Impact of siting ordinances on land availability for wind and solar development

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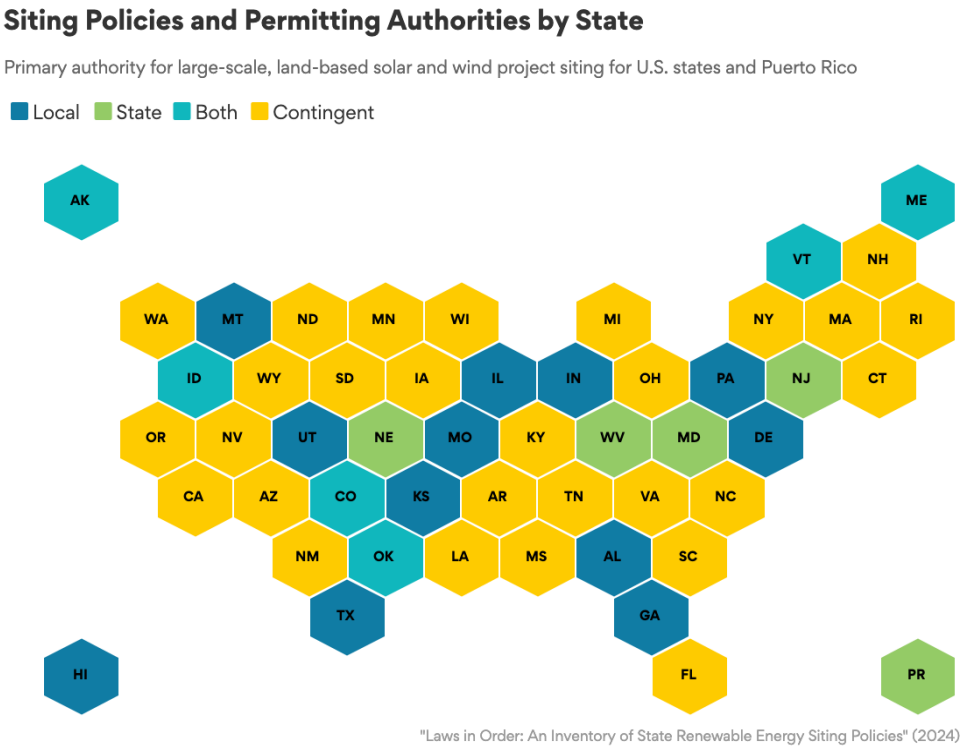
There is a wide range of ordinances that can impact new wind and solar builds

Examples of ordinance types:

- Setbacks (structures, property, natural features, environmental protection, etc.)
- Height limits
- Density limits
- Maximum project size
- Moratorium/ban



Source: https://www.energy.gov/eere/siting-large-scale-renewable-energy-projects

A database on siting ordinances for wind

ELSEVIER

Energy
Volume 223, 15 May 2021, 119998

Interactions of wind energy project siting, wind resource potential, and the evolution of the U.S. power system

Trieu Mai, Anthony Lopez, Matthew Mowers [1], Eric Lantz

ELSEVIER

Energy
Volume 223, 15 May 2021, 120044

Land use and turbine technology influences on wind potential in the United States

Anthony Lopez, Trieu Mai, Eric Lantz, Dylan Harrison-Atlas, Travis Williams, Galen Maclaurin

Towards an updated database on siting ordinances for wind and solar

Ordinance collection and database structure

A machine-readable database

Westlaw legal database + web searches

Searched Oct 2021-April 2022

State	City/Town	County	Feature Type	Value Type	Value	Citation	Comment
Alabama		Baldwin	Banned			13.13	
Alabama		Cherokee	Property Line	Meters	782	Ala. Code § 45-10-260.05	
Alabama		Dekalb	Property Line	Meters	782	Ala. Code § 45-25-260.05	
Alabama		Etowah	Property Line	Meters	782	Ala. Code § 45-28-260.05	
Alabama		Cherokee	Sound	dBA	40	Ala. Code § 45-10-260.05	
Alabama		Dekalb	Sound	dBA	40	Ala. Code § 45-25-260.05	
Alabama		Etowah	Sound	dBA	40	Ala. Code § 45-28-260.05	
Alabama		Cherokee	Transmission	Max tip-height Multi	1.5	Ala. Code § 45-10-260.05	Minimum Setback of 1.5 the max height to an overhead electric line
Alabama		Dekalb	Transmission	Max tip-height Multi	1.5	Ala. Code § 45-25-260.05	
Alabama		Etowah	Transmission	Max tip-height Multi	1.5	Ala. Code § 45-28-260.05	§ 45-28-260.05
Arizona		Apache	Property Line	Max tip-height Multi	1.1	Apache County Art. 750	

State: The state in which the county is situated

City/Town: Used only where county level zoning was not present in a state

County: The county in which the ordinance was found

Feature Type: Describes the feature (e.g., road, structure, height) the restriction is applied to

Value Type: Describes the measure of the restriction
(e.g., the restriction on maximum height is to be measured in meters)

Value: Describes the specific measurement of the value type of the restriction

Citation: The ordinance's legal citation

Comment: Brief annotations of the ordinance for clarity or for translation of a value (e.g., meters to feet)

Caveats and limitations

Recording ordinances into the database is performed by humans, thus there is potential for errors and limitations.

Timestamping the date an ordinance was established is not possible on most occasions.

In Texas, Oklahoma, and New York, ordinances are established at the municipal or township level. In these cases, searching all municipalities was not possible. Townships and municipalities within proximity to existing solar facilities were sampled and searched for existing ordinances.

Examples of multiple ordinances

Gladwind, Michigan	Kearney, Nebraska	Darlington, South Carolina	King Williams, Virginia
Property line setback	Property line setback	Property line setback	Property line setback
Structures setback	Structures setback	Structures setback	Roads setback
Height limitation	Roads setback	Minimum lot size (1 acre)	Height limitation
	Wetland setback	Maximum project size (75 MW)	Minimum lot size (100 acres); Maximum lot size (1,500 acres)

