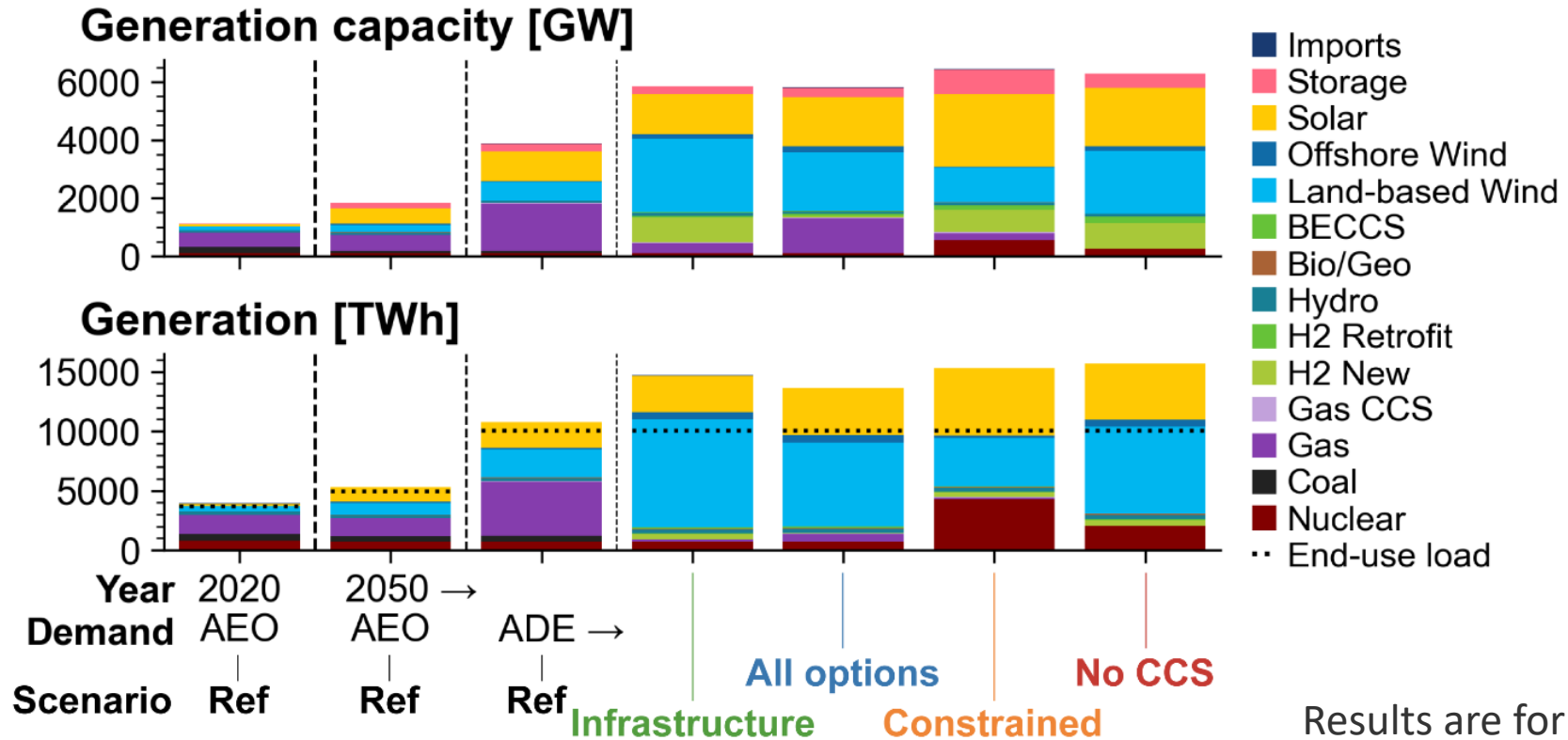


Impact of Siting Ordinances on Land Availability for Wind and Solar Development

Wesley Cole, Anthony Lopez, Brian Sergi,
Aaron Levine, Jesse Carey, Cailee Mangan,
Trieu Mai, Travis Williams, Pavlo Pinchuk,
and Jianyu Gu

National Renewable Energy Laboratory

Why Siting Ordinances?



Siting Ordinances Data Collection



Collection & Database Structure

State	City/Town	Count	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	

A machine-readable database

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)

