Supplementary Material

Low-impact land use pathways to deep decarbonization of electricity

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This file includes:

Supplementary text
Figs. S1 to S27
Tables S1 to S17
Captions for Databases S1 to S14
References for SI reference citations

Other materials for this paper available as separate files:

Databases S1 to S14

Supporting Information Text

Access to data, code, and results

1. Data

All data sources and weblinks for download are provided in the Supporting Information (Excel Data Table S1 - *EnvironmentalExclusionCategoryDataSources.xlsx*, Tables S5, S6, S7, S8, S9 - S12), and the vast majority of datasets are free and publicly available with the exception of the following two:

1) Ventyx spatial data on the U.S. transmission network is part of a proprietary subscription dataset, called the Velocity Suite, that was purchased under a non-disclosure agreement. This dataset is available for anyone to purchase using the following link: https://new.abb.com/enterprise-software/energy-portfolio-management/market-intelligence-services/velocity-suite

2) The spatial dataset on the footprints of California's solar power plants (up to 2018) that was created by The Nature Conservancy is not yet published. However, access to the dataset may be granted upon request prior to publication by contacting Brian Cohen (bcohen@tnc.org).

2. Code

Code to perform ORB (Optimal Renewable Energy Build-out) analysis, including resource assessment (site suitability; Step 2), site selection (Step 4), and strategic environmental assessment (Step 5) is available on Github in the following repository (not yet publicly accessible, but will be upon publication of paper): https://github.com/grace-cc-wu/LandUsePathwaysTo100.git. A generic version of the site suitability model using only raster inputs and the model used to create candidate project areas are available for free (open source) on https://mapre.lbl.gov/gis-tools as Script Tool B-1 and B-2, respectively.

The public version of RESOLVE with installation instructions is available on the California Public Utilities Commission (CPUC) website: https://www.cpuc.ca.gov/irp/prelimresults2017/. The following methods section A details the modifications made to the public CPUC version for the present study.

3. Results

All generated results are publicly available in Excel spreadsheet directly on the journal server (supply curves - *ResourceAssessment.xlsx*, RESOLVE outputs - *CapacityExpansionResults_RESOLVEportfolios.xlsx*, strategic environmental assessment - *StrategicEnvAssessment.xlsx*) or spatial data format (flattened Environmental Exclusion Category areas and resource potential maps) on https://github.com/grace-cc-wu/LandUsePathwaysTo100.git except the selected project area locations. The selected project area results associated with a given scenario identify optimal locations for possible new energy generation based on the criteria selected by the authors. This study is based on scenario analysis and is not a siting study capable of making prescriptions or predictions of where which areas will or should be developed. However, many of these lands are privately-owned so the data could easily be mis-interpreted by users or landowners as identifying lands which are targeted or sanctioned for renewable energy development by the organizations involved in the study. These data are not publicly available due to the risk of mis-interpretation and the legal and political risks associated with a possible change in market value associated with this identification. However, the code used to generate these selected project areas (i.e., the site selection methods and process) will be made publicly available upon publication.

Additional methods

4. Step 1. Environmental exclusions definitions and data collection

The gathering and compiling of environmental data for this study was informed by conventions established in prior work (1–9). Following prior studies, we aggregated environmental data into four categories. These data types, which we refer to as Environmental Exclusion Categories, range from low to moderate and high levels of protection for lands with high conservation value and intactness. The definitions of the four Environmental Exclusion Categories are as follows (see Supporting Information [SI] Tables S9–S12 and the full spreadsheet linked here for an exhaustive list of individual datasets in each Category):

- **Environmental Exclusion Category 1 (Legally protected)**: Areas with existing legal restrictions against energy development. (Examples: National Wildlife Refuge, National Parks)
- **Environmental Exclusion Category 2 (Administratively protected)**: Areas where the siting of energy requires consultation or triggers a review process to primarily protect ecological values, cultural values, or natural characteristics. This Category includes areas with existing administrative and legal designations by federal or state public agencies where state or federal law requires consultation or review. This Category includes tribal lands, as these areas are subject to the authority of Tribes, or nations, to determine if utility-scale renewable energy development is an appropriate or allowable use. Lands owned by non-governmental organizations (NGOs) that have conservation obligations also included in this Category. Multiple-use federal lands such as Forest Service lands without additional designations were not included in this Category, although in some prior studies they have been. (Examples: Critical Habitat for Threatened or Endangered Species, Sage Grouse Priority Habitat Management Areas, vernal pools and Wetlands, tribal lands)
- **Environmental Exclusion Category 3 (High conservation value)**: Areas with high conservation value as determined through multi-state or ecoregional analysis (e.g., state, federal, academic, NGO) primarily characterizing the ecological characteristics of a location. This category may also include lands that have social, economic, or cultural value. Prime farmlands as determined by U.S. Department of Agriculture (USDA) are also included in this Category. Despite their conservation value, these lands typically do not have formal conservation protections. (Examples: Prime Farmland, Important Bird Areas, big game priority habitat, The Nature Conservancy Ecologically Core Areas)
- **Environmental Exclusion Category 4 (Landscape Intactness)**: Lands with potential conservation value based on their contribution to intact landscape structure. This Category includes lands that maintain habitat connectivity or have high landscape intactness (low habitat fragmentation). Again, despite their conservation value, these lands typically do not have formal conservation protections. (Examples: landscape intactness, wildlife corridors)

