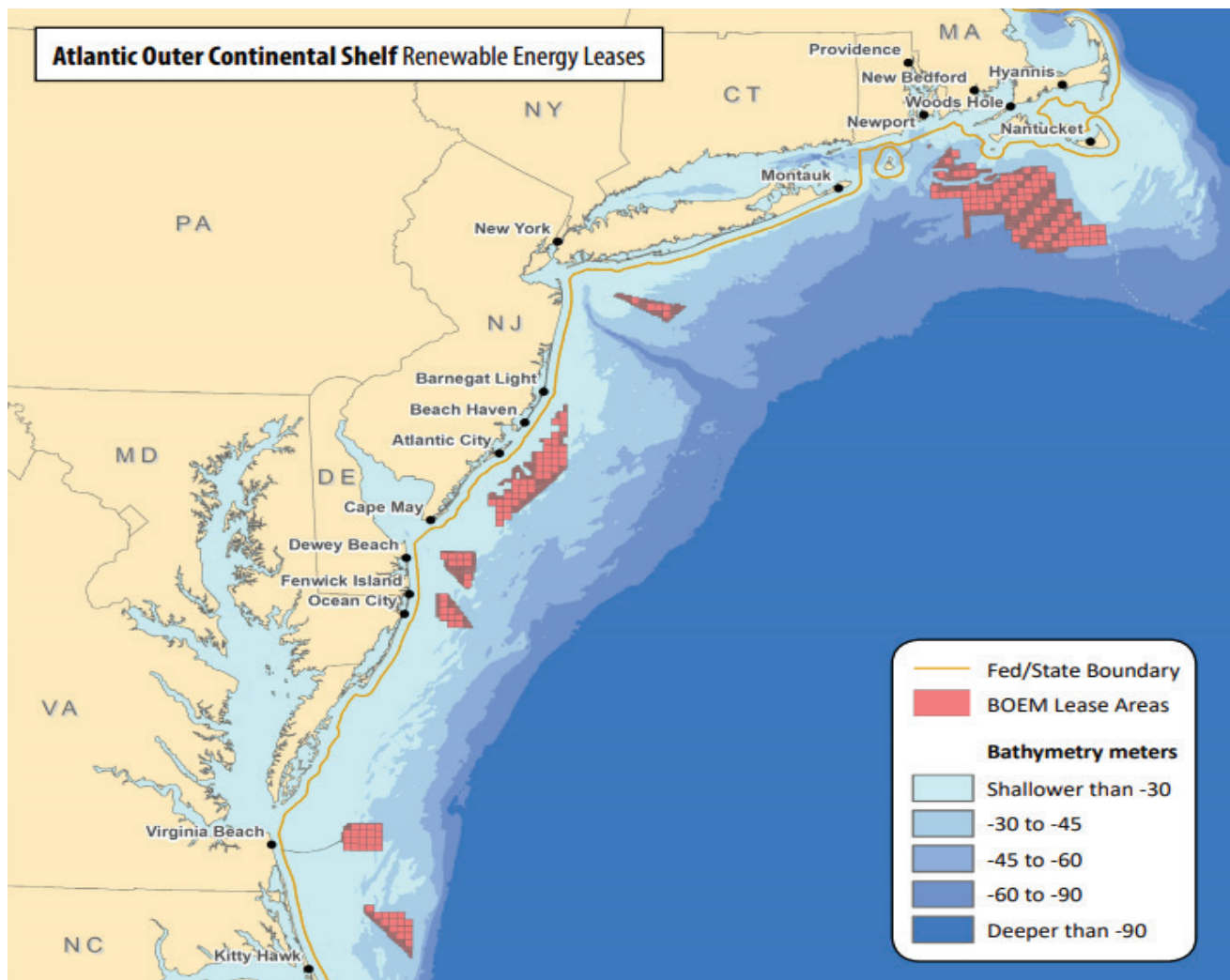
in both Missouri and Illinois.⁶⁸ In Missouri, the state House of Representatives approved a bill preventing the use of eminent domain to acquire land for the project; the bill died in the Senate due to a filibuster.⁶⁹ This opposition is understandable, but transmission lines such as this one will be necessary to maximize the amount of renewable power used in the United States.

As renewable energy expands, “sweet spots” for development — those with good wind or solar resources and proximity to power demand, transmission capacity, or at least minimal opposition to new transmission — may be more difficult to find. Is there another way to get around siting challenges?