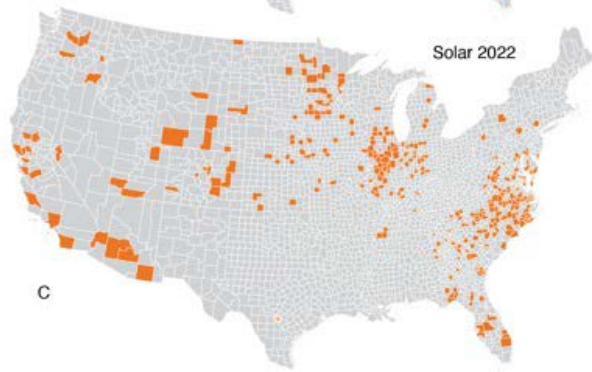
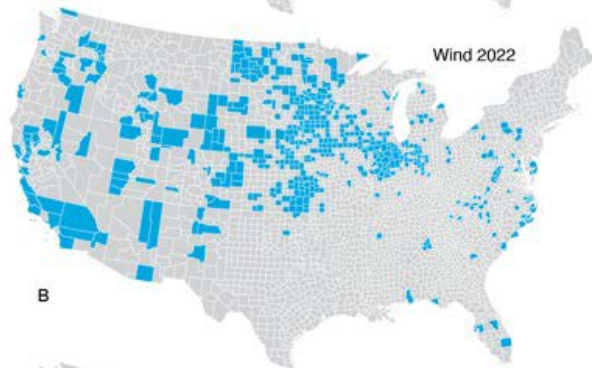
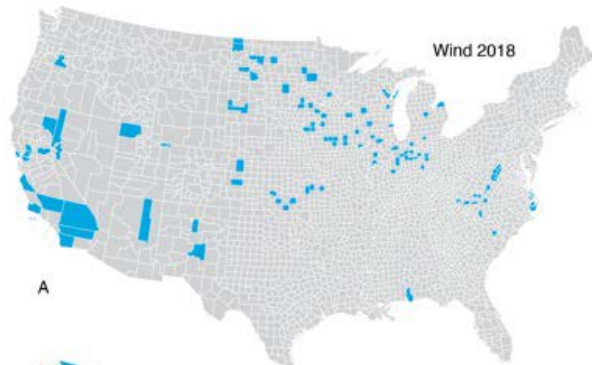
Value: Describes the specific measurement of the value type of the restriction

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)

Key Findings

- **1,800+** ordinances (~300 in 2018) for wind and **800+** ordinances for solar in 2022
- Extrapolating setbacks throughout the country can reduce wind and solar resources by up to **87%** and **38%** (depending on the setback size).
- Results indicate the importance of capturing setback ordinances in resources assessments and modeling work.



D

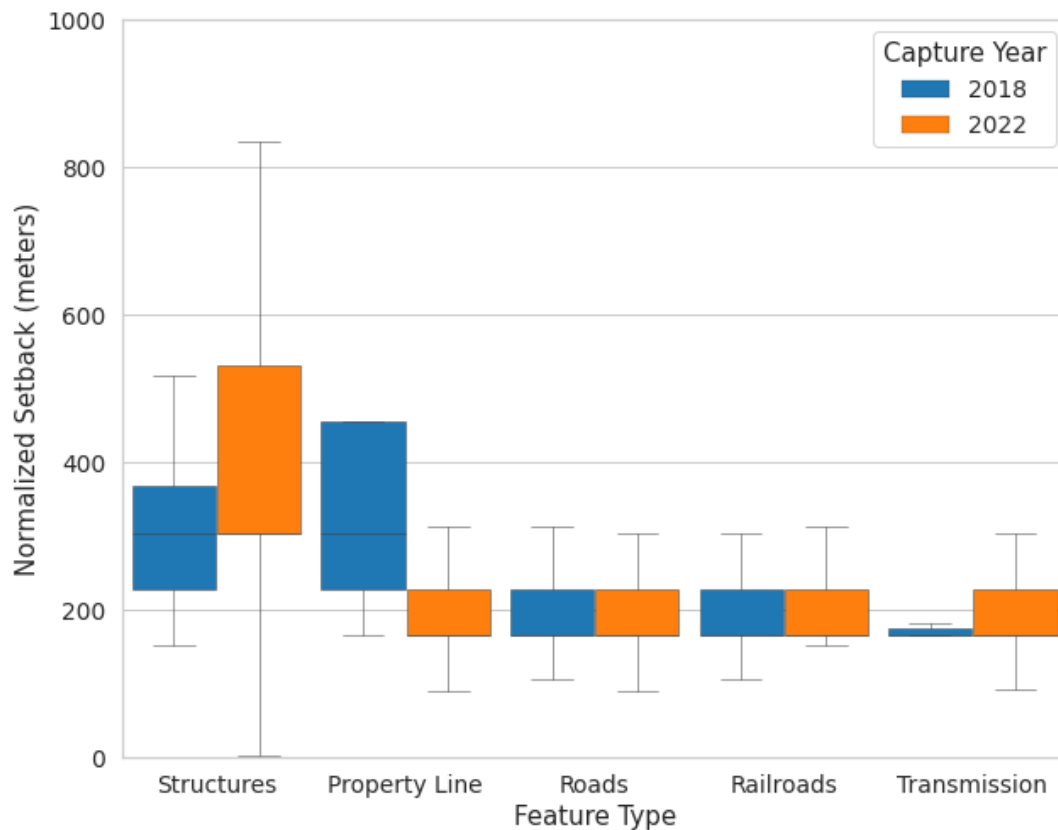
Ordinance Type	Wind 2018	Wind 2022	Solar 2022
Structure Setback	95	378	136
Road Setback	62	355	142
Property Line Setback	6	359	234
Sound Restriction	51	224	36
Transmission Setback	42	183	0
Height Limit	12	91	190
Water Setback	7	66	11
Railroad Setback	9	61	1
Moratorium or Ban	2	56	4
Density Limit	0	35	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