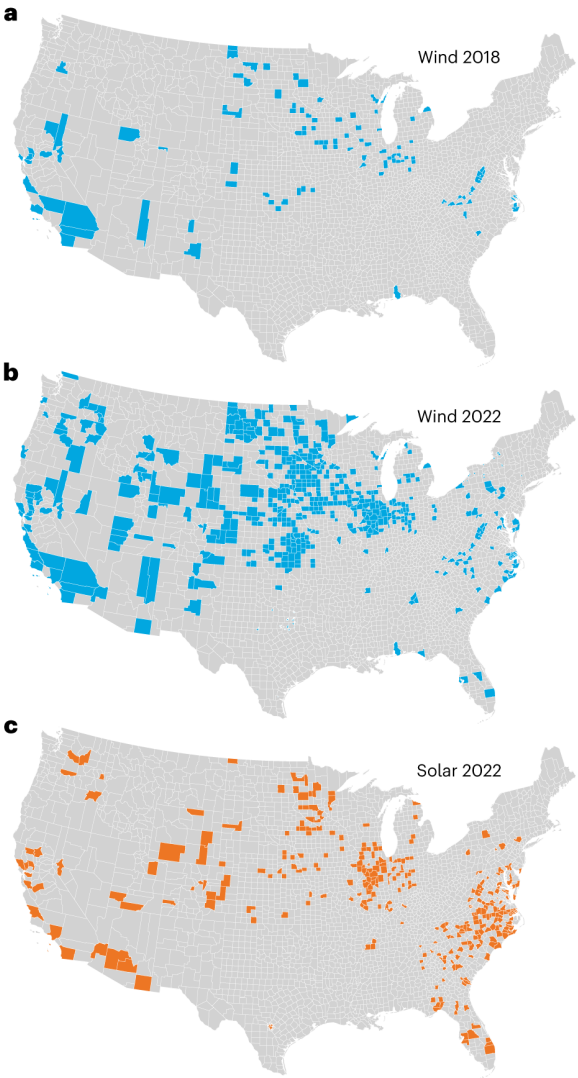
Examples of unique ordinances

- Lot coverage percentage (e.g., 10% of lot)
- Minimum spacing/density (e.g., solar plants must be sited at least one mile apart)
- Total installation size for county (e.g., 7,600 acres)
- Solar development bans
- Sound limitations (e.g., 65 dBA)

Summary of ordinances

Wind: 1,800+ ordinances (~300 in 2018)

Solar: 800+ ordinances



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Ordinance type	Wind 2018	Wind 2022	Solar 2022
Structure setback	95	378	136
Road setback	62	355	142
Property line setback	6	359	234
Sound restriction	51	224	36
Transmission setback	42	183	0
Height limit	12	91	190
Water setback	7	66	11
Railroad setback	9	61	1
Moratorium or ban	2	56	4
Density limit	0	35	5
Min/max lot size	0	22	64
Shadow flicker limit	0	13	N/A
Total installation size	0	3	6
Coverage limit	0	0	8
Maximum project size	0	2	2
Other	0	5	0
Total	286	1,853	839

Setback summaries in ordinances

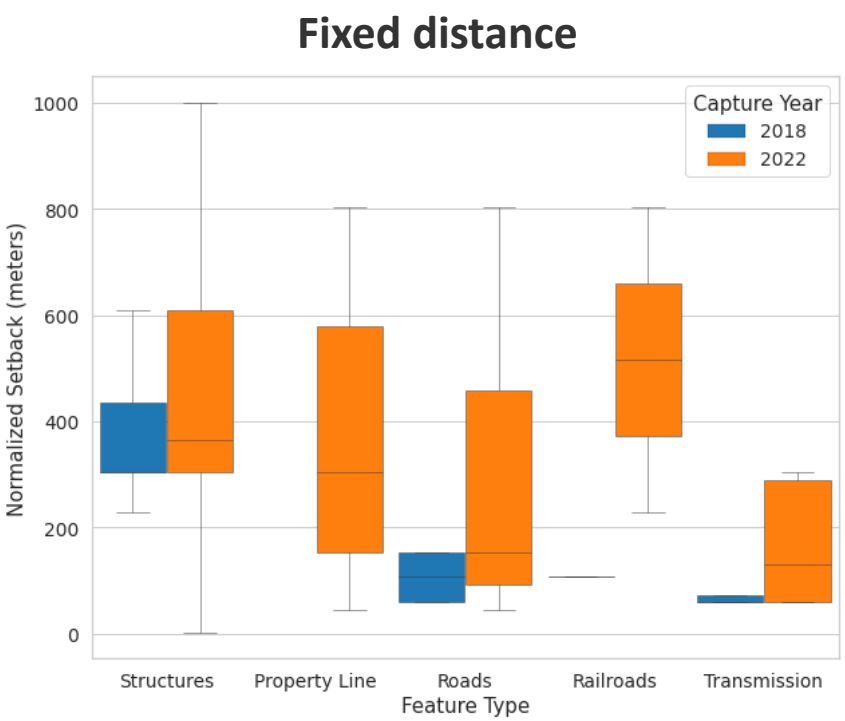
Wind (multiplier by tip height)

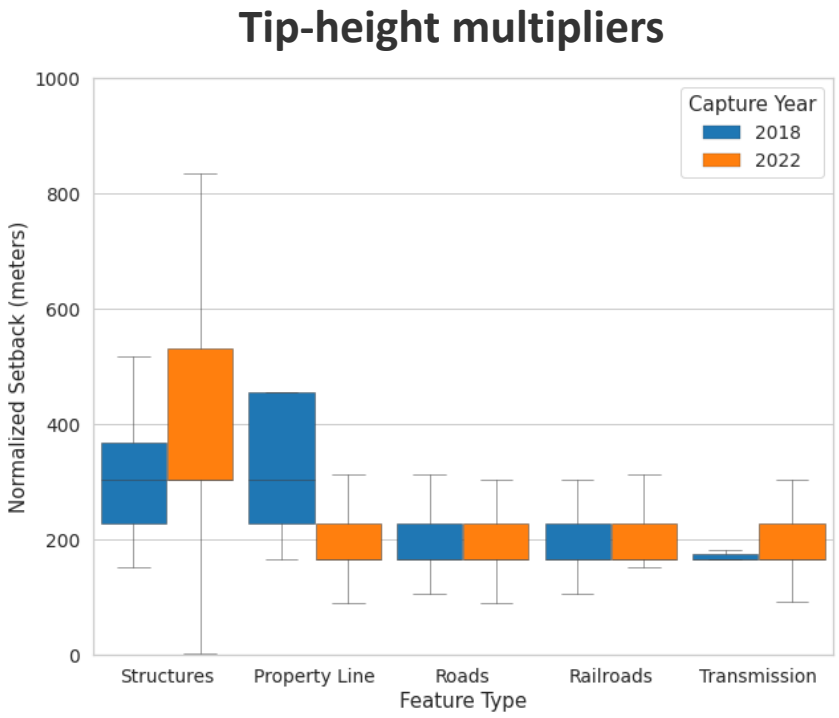
Feature(s)	Counties	Percentile 25%	50%	75%	90%
Roads, Trans, Rail	587	1.1	1.1	1.45	2
Property line	350	1.1	1.1	1.5	3
Buildings	372	2	2	3	5
Water	66	1.2	1.2	5.3	10.6

PV (fixed meters)