As a guiding principle for the environmental and land use data compilation, we strove for consistency with prior work. Where prior work included transparent peer review, public stakeholder processes, and agency adoption of the final work product, these products were prioritized for accurate incorporation into this study. However, there were many land use types that did not fit neatly into categories, where treatment varied in prior studies, and where discretionary judgment was applied. These areas are described briefly below, with further Supporting Information and a comparison of datasets included in other similar studies found in Supporting Information [SI] Tables S9–S12.

Studies vary in their treatment of the following area types: protected areas identified in different versions of PAD-US (the Protected Areas Database of the U.S. created by the U.S. Geological Survey and Conservation Biology Institute), multiple-use public lands (e.g., state and national forests), critical habitat, big game habitat, and species-related information. This study fills gaps in prior studies (e.g., improving west-wide treatment of wetlands, important habitat for non-listed species, Audubon Important Bird Areas, tribal lands, agricultural lands, county zoning ordinances, landscape intactness). Although we considered including a least-conflict land category such as that identified in A Path Forward, and that identified in the TNC Site Wind Right study, we decided not to include such a layer, as the intent of this study is to conduct scenario analysis and not to provide direct siting guidance. We did, however, include data that were used to inform the identification of least conflict areas. See Supporting Information (Tables S9–S12 and the full spreadsheet linked here) for more detailed descriptions of data, rationale for their categorization, and their sources.

The draft list of data layers and categorization decisions were subjected to several rounds of review, and comments were incorporated from the following: The Nature Conservancy (TNC) state chapters, the TNC Site Wind Right project team, and several peer NGOs. After review and refinement, we converged on a final list of more than 250 data layers for Categories 1, 2, 3, and 4 (SI Tables S9–S12). For each Category, the constituent data layers were aggregated into a single layer. These aggregated layers were later applied in the site suitability analysis (Step 2, Section 5) and in the strategic environmental assessment (Step 5, Section 9).

5. Step 2. Renewable resource assessment (ORB)

A. Site suitability modeling. The purpose of site suitability modeling is to identify areas that would be suitable for large-scale terrestrial renewable energy development, based on several siting criteria. The result of site suitability modeling is a spatial dataset representing wind and solar resource potential areas in the form of vector polygons and associated attributes. Attributes include Candidate Project Area size (km^2), potential capacity (MW), and capacity factor (modeled from irradiance and wind speed). These attributes are necessary components for constructing a generation "supply curve," which is an important input for the capacity expansion model, RESOLVE.

Technical and economic data inputs For this study, site suitability modeling of wind and solar potential closely followed methods described in several previous studies (1, 10, 11). To identify technically and economically suitable areas for renewable energy development, we used spatial datasets that capture technical (e.g., competitive wind resource locations), physical (e.g., slope, water bodies), and socio-economic or hazardous (e.g., densely populated areas, military zones, railways, airports, mines, flood zones) siting considerations. We used the National Renewable Energy Lab (NREL)'s WIND Toolkit metadata, which reports annual average capacity factor per point location, for the basis of economically and technically viable wind locations in the U.S. (12). We did not apply a capacity factor threshold for solar PV suitability, but allowed RESOLVE to select solar capacity from each RESOLVE Zone based on capacity factors generated from NREL's System Advisor Model (SAM) (13). A list of RESOLVE Zones can be found in the RESOLVE User Manual as Figure 7: In-state transmission zones in RESOLVE. A more complete list can be found in the RESOLVE "User interface" workbook, "REN_Candidate" sheet (14). For feasible geothermal locations, we relied on the Western Renewable Energy Zone's study of resources in the Western U.S. (4), which is also the source for RESOLVE's current geothermal resource availability inputs. We modeled the geothermal facilities' footprint using the appropriate buffer radius assuming 25.5 MW km^{-2} and the capacity (MW) in the attribute table. See SI Table S5 for sources of all non-environmental input datasets.

Although we modeled suitable sites for geothermal, the amount of geothermal potential in the RESOLVE Base case supply curve was significantly lower compared to potential estimates for wind and solar (SI Figs. S3B–S4B). Thus, while we show geothermal findings in the results figures, we focus on discussion of wind and solar results. We did not include offshore wind and concentrating solar power (CSP). Offshore wind resources were not included primarily to maintain consistency with assumptions in existing versions of the RESOLVE model, in which offshore wind has not yet been incorporated. Secondarily, the publicly available data for offshore wind along the Pacific Coast is not yet well enough characterized and vetted in stakeholder processes for incorporation at the time of the study. Although CSP is included in the supply curve for existing versions of RESOLVE, its estimated capital costs are too prohibitive for new capacity to be selected under any scenario.