TECHNOLOGICAL SOLUTIONS TO REDUCE PUBLIC OPPOSITION

A number of technologies may help lessen the land use impact and public opposition to renewable development. One potential solution to land use concerns is to move these projects away from land entirely. Wind is particularly amenable to moving offshore. Winds are generally stronger offshore and wind speed and direction are more consistent, leading to greater potential generation and greater efficiency.⁷⁰ Offshore wind may be particularly helpful in the Northeast, where several states have ambitious renewable energy goals, but less open space for renewable development. The U.S. Bureau of Ocean Energy Management has leased a total of 1.7 million acres off the East Coast for offshore wind development (see Figure 5).⁷¹

FIGURE 5: OFFSHORE WIND LEASES IN FEDERAL WATERS AS OF MARCH 2019



Source: U.S. Department of the Interior’s Bureau of Ocean Energy Management⁷²

Public opinion of offshore wind depends on the specifics of the project. The ill-fated Cape Wind project, which intended to place 130 wind turbines in the shallow waters of Nantucket Sound, provides a stark example of a project gone wrong. Opposition to the project was fierce, from wealthy homeowners concerned about the project spoiling their views and from other citizens concerned about its high cost, hazards to navigation, and threats to the marine environment. The developer finally pulled the plug on the project in 2017, after 16 years of legal battles.⁷³ A new project, Vineyard Wind, is now proposed for an area nearby, 15 miles off Martha's Vineyard. Vineyard Wind is also facing challenges, as the U.S. government decided in August 2019 to extend the environmental review process,⁷⁴ which will delay the project schedule.⁷⁵ Meanwhile, the project faces continued opposition due to concerns about potential impacts to commercial fisheries,⁷⁶ and of underwater cables on the endangered North Atlantic right whale.⁷⁷

As Cape Wind was dying a slow and painful death, five turbines about three miles off Rhode Island's Block Island began operation in December 2016, the first offshore wind farm in the United States. Block Island is a summer tourist destination and the turbines are visible from the island and from the ferries that tourists take to and from the island. Concern that the wind farm would negatively affect tourism was an important argument against the project, but preliminary data show that the development actually increased tourism to the area, perhaps, in part, due to curiosity about the project.⁷⁸ Impacts on fishing are mixed. The turbine structures are acting as artificial reefs, attracting a variety of fish and other marine life to the area. The area around the turbines has become a prime destination for recreational fishing, but commercial fisherman view the additional traffic in the area negatively and are concerned about navigating around the turbines.⁷⁹ The project also connected the island to the mainland electricity grid for the first time and eliminated the diesel generating system that had previously provided power, eliminating nearly 1 million gallons of annual diesel fuel use.⁸⁰

Solar generation can also be installed on water. Floating photovoltaic (PV) systems, sometimes called "floatovoltaics," can be installed on man-made bodies of water with few other uses, such as utility cooling ponds. In addition to their land use advantages, floating PV systems are more efficient than their land-based counterparts due to lower temperatures under the panel. A study from the U.S. National Renewable Energy Laboratory found that sites appropriate for floating PV could provide 10% of current U.S. electricity generation.⁸¹

Combining solar systems with agriculture is another potential technological solution to the challenge of siting large-scale solar facilities. Such systems mount the solar panels on stilts, allowing standard agricultural machinery to work beneath the panels. Crops below are partially shaded as the sun moves across the sky during the day. Some crops are tolerant of partial shade and may even produce higher yields during times of drought stress, due to lower water transpiration through the leaves and a reduction in heat stress.⁸² Colocation of solar PV with agriculture can also increase the efficiency of electricity production because vegetation tends to lower the temperature beneath the panels.⁸³ Finally, combining solar power generation with agriculture could provide additional revenue to farmers, helping to protect farmland and keep food costs down.

LOCAL COOPERATION AND STRONG LAWS ARE KEY TO RENEWABLE ENERGY DEVELOPMENT

A shift toward renewable electricity involves a wholesale change in the shape of the power system and the required infrastructure. Power plants and the transmission lines to move that power to load centers will be located in areas not accustomed to industrial development, and potentially areas with strong, politically active opposition. Clearly, project developers will need to engage in serious public consultation to get buy-in.