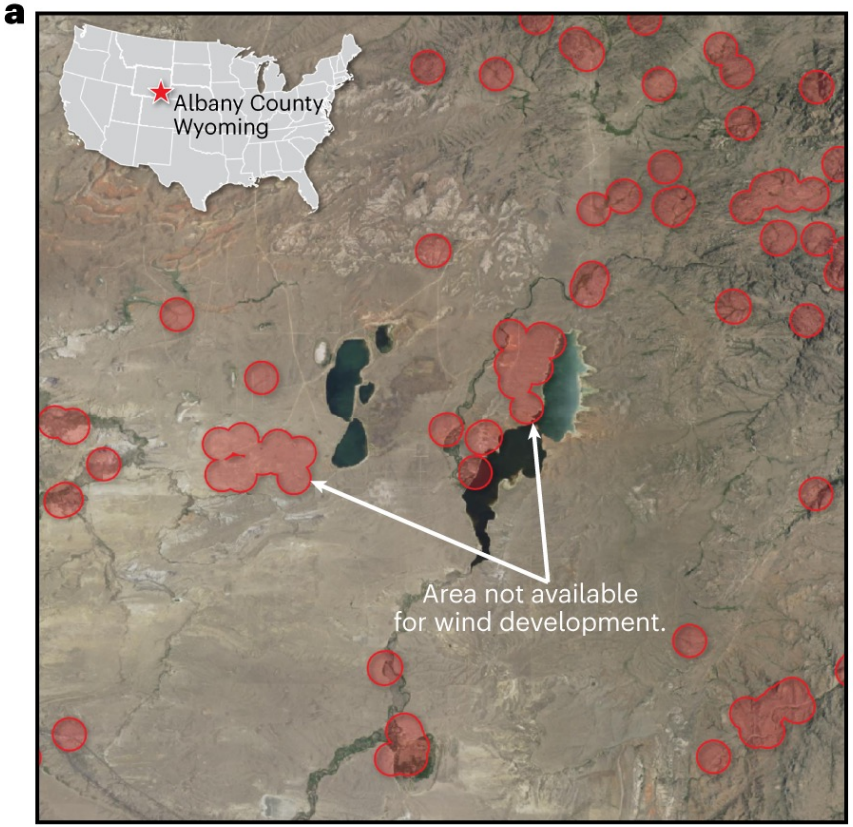
Feature(s)	Counties	25%	50%	75%	90%
Roads, Trans, Rail	140	18	30	46	76
Property line	226	12	15	30	46
Buildings	135	46	61	122	152
Water	11	23	30	38	76

Are setback ordinances becoming more stringent?



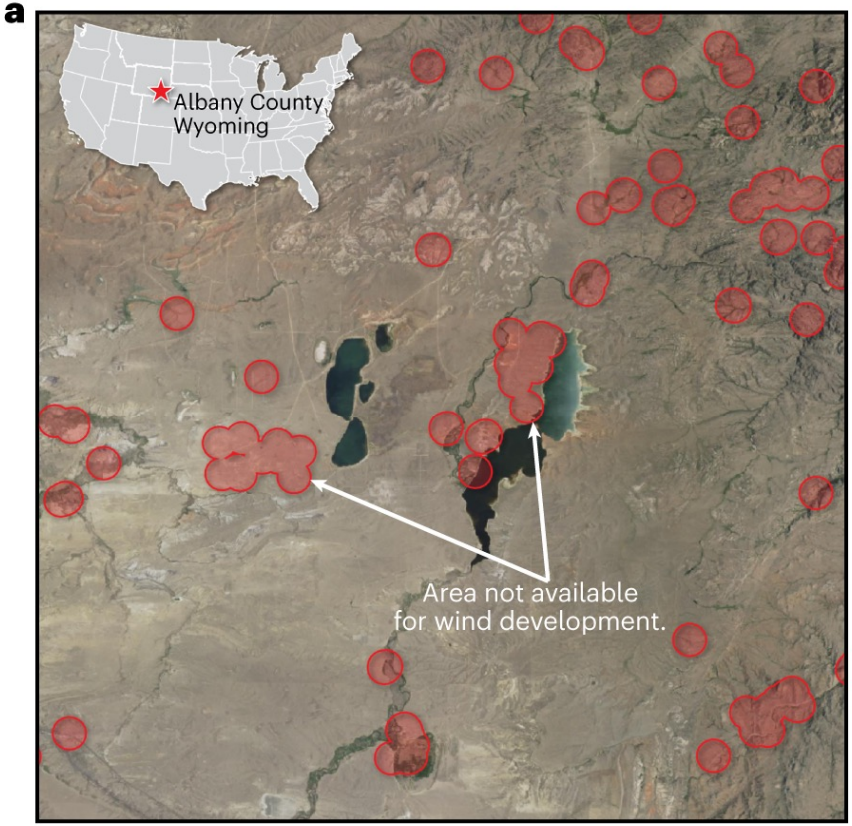


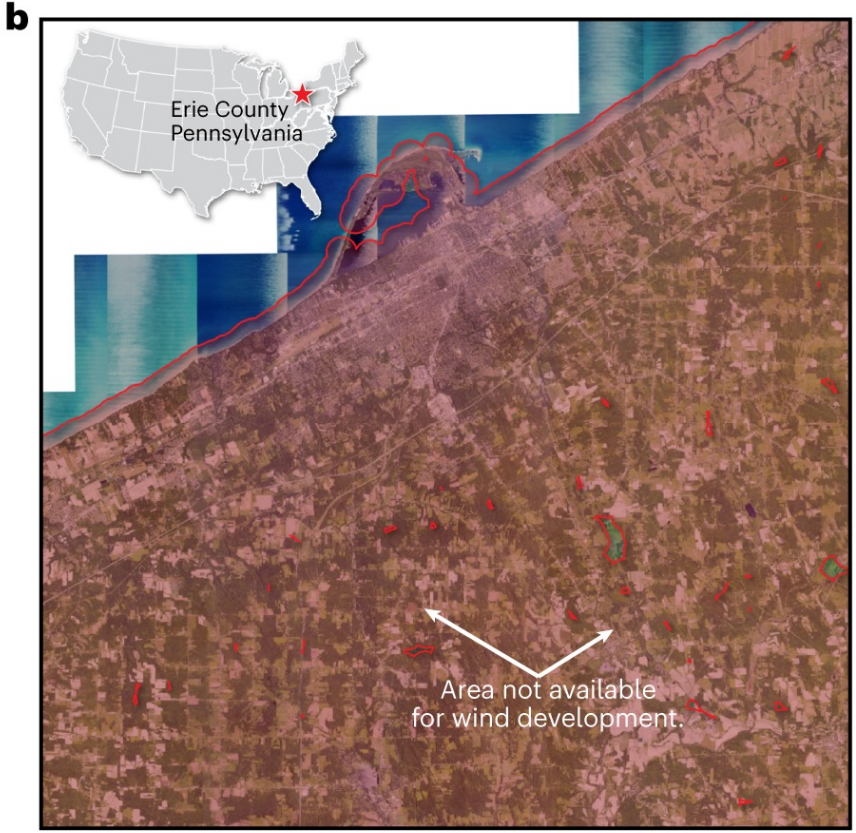
Impact of ordinances depends on spatial context