Identification of suitable sites and Candidate Project Areas In order to create resource potential maps, we used Stage 1 of the MapRE (Multi-criteria Analysis for Planning Renewable Energy) Zoning Tool (11), which uses Python raster-based algebraic geoprocessing functions and siting assumptions specified for each dataset and technology (SI Table S5). MapRE Zone Tools are the graphical user interface version of the ORB tools and are part of the ORB suite of siting tools. Using the MapRE Script Tool B-1, we created a single 250 meter resolution raster of areas that satisfy techno-economic siting criteria for each technology (i.e., suitability map). For each technology, we removed the Environmental Exclusion Categories (section 4) from the techno-economic suitability map using vector geoprocessing in Python to create four Siting Levels (SL) of suitable areas that meet both techno-economic and environmental siting criteria (see Section A for a full description of Siting Levels). We applied the Environmental Exclusion Category data in native vector format in order to preserve the spatial accuracy of the environmental datasets.

In order to simulate potential project locations within suitable areas identified, we used MapRE Script Tool B-2, or the "project creation stage", to create Candidate Project Areas (CPAs) by subdividing suitable areas into smaller, utility-scale project-sized areas. Solar potential project areas ranged from 1 km^2 to 7 km^2 (or about 30–270 MW), with the vast majority of solar CPAs designed to be 4 km^2 or to accommodate approximately 120 MW of solar capacity. Wind CPAs ranged from 1 km^2 to 10 km^2 (or about 6.1–61 MW), with the vast majority of wind CPAs designed to be 9 km^2 or to accommodate approximately 55 MW of wind capacity. We eliminated CPAs less than 1 km^2, as these parcels would typically be considered too small for commercial utility-scale renewable energy development.

Creation of candidate supply curves for capacity expansion modeling To create supply curves for RESOLVE, we summarized site suitability results for each RESOLVE Zone. Each row in the supply curve table corresponds to an area within which resources and their attributes have been aggregated or averaged (i.e., RESOLVE Zones in this study). From this supply curve, RESOLVE selects certain quantities of candidate resources in a capacity expansion optimization. Within California, RESOLVE Zones are comprised of one or more Super Competitive Renewable Energy Zones, regions identified in previous California renewable energy planning processes and studies (3, 15) (Fig. S1). Outside of California and within the Western Electricity Coordinating Council (WECC) states, RESOLVE Zones are collections of various Qualifying Resource Areas (QRA) (4) specific to each technology (Fig. S1).

To generate these RESOLVE-specific supply curves, we spatially averaged capacity factors (CF) across all CPAs (CFs are from resource datasets listed in SI Table S5) and calculated the megawatts (MW) of potential generation capacity for each technology (assuming 6.1 MW km^{-2} for wind (16), 30 MW km^{-2} for solar PV (17), and 25.5 MW km^{-2} for geothermal (17)), for each RESOLVE Zone or state, and for each Siting Level (see Section A for explanation of Siting Levels). These Zone- and state-specific MW and CF values formed the basis for the supply curve inputs for RESOLVE. See SI Figures S3, S4 for plotted supply curves. We made modifications to the supply curve to account for wind capacity that can be accessed via existing transmission lines. RESOLVE assumes that 500 MW and 1500 MW of wind potential in New Mexico and Pacific Northwest RESOLVE Zones, respectively, can utilize existing transmission infrastructure (and thus have lower system costs). Because CPAs represent all suitable sites for energy development, in order to avoid over-estimating candidate wind resources, we subtracted these 500 MW and 1500 MW of "existing transmission" candidate resource capacity amounts from the total capacity in all wind Candidate Project Areas in the New Mexico and Pacific Northwest RESOLVE Zones. This meant that the sum of CPAs in New Mexico RESOLVE Zones and the "existing transmission" resources in New Mexico should equal the total available CPAs identified for New Mexico. The "existing transmission" resources in RESOLVE are additional, non-spatial resources, with no associated project footprint. As such, RESOLVE treats them as additional to the CPAs. When selected by RESOLVE, these resources must be assigned to a spatial footprint. This subtraction essentially completes this assignment.

Because the existing policy assumptions and the version of RESOLVE currently being used in California energy planning do not include Montana and Colorado, the supply curve inputs for the RESOLVE capacity expansion model and all subsequent steps do not include Montana and Colorado wind, solar, or geothermal resources.