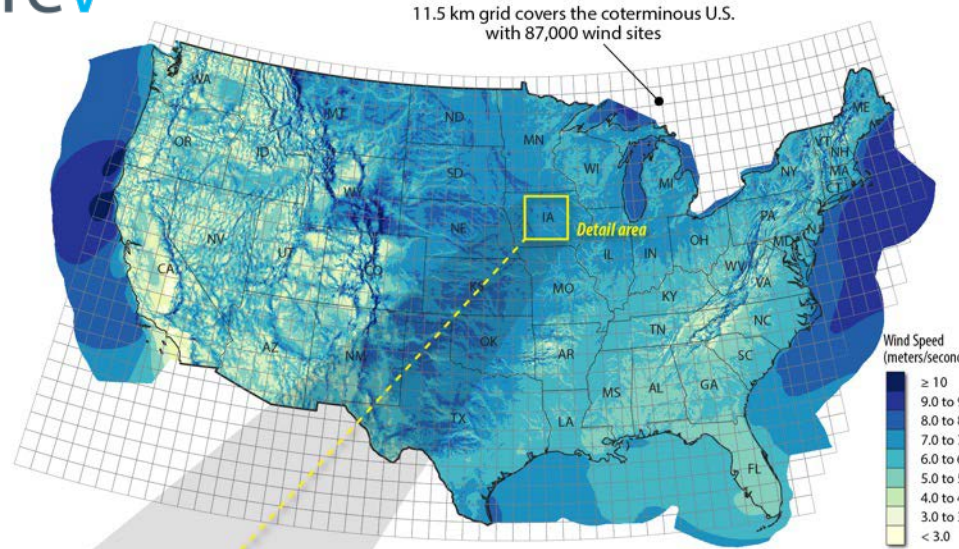
Wind (multiplier by tip height)			
Feature(s)	Counties	50%	90%
Road, Transmission, Rail	587	1.1	2
Property Line	350	1.1	3
Structure	372	2	4
Water	66	1.2	10.6

PV (fixed meters)			
Feature(s)	Counties	50%	90%
Road, Transmission, Rail	140	30	76
Property Line	226	15	46
Structure	135	61	152
Water	11	30	76

Are Ordinances Becoming More Stringent?



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



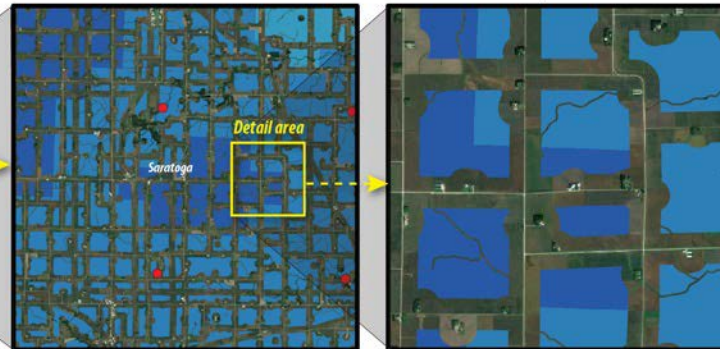
Geothermal



Detailed view of wind sites (red)