Impact of ordinances depends on spatial context

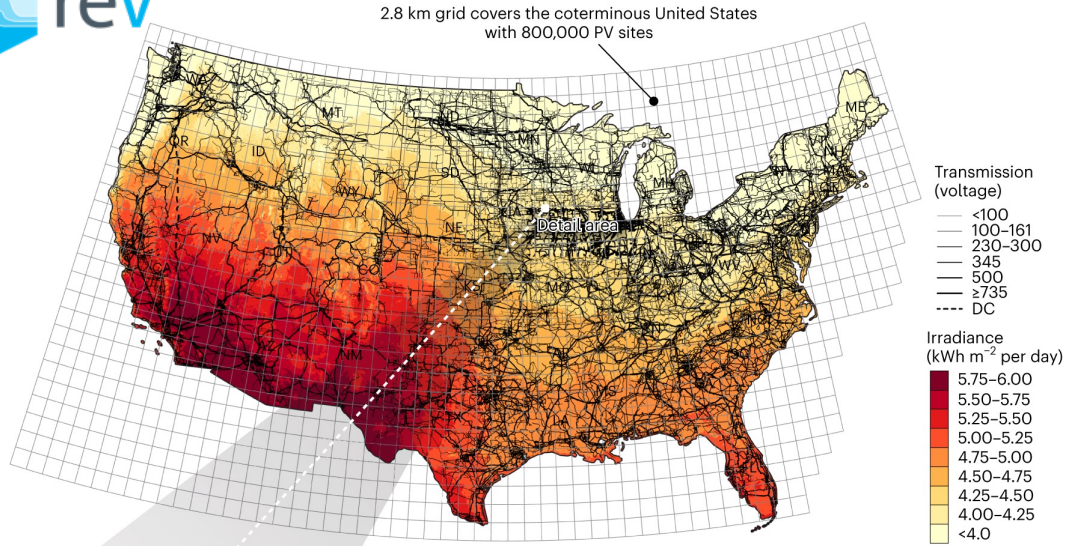
Maps are same size/scale and depict existing ordinances. Structures data from Microsoft Buildings dataset (https://github.com/microsoft/USBuildingFootprints)