B. Accounting for existing power plant footprints. The results of the above site suitability modeling steps include maps of possible locations for wind and solar development. For many of these possible locations, however, there are wind and solar power plants that have already been constructed. Existing power plants must be removed from the CPAs and supply curve in order to ensure that the supply curve only contains undeveloped future candidate projects. By removing existing projects, we enable RESOLVE to optimize future capacity expansion investment decisions and avoid overestimating the resource potential.

For existing wind facilities, we used a combination of Ventyx/ABB wind farm boundaries and theU.S.Wind Turbine Database (USWTD) to fill in gaps in both datasets (SI S6). We selected only turbines greater than 1 MW (or with no MW data but built after the year 2000) for removal as existing projects. In order to account for re-powering potential, for older, smaller wind turbine models, we assumed that existing wind turbines smaller than 1 MW or with online dates prior to the year 2000 could be re-powered. This increased the candidate wind resource potential significantly in some areas with existing wind turbines (e.g., the Tehachapi region of California). The remaining >1MW turbines were buffered using 1200 meters. This was the distance that best approximated the Ventyx wind farm boundaries in the locations where turbines and farm boundaries overlapped. Because substantially large regions of several Ventyx "wind farms" did not contain turbines (as verified by overlaying the USWTD points and visual inspection of recent satellite imagery), we clipped the Ventyx wind farm boundary feature classes to the buffered USWTD extent (creating the "corrected Ventyx boundaries" polygons), which effectively removes areas in the Ventyx dataset that do not have existing wind turbines. However, we also found that the Ventyx wind farm boundary did not encompass all existing wind turbines in the USWTD, so we isolated these turbines without wind boundaries and created wind farm boundaries for them using a 750-m buffer radius (creating the "additional USWTD boundaries" polygons). Finally, we merged the corrected Ventyx and additional USWTD polygons to have a gap-filled existing wind turbine footprint dataset. These areas with existing wind turbines were removed from the candidate wind project areas.

For solar resource potential, we used the TNC solar array footprint dataset for within California (18) and the USGS national solar array footprint datasets for all other states in the study (19) (SI Table S6). These existing solar projects were removed from the candidate solar project areas.

6. Step 3. Capacity expansion modeling (RESOLVE)

A. Overview of RESOLVE. The capacity expansion modeling was carried out using Energy and Environmental Economics' (E3) RESOLVE model, developed for the California Energy Commission (CEC) Deep Decarbonization in a High Renewables Future study (20). The CEC study evaluates long-term scenarios that achieve a 40% reduction in economy-wide greenhouse gas (GHG) emissions by 2030 and an 80% reduction by 2050, relative to 1990 levels. The RESOLVE model determines the resource portfolios necessary for the electric sector to reliably serve loads without exceeding a sectoral carbon budget consistent with meeting these goals.

RESOLVE uses linear programming to identify optimal long-term generation and transmission investments in an electricity system, subject to reliability, technical, and policy constraints. Designed specifically to address the capacity expansion questions for systems seeking to integrate large quantities of variable renewable resources, RESOLVE layers capacity expansion logic on top of a production cost model to determine the least-cost investment plan, accounting for both the up-front capital costs of new resources and the variable costs to operate the grid reliably over time. In an environment in which most new investments in the electricity system have fixed costs significantly larger than their variable operating costs, this type of model provides a strong foundation to identify potential investment benefits associated with alternative scenarios.

RESOLVE's optimization capabilities enable it to select from among a wide range of potential new resources. For this study, the options for new investments are limited to those technologies that are commercially available today. This approach ensures that the GHG reduction portfolios developed in this study can be achieved without relying on assumed future technological breakthroughs. A more detailed description of the RESOLVE model structure and operations, along with a publicly available version of the model used in the state's Integrated Resource Plan (IRP) process, are available on the California Public Utilities Commission (CPUC) website (14). Because this study was designed to look at the entire state of California's electricity demand on the 2050 timeframe, the CEC version of the model was the appropriate choice.

The two key differences between the CEC version of the RESOLVE model used as the starting point for this analysis and the version available from the CPUC are as follows:

- The CEC RESOLVE model used for this study includes loads and resources from the entire state of California, while the CPUC RESOLVE model only accounts for those within the California Independent System Operator (CAISO) service territory. The CAISO territory represents about 80% of the total electricity demand in California.
- The CEC version models the resource build on a timeframe that extends out to 2050, while the CPUC RESOLVE version only models the system on a 2030 timeframe.

B. Key assumptions. The inputs and assumptions used in this analysis are generally consistent with those used in the CEC study, but certain parameters were updated to allow modeling of the specific scenarios for this study. In the case of renewable and storage costs, values were updated to include the latest available data on the costs of resources.