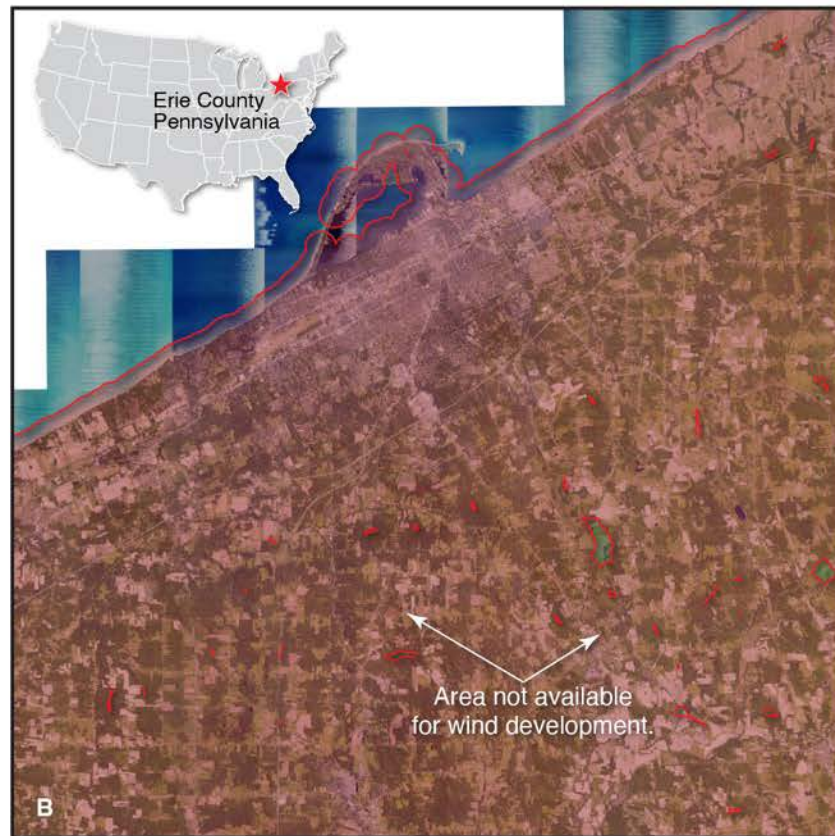
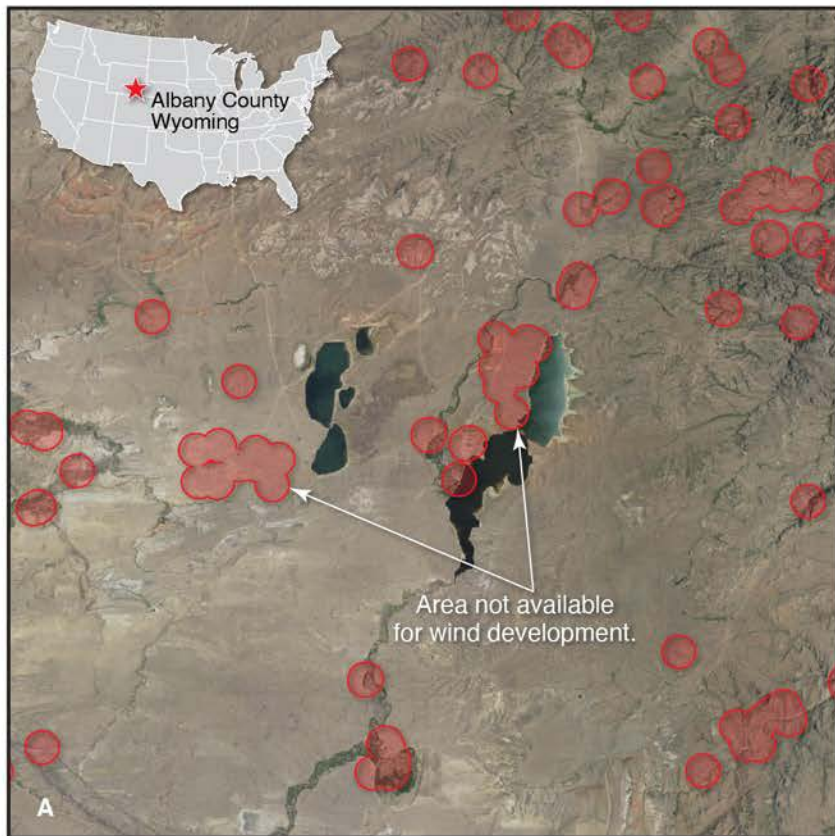


Detailed view of exclusion analysis; areas around roads, structures and streams



Spatial Context Is a Driver of Impact

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



Scale 1:500,000

Scenarios

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.

Surveyed Setbacks

Baseline + existing setback ordinances

50th Percentile Setbacks

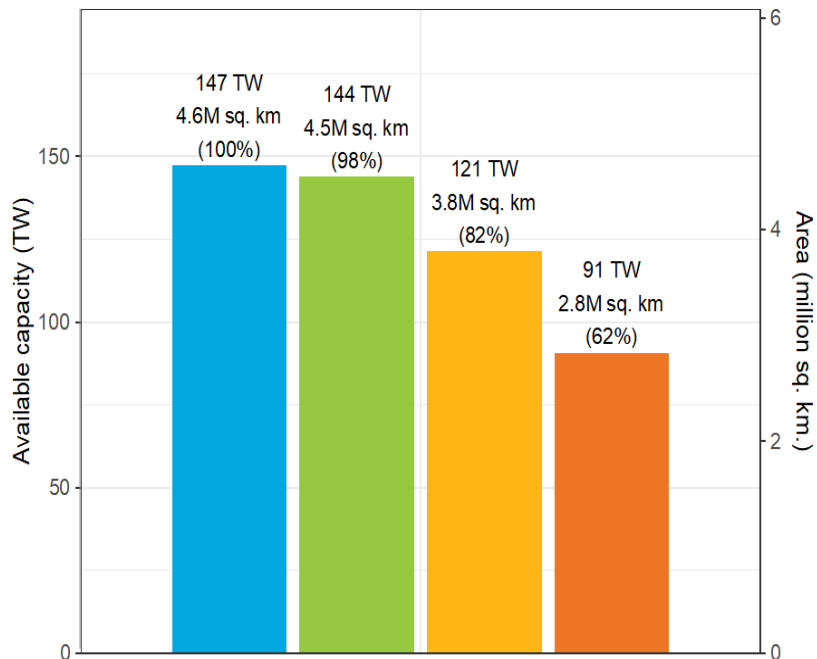
Baseline + existing setback ordinances +
50th percentile ordinances extrapolated
to rest of the country