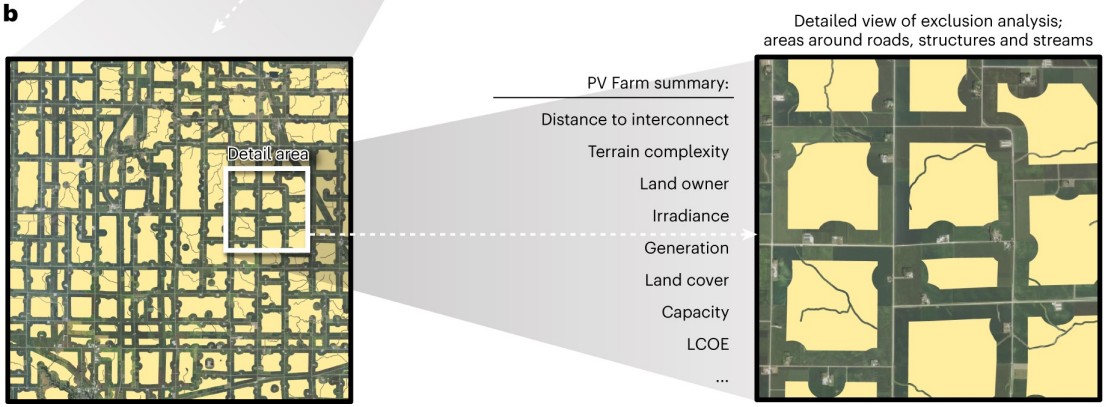




Scale 1:500,000

A Best-in-Class Model for Estimating Renewable Energy Supply





Technologies Modeled

Land-based Wind

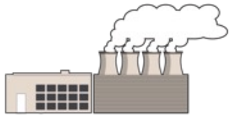
Offshore Wind

Rooftop PV

Utility-scale PV

Concentrating Solar Power

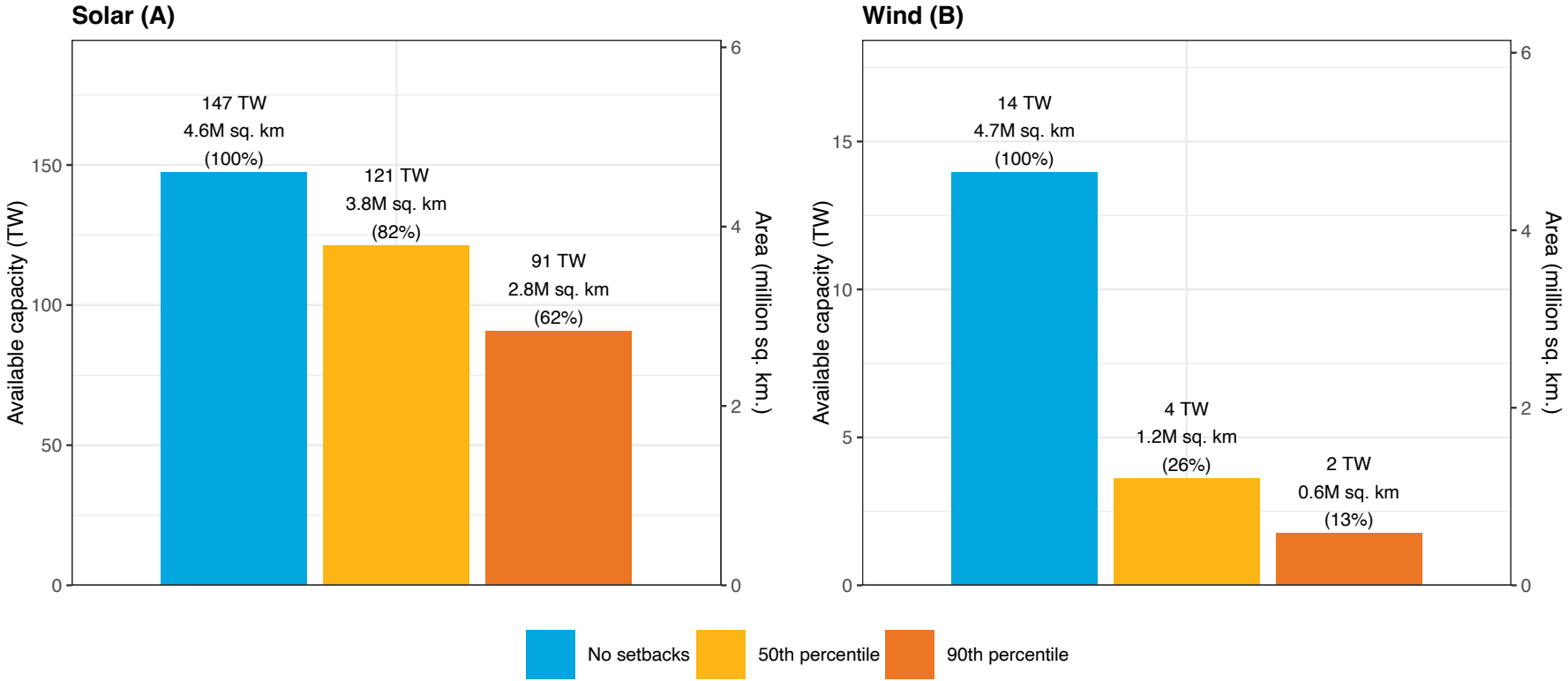
Geothermal



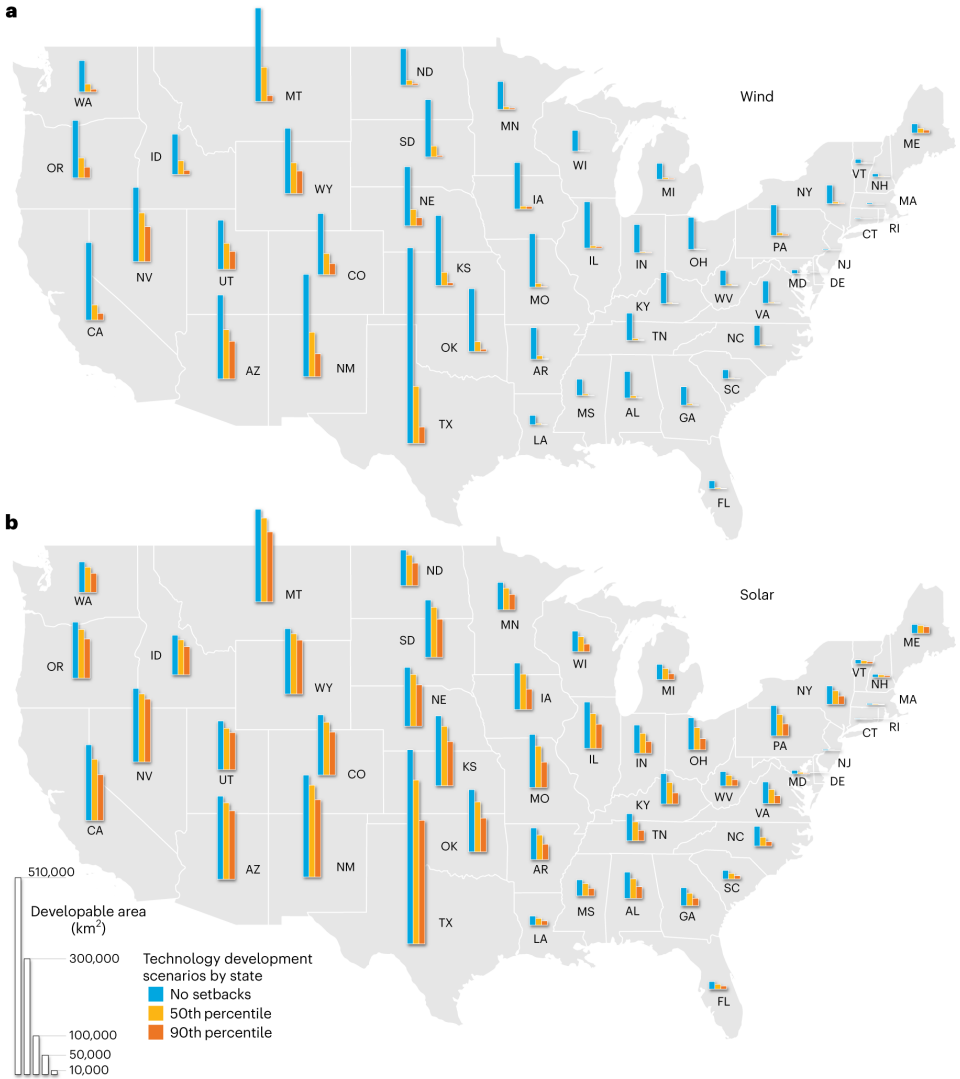
What happens to the ability to site wind and solar if ordinances continue to expand?

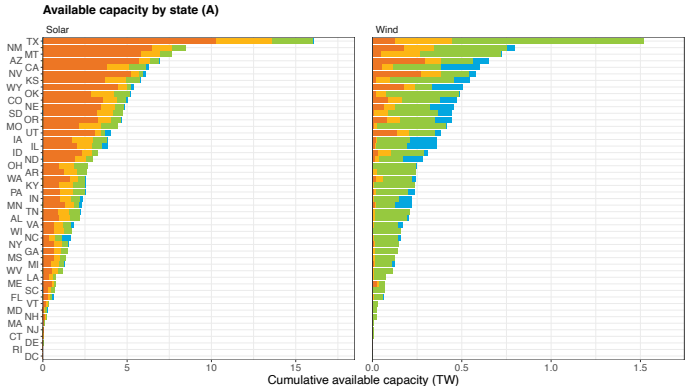
No Setbacks (Baseline)	Upper limit of technical potential. Only excludes areas that are legally or administratively protected + other unsuitable areas including water, infrastructure, mountainous landforms, etc.
50th Percentile Setbacks	Baseline + existing setback ordinances + 50th percentile ordinances extrapolated to rest of the country
90th Percentile Setbacks	Baseline + existing setback ordinances + 90th percentile ordinances extrapolated to rest of the country

Expanded ordinances likely to have large impact on land available for wind development



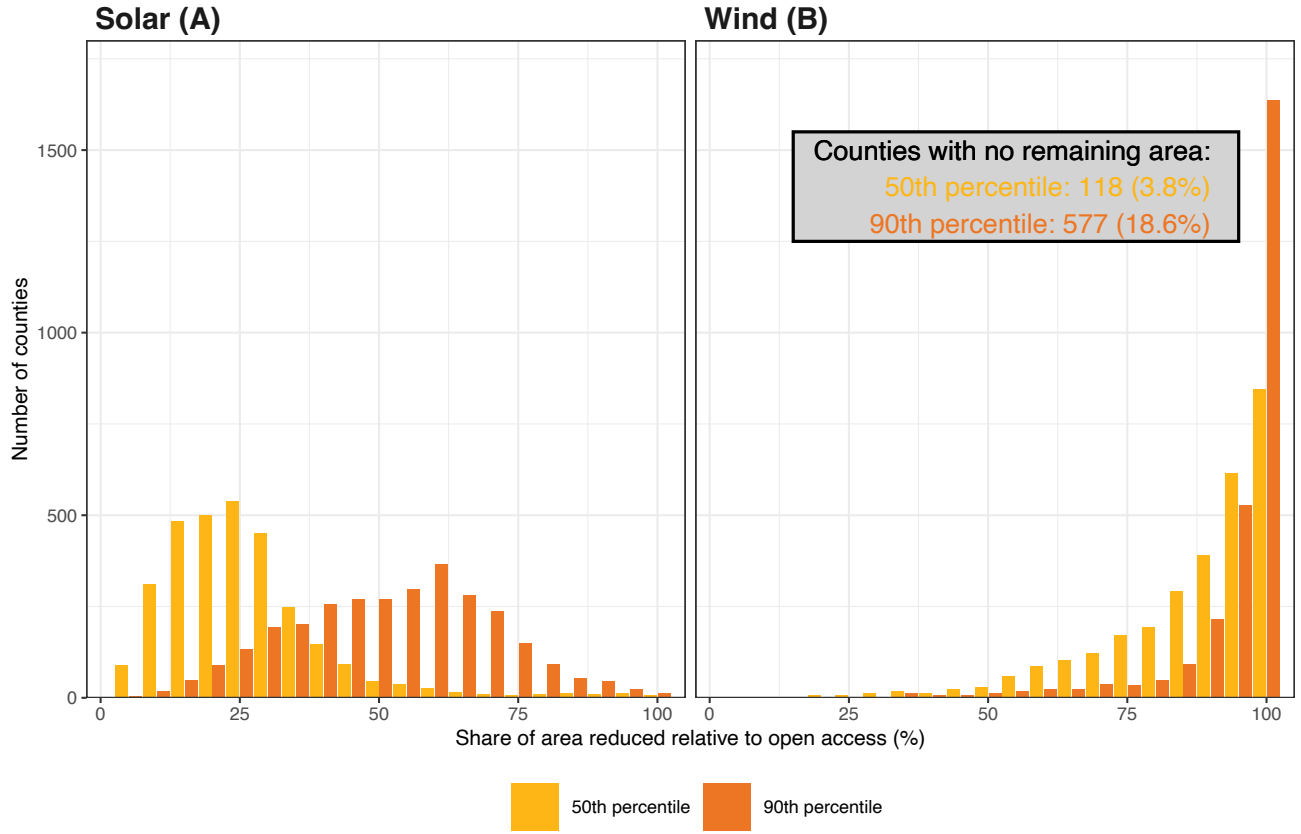
Impacts on availability at the state level