Electricity Demand The electricity demand forecast is consistent with the"high electrification" scenario from the CEC Deep Decarbonization study, which achieves California's long-term emission goals through extensive electrification of space and water heating loads in buildings and a heavily decarbonized electricity sector. The demand forecast from the CEC Deep Decarbonization study incorporates findings from recent studies regarding impacts of climate change on California's electricity sector, including a lower average availability of hydroelectric generation available to meet California demand in 2050, and higher average temperatures, which result in lower heating demands in buildings and higher air-conditioning demands. After exploring ten "mitigation" scenarios, the Deep Decarbonization study identified the "high electrification" scenario as one of the lower-cost, lower-risk mitigation scenarios. The "high electrification" scenario assumes high levels of energy efficiency and conservation, renewable electricity, and electrification of buildings and transportation, with reliance on biomethane in the pipeline to serve mainly industrial end uses. It also assumes a transition of the state's buildings from using natural gas to low-carbon electricity for heating demands. More details on the assumptions behind this scenario can be found in the CEC publication (21).

RESOLVE Base resource potential The RESOLVE model contains a list of candidate resources also referred to as the supply curve. The supply curve is a list of resource potentials identified in zones, often referred to simply as "resource potential." The current versions of RESOLVE contain resource potential estimates, which are referred to here as the "RESOLVE Base" case (3, 4). In most scenarios, the "RESOLVE Base" resource potential estimates only assume Categories 1 and 2 lands to be protected in California and west-wide; however, characterization of Category 2 lands outside of California is incomplete. All other lands (outside of the techno-economic-environmental screens) are assumed available for renewable energy development in the "RESOLVE Base" scenarios. However, there are differences in the Category definitions and their underlying datasets between the current study and the "RESOLVE Base."

The resource potential values developed for the CPUC IRP RESOLVE model used only 5% of the total solar technical potential from the California RESOLVE zones, reflecting concerns about the level of conversion to industrial land use associated with developing the full potential in any given resource area. In the CEC study and this analysis, this assumption was expanded to 20% of the technical potential due to the increase in demand for clean electricity in 2050 relative to 2030. The estimated resource potential in the CEC study for all other supply-side resources is consistent with the amounts assumed in the CPUC RESOLVE model. For creating Siting Level portfolios constrained by the Environmental Exclusion Categories, these RESOLVE Base resource potential values were replaced by estimates derived from the site suitability analysis (Section A).

The existing versions of the RESOLVE model currently being used by state agencies in California, do not include any wind or solar resource potential in Colorado or Montana. Colorado resources are not included because Colorado is not well electrically interconnected to export power to California. Montana resources were not included because the geographic scope was limited to what were considered the most economically attractive and feasible resources at the time. For this study, we addressed a broader geographic extent and longer timeframe than prior studies, and thus we did complete a site suitability analysis and resource potential assessment for Colorado and Montana. However, for consistency with existing RESOLVE model conventions in state energy planning forums, we did not incorporate Montana or Colorado zones into the supply curve. RESOLVE Zones are currently being used in California energy planning, and so we retain the RESOLVE Zone convention for consistency.

Existing or Baseline Resources In addition to candidate future resources, the RESOLVE model also includes a list of baseline resources (for all renewable and conventional technologies, including nuclear and hydropower; this is the list of contracts included in the RESOLVE model User Interface workbook, within the sheet called "REN_Existing Resources." This list represents commercial projects that are existing and under development—including projects with online dates in the past and in the future. This list of contracts was incorporated into the site selection process, and hence removed from the future candidate resource potential.

Resource Cost Assumptions Each candidate resource in the RESOLVE model supply curve has capital cost attributes. Capital costs for solar, wind, batteries, etc. are updated periodically. For this study, capital costs for solar, and battery storage resources were updated to reflect recent cost estimates from the National Renewable Energy Laboratory's (NREL) Annual Technology Baseline (ATB) (22) and Lazard's Levelized Cost of Storage studies (23). Table S1 shows the capital cost differences among the three versions of the model.

The solar PV costs in this study are higher than the costs assumed in the CPUC IRP and the CEC study because of differences in data sources used as the basis for the capital cost assumptions. Previous capital cost assumptions were based on 2016 estimates provided by Black & Veatch as part of the IRP process. The latest cost assumptions are based on estimates from NREL's ATB (22). Forecasted battery costs for this study are lower than 2016 forecasts in the CPUC IRP and the CEC studies because of cost updates in the Lazard study used as the basis for the capital cost assumptions.

Transmission Assumptions For California zones, RESOLVE assumes a limited transmission capacity is available per zone. Beyond this available capacity, a cost is assumed for building additional transmission capacity. See Table S2 for resources able to be accommodated per transmission zone.