90th Percentile Setbacks

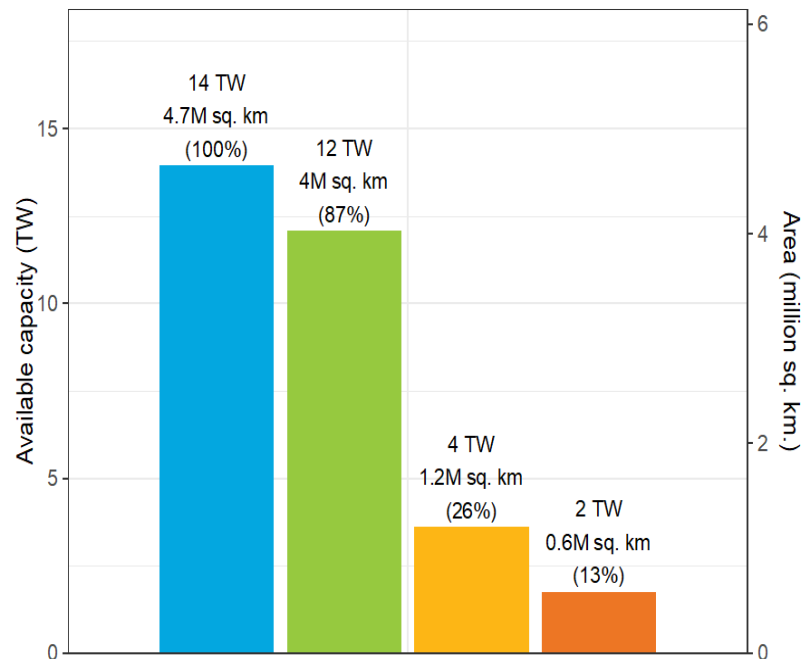
Baseline + existing setback ordinances +
90th percentile ordinances extrapolated
to rest of the country

Land Area and Capacity

Solar (A)

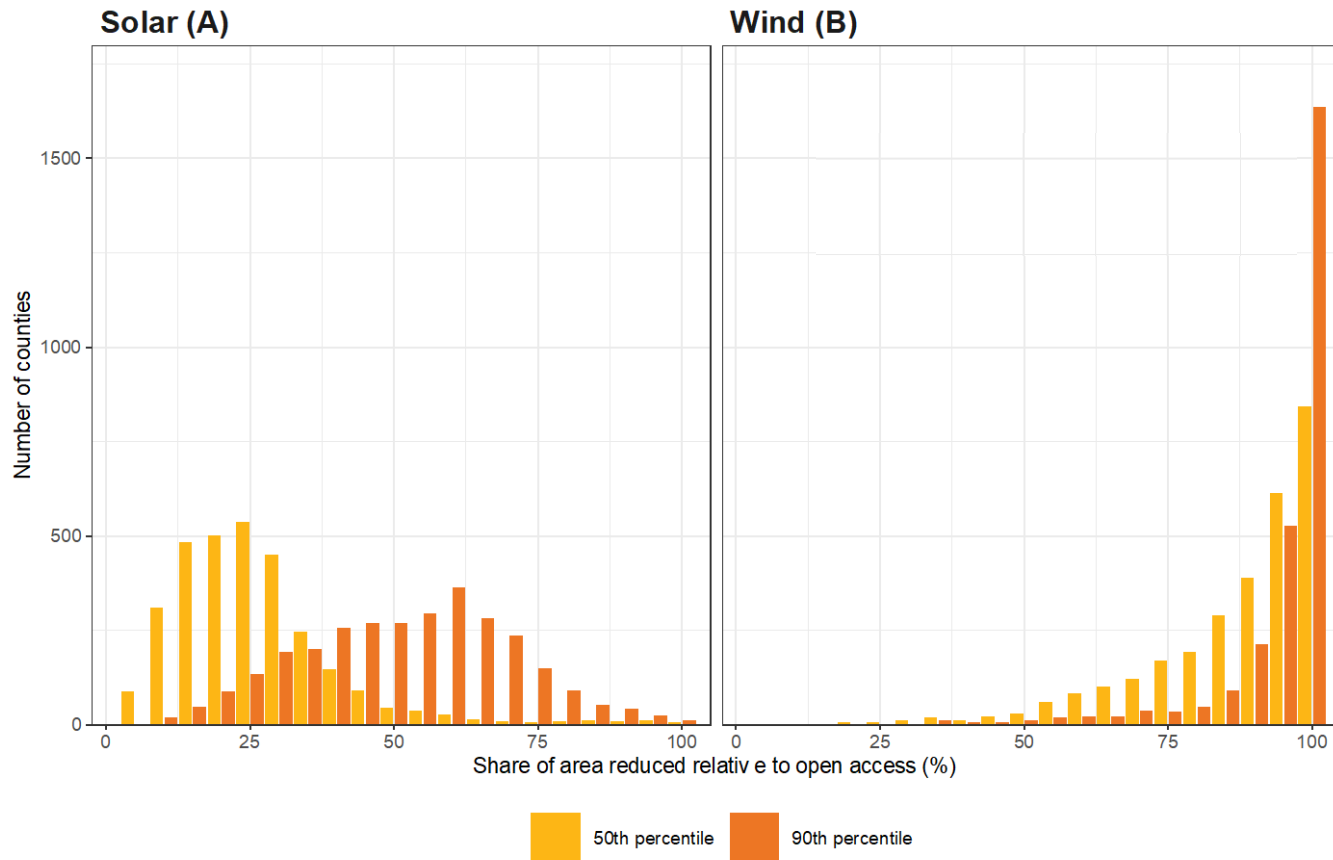


Wind (B)