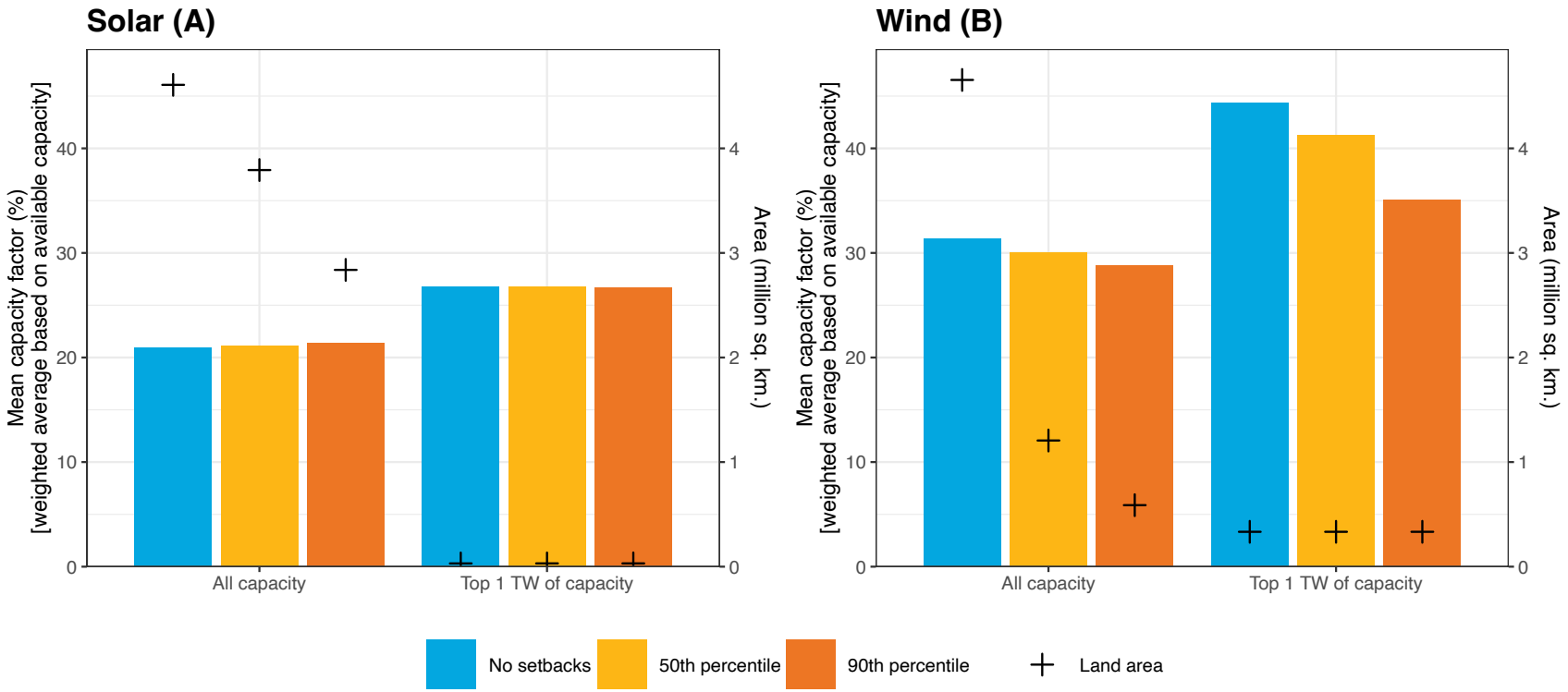


90th percentile | 50th percentile | Surveyed setbacks | No setbacks

Summary of impact at the county level



Expanded ordinances could impact the quality of the resource available for development