There are two forms of transmission costs associated with resources in the supply curve. First, for all resources (in-state and out-of-state), there is the \$/kW-yr cost of transmission upgrades within CAISO once the Full Capacity Deliverability Status (FCDS) limit for the resource's associated transmission zone is exceeded (Table 24 of the RESOLVE Inputs and Assumptions (14)). Second, for the out-of-state resources, there are 2,000 MW of existing transmission capacity into California from the "Existing Northwest" (from the Pacific Northwest) and "Existing Southwest" (from New Mexico) transmission zones. Beyond this cost-free existing transmission capacity, there is a \$/kW-yr cost for delivery to the California border (Table 25 of the RESOLVE Inputs and Assumptions document (14)). These transmission costs are in addition to the other costs associated with each resource, resulting in an all-in fixed \$/kW-yr resource vintage cost. See RESOLVE model Inputs and Assumptions documentation for more information (14).

7. Description of cases and sensitivity assumptions

We developed several cases and modified sensitivity assumptions in order to understand the impact of the following changes: 1) applying different Environmental Exclusion Categories to resource availability (Siting Levels, Section A); 2) expanding geographic availability of renewable resources in the Western U.S. (Geographic cases, Section B); 3) relaxing existing constraints on renewable resource assumptions in RESOLVE (Resource Assumption cases, Section C); 4) reducing battery costs (Battery cost sensitivity, Section D); and 5) increasing behind-the-meter PV adoption (Distributed Energy Resources sensitivity, Section D). See Fig. S2 for summary of cases and sensitivities examined. *Constrained* cases were identified as the core cases for this study because they are most closely aligned with existing models being used in California state planning. We refer to a case as a modification of a single assumption (e.g., Siting Level 1), whereas a scenario is a combination of cases or a set of assumptions that generate a specific result (e.g., Siting Level 1, *Full West* Geography, *Constrained* resource assumptions, base case DER, and battery cost assumptions; see sections below for an introduction and explanation of example case names).

A. Environmental Siting Levels for candidate resources. Using the Environmental Exclusion Categories (Section 4) and the technical and economically suitable areas (Section A), we created four supply curves, which are referred to as Siting Levels (SL) 1, 2, 3, and 4 (Fig. S2). All Siting Levels use the same set of technical and economically suitable areas, but are additive in their use of the Environmental Exclusion Categories. That is, Siting Level 1 excludes only land area datasets in Category 1; Siting Level 2 excludes land area datasets in Categories 1 and 2; Siting Level 3 excludes land area datasets in Categories 1, 2, and 3; and Siting Level 4 excludes datasets in Categories 1, 2, 3, and 4. As such, as the Siting Level increases, more land is protected from development (Fig. S2). As described in Section A, we created candidate resource supply curves for each of these Siting Levels using the land area in each RESOLVE Zone or state by converting km^2 to MW of capacity for each technology and calculating spatially-specific average capacity factors for each Siting Level. These supply curves were further modified to create *Constrained* and *Unconstrained* cases, as introduced and explained in Section C below. We compare these Siting Levels with the unmodified RESOLVE supply curve, which we refer to as the RESOLVE Base case (Section B).

To ensure consistency with the representative RESOLVE resource temporal profiles for wind and solar generation, we adjusted the site suitability supply curve potential values using the average CF of the temporal profiles. The adjustments to capacity were necessary to ensure that the amount of energy generated by the resource (assuming load profiles and average capacity factors in RESOLVE) will match the expected energy based on the supply curve. To do this, we calculated the amount of generation (MWh) using the resource potential and the average CF for each RESOLVE Zone estimated from the site suitability analysis. We then divided this value by 8760 hours and the RESOLVE temporal profiles' average CF for that zone to calculate an adjusted site suitability potential (MW). For example, if a 100 MW solar resource has a 25% capacity factor in the supply curve, but a 22% capacity factor based on the resource's generation profile, the associated capacity with that resource in RESOLVE becomes 113 MW (i.e. (25%)/(20%)*100 MW). See Figure S4 for the unadjusted supply curve values and Figure S3 for the adjusted values. For the most part, the adjustments did not result in significant changes to the original resource values.

B. Geographic cases. Three Geographic cases—also referred to as Geographies—were constructed for the analysis, representing different potential for imported out-of-state resources to meet California's need for clean electricity (Fig. S2). The *In-State* case restricts renewable resource availability to within California's borders while allowing up to 2,000 MW of out-of-state wind resources delivered to California using existing available transmission capacity (see Transmission Assumptions in Section B). This allowance was made in order to most closely reflect existing market conditions. In the *Part West* case, RESOLVE has access to renewable resources in five other states with strong electrical ties to California. In this case, New Mexico wind resource is Constrained at 3,000 MW based on the capacity of an existing 500-kV dual-circuit HVDC transmission line. In the *Full West* case, RESOLVE has access to renewable resources across eight other states in the Western Interconnection. The *Part West* and *Full West* cases would require changes to markets and policies to allow for import of electricity at the quantities in the 2050 portfolios. Table S2 shows the zones and the maximum available resources allowed in each Geography.