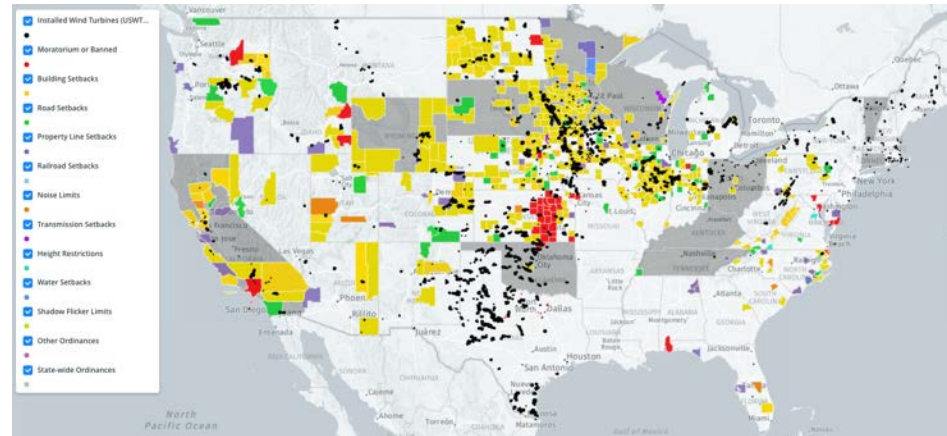
No setbacks Surveyed setbacks 50th percentile 90th percentile

Area Impacts by County



Links to Resources

- **Website** (includes interactive maps)
 - <https://www.nrel.gov/gis/renewable-energy-supply-curves.html>
- **Data** (download entire database for wind, solar)
 - Solar:
<https://data.openei.org/submissions/5734>
 - Wind:
<https://data.openei.org/submissions/5733>
- **Tools** (NREL tools for spatially modeling the database)
 - reV: <https://github.com/NREL/reV>
 - reVx: <https://github.com/NREL/reVx>
- **Paper**
 - <https://www.nature.com/articles/s41560-023-01319-3>



Interactive map that includes the ability to hover and examine unique ordinances

Summary

- Siting ordinances are becoming increasingly common with a range of setback distances
- The setback distance can have a considerable impact on available resource
- Ordinances have a larger impact on wind resource than solar resource



Follow-up:
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www.nrel.gov

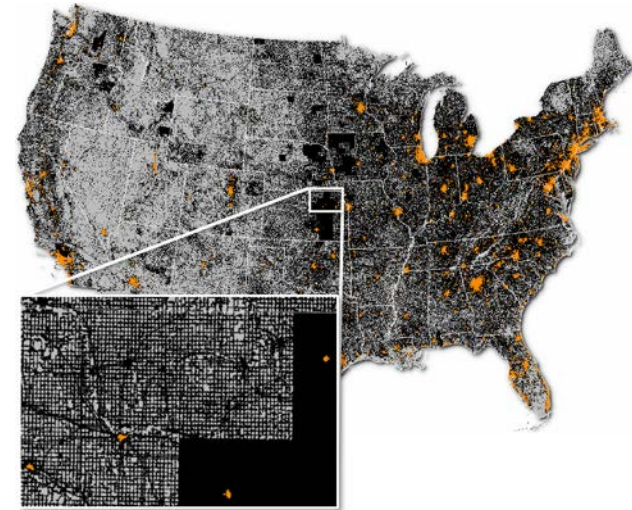
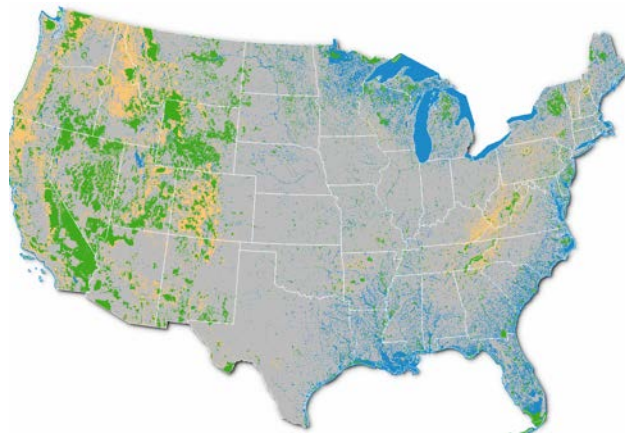
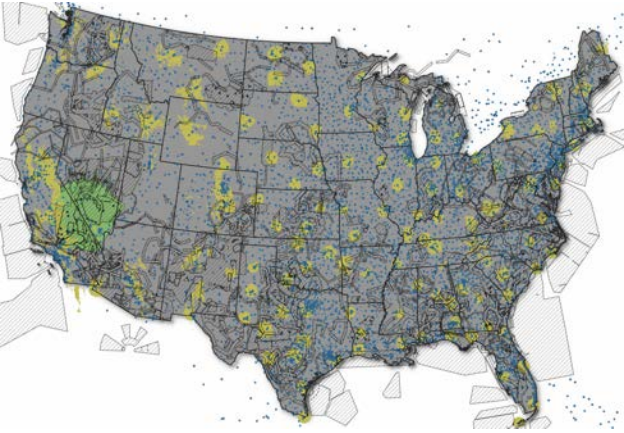
This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Solar Energy Technologies Office Award Number 38421. 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.