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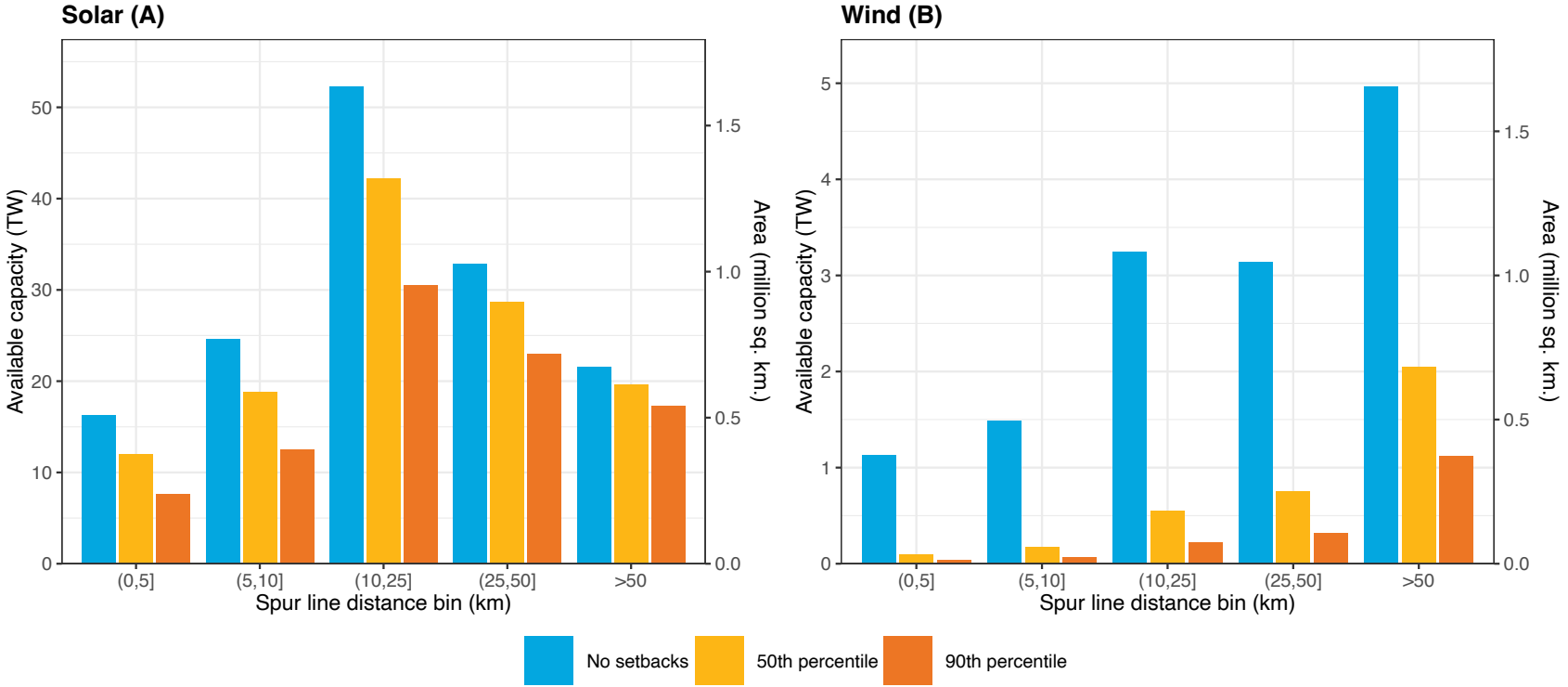


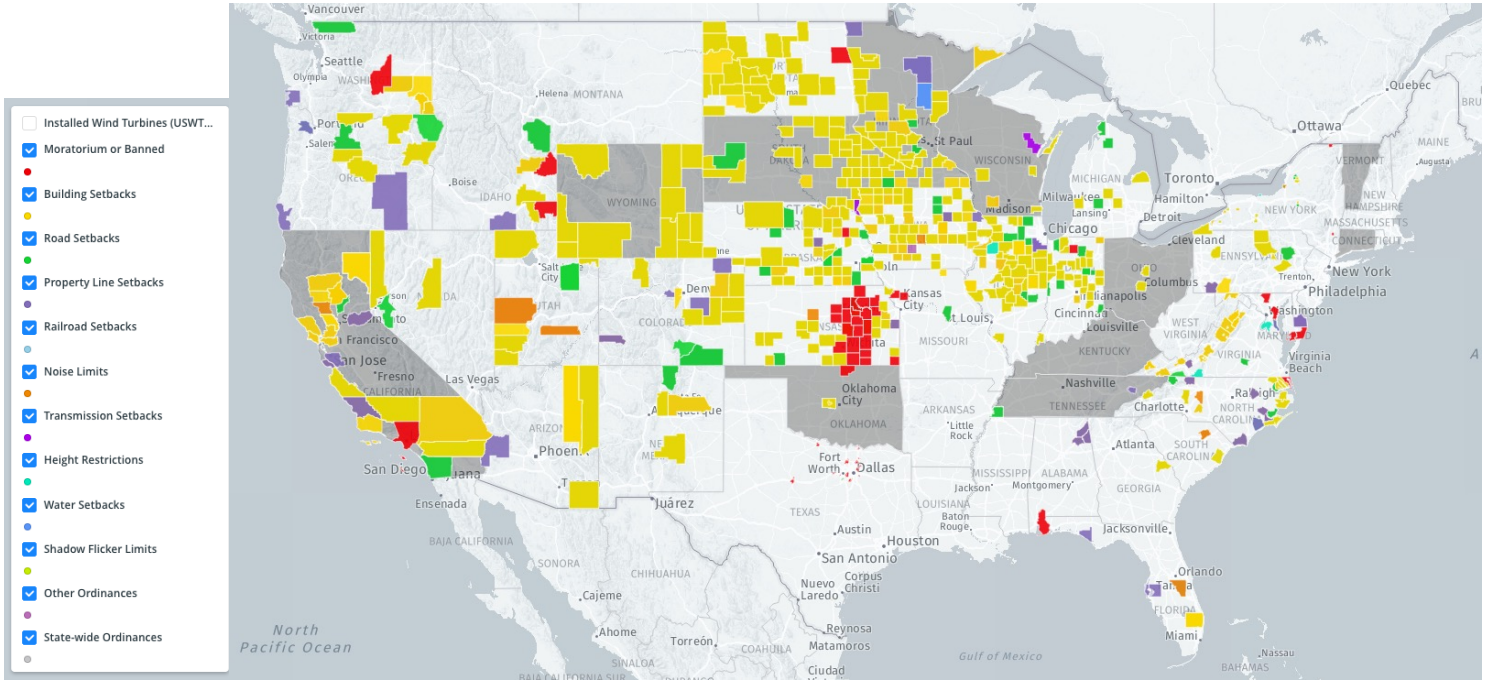
Summary

Siting ordinances are becoming increasingly common with a range of setback distances.

Extrapolating the most stringent setbacks throughout the country could reduce wind and solar resources by up to **87%** and **38%**, respectively.

We don’t capture or model all ordinances, and new or changing ordinances may change resource availability.

Siting database and viewer



	Solar	Wind
Dataset	https://data.openei.org/submissions/5734	https://data.openei.org/submissions/5733
Interactive map	https://www.nrel.gov/gis/solar-supply-curves	https://www.nrel.gov/gis/wind-supply-curves

Additional resources

Ordinance paper

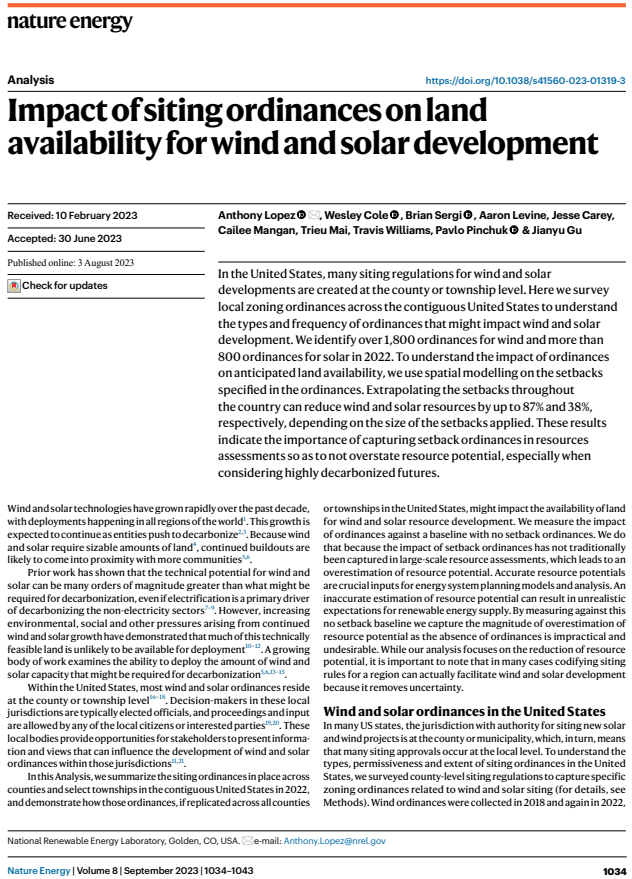
- https://www.nature.com/articles/s41560-023-01319-3