C. *Constrained* and *Unconstrained* sensitivity cases. The publicly-available RESOLVE model used in the California Public Utilities Commission's (CPUC) Integrated Resource Planning (IRP) process assumes that out-of-state development is limited to "Qualifying Resource Areas" (QRA) identified by Black and Veatch through the 2009 Western Renewable Energy Zones study (4). This assumption stands as the current policy default. As explained in Section A, these QRAs have been reclassified as "RESOLVE Zones". As previously explained (Section B), the CPUC RESOLVE model "discounts" solar resources estimates within California by 95% and the CEC RESOLVE model discounts it by 80%. For example, if a resource assessment identified

100 GW of solar in a particular RESOLVE Zone, the CEC version of the RESOLVE model assumes 20 GW of that solar will be available for development, as reflected in the supply curve. For the *Constrained* assumptions case, we maintained these current (RESOLVE Zone and solar discount) resource assumptions. For the *Constrained* case, we also restricted non-California resource potential estimates to within these RESOLVE Zones for each Siting Level and used the lower of the two following values: the site suitability resource estimates within RESOLVE Zones and the default RESOLVE "discounted" Base case resource potential values (Figs. S1, S2).

To understand how these current resource assumptions affect cost and generation mix, we developed an *Unconstrained* sensitivity case in which the supply of out-of-state resources is not limited to RESOLVE zones, but rather is based on a "wall-to-wall" estimate of technical potential across the entire state for each of the Siting Levels (Fig. S2). Additionally, the *Unconstrained* case uses the site suitability resource potential estimates directly for all solar RESOLVE Zones, thus removing RESOLVE's "discounted" base case resource potential as the upper limit.

As an example of how the *Constrained* and *Unconstrained* cases were developed for the present study, consider the Westlands RESOLVE Zone in central California. Within the Westlands RESOLVE Zone, the default RESOLVE Base solar potential in the existing model is 28.1 GW. The site suitability analysis for this study identified a much greater solar resource potential—210 GW—under *Unconstrained* assumptions in Siting Level 3 (which assume no development on high conservation value lands). Thus, for Westlands, we assumed 28.1 GW of solar potential in the *Constrained* case and 210 GW of solar potential in the *Unconstrained* case for SL 3 (SI Fig. S3). Again, potential values are options for the capacity expansion model to select from in creating an optimal generation portfolio—not all candidate renewable resources may be chosen.

As an example of how the *Constrained* and *Unconstrained* assumptions differ for regions outside of California, consider that in Siting Level (SL) 1, the estimated amount of wind resource potential within the New Mexico RESOLVE Zone is 36.1 GW (SI Fig. S4B). Looking beyond the RESOLVE Zone, the amount in the entire state of New Mexico is 190 GW (SI Fig. S4B) while the default RESOLVE Base potential is 34.6 GW (SI Fig. S3B). Thus, for New Mexico, we assumed 34.6 GW of wind potential in the *Constrained* assumptions case and 190 GW of wind potential in the *Unconstrained* assumptions case (SI Fig. S3).

D. Battery cost and distributed energy sensitivity cases. Along with the cases considered above, we considered two additional sensitivities: high behind-the-meter PV distributed energy resource (High DER) and low battery cost.

High DER sensitivity A high behind-the-meter (BTM) PV adoption forecast was developed for the High DER sensitivity analysis, using the relationship between the High BTM PV and Mid BTM PV forecasts from the 2016 CEC Integrated Energy Policy Report (IEPR) (24). A capacity factor of 22.7% is assumed for the DER resource. Table S3 below shows the forecast for the Base and High DER cases.

There are several publicly available DER forecasts that were considered (LBNL technical potential, NREL technical potential, IEPR). The IEPR High DER forecast is widely considered a realistic optimistic forecast, assuming faster customer adoption rates and continued falling costs. It includes more residential solar tied to Title 24 (high penetration assumes 90% of new houses built after 2020 install rooftop solar). Other publicly available forecasts may include additional considerations such as major policy changes, new incentives, and technological disruption. Because we do not have control over policies or market forces, we chose to use the forecast that assumes fulfillment of current policy mandates with expected increased adoption rates and does not assume major disruptive changes.

The RESOLVE model treats BTM PV resources as a demand modifier, reducing the total demand that will be met by the optimized resource portfolio. Assuming a projected demand of 400 TWh year^{-1} in 2050, the high BTM PV sensitivity case reduces demand by about 5%. Using NREL's estimate for technical potential of rooftop PV in California of 128.9 GW (25), the High DER scenario assumes the installation of about 25.7% of technical potential and is about 35% greater than the Base BTM assumptions (Table S3). The NREL technical potential study does not consider limits such as how much rooftop solar the distribution system can accommodate before needing upgrades, nor does it consider load balancing costs. These and other integration challenges are why economic potential typically tends to be less than the technical potential for a resource, as is the case here.