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NREL/PR-6A40-87476



Spatial Siting Considerations



Airspace

- Airport Setbacks (variable)
- Intercontinental Ballistic Missiles ICBMs
- Risk of Adverse Impact on Military Operations and Readiness Area (RAIMORA)
- DoD Lands
- DoD Radar setbacks and line-of-site
- NEXRAD setbacks and line-of-site
- Military training routes
- Special-use airspace

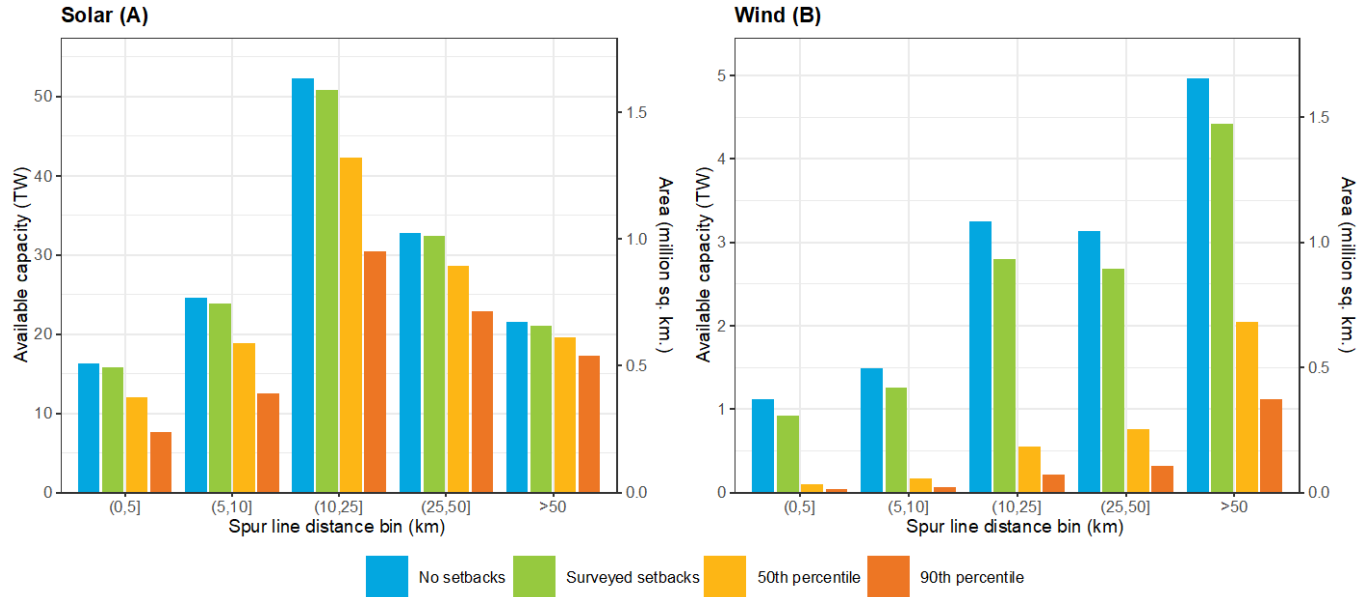
Environmental

- Bat Hibernacula
- ANL BLM Wind Exclusions
- Sage Grouse Core Habitat (federal land)
- T&E Species Core Habitat (subset)
- USFWS NWI
- American Farm Trust Conserved Farmlands
- Nationally Significant Ag Lands
- Big game migration corridors
- Conservation Reserve Program (CRP)
- Water, Woody/Herbaceous Wetlands
- Bureau of Land Management Areas of Critical Environmental Concern
- National Forest Service Inventoried Roadless Areas
- NCED GAP 1, 2
- PAD-US GAP 1, 2
- Slope Exclusion(s)
- Elevation & Mountainous Landforms