The concepts of “social license to operate” — acceptance from local communities and stakeholders — and “above-ground risk” are common in mining and oil and gas development. Renewable project developers sometimes assume that the inherent benefits of their projects mean that such community approval is automatic, but lessons-learned from extractive industries can be applied to renewable development as well. Best practices include establishing an ongoing dialogue with external stakeholders, understanding who represents the community and not dealing exclusively with the loudest or most powerful members, and considering global and local concerns together, since nothing is truly local in our hyperconnected world.⁸⁴

The debate about siting renewable energy and transmission has much in common with other debates about socially important, but “undesirable” types of businesses and infrastructure, including low-income housing; water, wastewater or solid waste facilities; and logistics centers. As land use decisions have become more responsive to local concerns, siting such facilities has become more challenging. However, paying too much attention to local opposition runs the risk of siting necessary but unpopular facilities only in areas with lower levels of political activity or clout, potentially exacerbating issues of environmental justice or disparities in property values. Our current system of land use governance is not well-suited to providing public goods in socially-optimal ways.

The concept of “not-in-my-backyard,” or “NIMBY-ism,” comes to mind when stakeholders generally support a technology, but don’t want it located near them. However, the term is pejorative, minimizes communities’ genuine concerns about projects, and can distract from efforts to look for common ground.⁸⁵ People often feel a strong attachment to their local area and value its aesthetic qualities. Change is difficult. Wind projects are particularly challenging in this respect because they can be seen for much greater distances, but solar projects are not immune from concerns about changing the character of a landscape.

Additionally, a power system based on renewables will require greater coordination across geography and different market design than the current system, to minimize the disruptive effect of intermittent generation with zero marginal operating cost. Achieving these changes may prove challenging for existing power governance structures, like the independent system operators and regional transmission organizations that operate in various regions of the United States today. However, these changes may create winners and losers and involve giving up some element of local control, making them difficult to implement politically.

Achieving U.S. and global goals for decarbonization will require cooperation across levels of government. At the national level, it’s easy to see how particular projects are in the public interest, but often the benefits of these projects accrue nationally or globally, while the land use impacts are local. This problem is similar to the larger climate problem — getting people to make local sacrifices for the greater good is always a challenge.

A number of specific policies can make siting and land use decisions easier. None of these policies is a panacea, but a combination of policies can increase collaboration and minimize community resistance to development.

- **Improving land use planning:** Planning and zoning are crucial to balance energy needs with other community goals and concerns. Defining the siting requirements for renewable generation and transmission and declaring particularly sensitive areas off-limits in advance can help communities effectively deal with developers and prevent the scramble of project supporters and opponents that can occur without clear rules. The reverse is also true — establishing renewable energy zones and encouraging generation and transmission development in these areas can streamline siting and permitting in the best resource areas. However, many local governments, especially in rural areas, lack the expertise and capacity to effectively regulate siting of renewable generation and transmission.

- **Converting brownfields:** Renewable development can be focused on previously-disturbed lands, such as brownfields or degraded agricultural land. Not all of these lands will be appropriate for renewables and there is not enough degraded land to meet energy needs. Nonetheless, renewable energy development on brownfields can be an attractive business proposition since the sites often have existing infrastructure and likely result in lower land costs. Streamlining permitting for these areas and removing barriers to development could bring renewable generation to areas less likely to face community opposition or alternative uses.
- **Facilitating rooftop solar:** Rooftop solar installations directly benefit the consumers that host them, more than any other renewable technology. Commercial and residential installations of rooftop solar are likely to cause less backlash and are more appropriate for crowded or protected settings. Rules that make rooftop solar more difficult, like those preserving the historical character of buildings, are unhelpful.⁸⁶

- **Expediting transmission infrastructure:** Some areas have more land appropriate for renewables than others. Densely-populated areas and areas with low wind and solar resources will likely need to import power from other areas. Federal, state, and local regulations that facilitate the development of transmission infrastructure needed to move renewable power will be important. Rules that favor infrastructure projects that benefit the immediate local area will be challenging if they make interstate transfer of power more difficult.

There is no perfect way to produce electricity, especially on an industrial scale. Any modern energy system will require disturbing land as well as visual impacts that some will find objectionable. Moving toward an electricity system based on renewable power will not eliminate these problems and will make some of them worse. Local air pollution issues will certainly improve in a system with more renewables, but renewables will bring power system impacts to people not accustomed to them, especially rural residents. A transition toward more renewable power must recognize these challenges and work with affected populations to understand and assuage their concerns.

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