Tools (NREL tools for spatially modeling the database)

- reV: https://github.com/NREL/reV
- reVx: https://github.com/NREL/reVx

reV supply curves

- documentation: https://www.nrel.gov/docs/fy24osti/87843.pdf
- dataset: https://data.openei.org/submissions/6001



nature energy

Analysis

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Check for updates

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In the United States, many siting regulations for wind and solar developments are created at the county or township level. Here we survey local zoning ordinances across the contiguous United States to understand the types and frequency of ordinances that might impact wind and solar development. We identify over 1,800 ordinances for wind and more than 800 ordinances for solar in 2022. To understand the impact of ordinances on anticipated land availability, we use spatial modelling on the setbacks specified in the ordinances. Extrapolating the setbacks throughout the country can reduce wind and solar resources by up to 87% and 38%, respectively, depending on the size of the setbacks applied. These results indicate the importance of capturing setback ordinances in resources assessments so as to not overstate resource potential, especially when considering highly decarbonized futures.

Wind and solar technologies have grown rapidly over the past decade, with deployments happening in all regions of the world[1]. This growth is expected to continue as entities push to decarbonize[2,3]. Because wind and solar require sizable amounts of land[4], continued buildouts are likely to come into proximity with more communities[5,6].

Prior work has shown that the technical potential for wind and solar can be many orders of magnitude greater than what might be required for decarbonization, even if electrification is a primary driver of decarbonizing the non-electricity sectors[7–9]. However, increasing environmental, social and other pressures arising from continued wind and solar growth have demonstrated that much of this technically feasible land is unlikely to be available for deployment[10–12]. A growing body of work examines the ability to deploy the amount of wind and solar capacity that might be required for decarbonization[4,6,13–15].

Within the United States, most wind and solar ordinances reside at the county or township level[16–18]. Decision-makers in these local jurisdictions are typically elected officials, and proceedings and input are allowed by any of the local citizens or interested parties[19,20]. These local bodies provide opportunities for stakeholders to present information and views that can influence the development of wind and solar ordinances within those jurisdictions[21,22].

In this Analysis, we summarize the siting ordinances in place across counties and select townships in the contiguous United States in 2022, and demonstrate how those ordinances, if replicated across all counties or townships in the United States, might impact the availability of land for wind and solar resource development. We measure the impact of ordinances against a baseline with no setback ordinances. We do that because the impact of setback ordinances has not traditionally been captured in large-scale resource assessments, which leads to an overestimation of resource potential. Accurate resource potentials are crucial inputs for energy system planning models and analysis. An inaccurate estimation of resource potential can result in unrealistic expectations for renewable energy supply. By measuring against this no setback baseline we capture the magnitude of overestimation of resource potential as the absence of ordinances is impractical and undesirable. While our analysis focuses on the reduction of resource potential, it is important to note that in many cases codifying siting rules for a region can actually facilitate wind and solar development because it removes uncertainty.

Wind and solar ordinances in the United States

In many US states, the jurisdiction with authority for siting new solar and wind projects is at the county or municipality, which, in turn, means that many siting approvals occur at the local level. To understand the types, permissiveness and extent of siting ordinances in the United States, we surveyed county-level siting regulations to capture specific zoning ordinances related to wind and solar siting (for details, see Methods). Wind ordinances were collected in 2018 and again in 2022,

National Renewable Energy Laboratory, Golden, CO, USA. e-mail: Anthony.Lopez@nrel.gov

Challenges and next steps

Other types of ordinances are difficult to model yet could have large impacts.

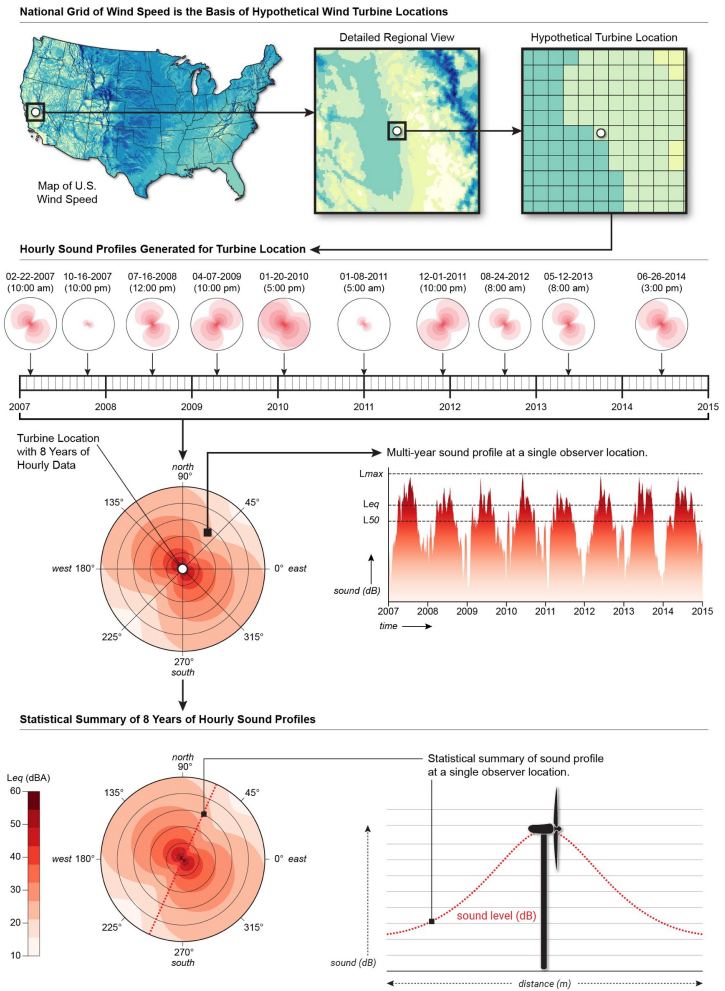
- Surrogate modeling (ML) to solve wind turbine sound modeling at national scales.

Collection of ordinances is labor-intensive and ordinances change often, requiring frequent, unanticipated updates.

- Can we apply large language models for semi-automated ordinance identification and extraction?
- Initial testing suggests 85-90% accuracy for capturing wind ordinances (Buster et al, 2024).

Ordinances are an important for jurisdictions to determine appropriate land use.

- Codifying siting rules for a region can facilitate wind and solar development if it removes uncertainty.



Thanks!

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