Social / Regulatory

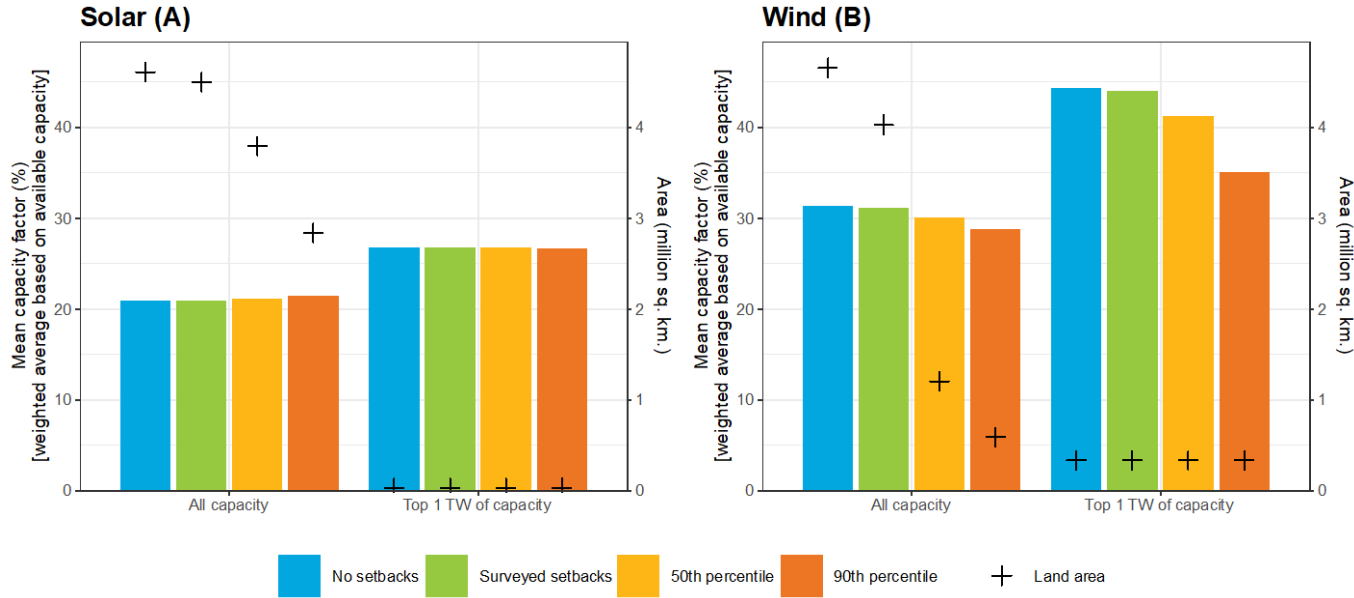
- Oil & Gas Wells
- Oil & Gas Pipelines (ROW)
- Water Setbacks
- Existing wind facilities
- Bans or Moratoriums
- Height Limits
- Rail Setbacks
- Railroads
- Road Setbacks
- Structure Setbacks
- Transmission Setbacks
- Shadow Flicker
- Sound Limits
- Roads
- Structures
- Transmission (ROW)

Gen-tie Impacts



Available capacity (left axis) and land area (right axis) for solar (Figure A) and wind (Figure B) binned by gen-tie distance. The gen-tie line is the line that connects the site to the bulk power transmission infrastructure. The largest decreases in resource availability are those that are closest to the transmission infrastructure. Note the different y-axis scales.

Capacity Factor of Remaining Resources

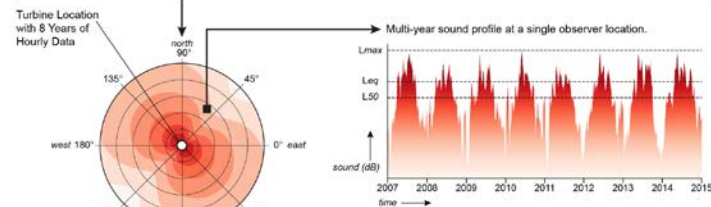
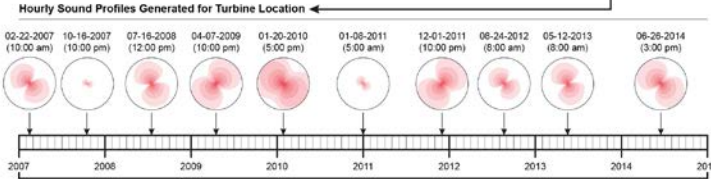
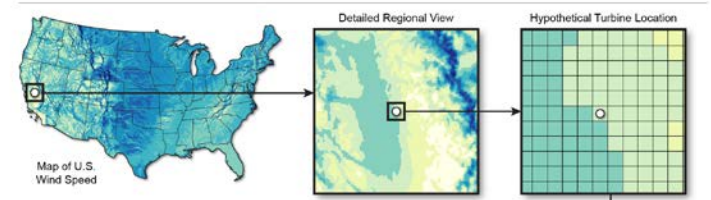


Weighted-average capacity factor for solar PV (A) and wind (B). Each figure shows the capacity factor and land area of all available capacity as well as for the top 1 TW of available capacity.

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.
 - LLM's for semi-automated ordinance identification and extraction

National Grid of Wind Speed is the Basis of Hypothetical Wind Turbine Locations



Statistical Summary of 8 Years of Hourly Sound Profiles