For more detail about the High DER assumptions, see the IEPR California Energy Demand Updated Forecast 2016, and the independent 2018 Distribution Working Group Forecast Report by Itron, which confirms the robustness of the IEPR forecast. The amount of BTM PV assumed in the model is separate from, and additional to the 40 GW of distributed solar that is available for RESOLVE's optimization as a supply-side candidate resource. It should be noted that the supply-side distributed solar in RESOLVE is characterized with the cost and generation profiles of a typical parking lot and warehouse rooftop solar array.

Low Battery Cost sensitivity We also explored the effect of an optimistic battery cost forecast by assuming 25% reduction in the levelized cost of battery storage through the modeled period (23) (Table S4).

8. Step 4. Site selection and transmission modeling

A. Generation site selection. The RESOLVE model selected an amount of generation from each spatially coarse RESOLVE Zone or state (depending on *Constrained* or *Unconstrained*). In this step, we spatially disaggregated the generation and assigned each MWh to locations within each RESOLVE Zone or state by selecting CPAs to meet each portfolio's technology-specific generation requirements. This site selection step is necessary because impacts to natural and working lands vary significantly by location, and power plants have specific siting requirements that make them more likely to be sited in some areas over others. This approach models the possible build-out of infrastructure and enables a "strategic environmental assessment" of each portfolio, enabling comparison of portfolios by their modeled overall impact on natural and working lands (Section A).

Attribute calculations We calculated the following set of attributes for each CPA, with details for specific calculations described in subsequent paragraphs: generation land area, Euclidean distance to the nearest existing or planned transmission line or the interconnection/gen-tie distance (i.e., transmission line to interconnect the new generator with the grid), gen-tie land area, adjusted gen-tie land area (see explanation below), total land area (generation and gen-tie), estimated generation capacity (MW), area-weighted average capacity factor (CF), area-weighted average CF adjusted using RESOLVE assumptions, annual average generation in MWh, the average total (generation and gen-tie) land use efficiency in MWh km^{-2}, and distance to the nearest "RPS executed" wind or solar power plant. We performed these attribute calculations for each CPA after removing other technologies' selected CPAs to account for changes in land area due to removal of previously selected CPAs. For example, if a CPA was selected as the site of a future wind project to fulfill the generation requirements of a portfolio, then that CPA was removed from the solar resource potential.

We then calculated gen-tie paths distances for each CPA. We assumed developers of selected CPAs would need to permit and develop interconnection corridors to the nearest existing transmission line >69 kV (data from the California Energy Commission and Ventyx/ABB) or an interstate planned transmission line in "advanced development" (SI Table S6). As in the ORB study (1), Euclidean distances from each CPA to the nearest transmission line were multiplied by a rule-of-thumb factor of 1.3 (1) in order to account for the additional length required due to topography and other environmental or social right-of-way constraints. Gen-tie Euclidean distances were then multiplied by an average transmission corridor width of 76 meters to estimate gen-tie land area. Since the sizes of CPAs span a large range and to avoid systematically reducing the total land use efficiency (MWh km^{-2}) of smaller CPAs as a result of a fixed interconnection area, we applied a correction factor to the gen-tie area using the ratio of the CPA area (as small as 1 km^2) to the largest possible CPA area (10 km^2 for wind and 7 km^2 for solar). This correction results in a fixed generation-to-interconnection area ratio for CPAs of different sizes that are the same distance from the nearest transmission line and have the same capacity factor. Note, however, that the least-cost gen-tie paths modeled after the generation site selection step (Section B), not these adjusted Euclidean distance gen-tie areas, are the areas that are finally reported in the results section as transmission land use requirements.

Wind and solar average CFs per RESOLVE Zone in the RESOLVE Base case differ from the area-weighted average CFs estimated from site suitability renewable resource CFs (see Section 6 for an explanation). Thus, to achieve consistency with existing RESOLVE CFs for both wind and solar, we scaled the average CF per CPA using an adjustment factor calculated as the ratio of the RESOLVE Base CF to the average site suitability CF of each RESOLVE Zone in Siting Level 1. This approach assumes that SL 1 resource assumptions are the most similar to the RESOLVE Base resource assumptions. We applied this RESOLVE Zone and technology-specific adjustment factor to each CPA across all Siting Levels, which maintains relative variation in CFs geographically and between Siting Levels.

Selection process Due to the relatively fewer areas of spatial overlap between CPAs of different technologies across the study region (primarily as a result of not including concentrating solar power and constraining resource areas to RESOLVE Zones outside of California) and the significantly lower availability of wind resources compared to solar resources, we did not perform site selection using an integer optimization program as per the approach in the ORB study (1). Instead, we implemented a sequential selection approach that chooses CPAs based on their potential candidacy as a planned or commercial project (based on proximity) and total (generation and estimated transmission interconnection) land use efficiency (in MWh km^{-2}). By choosing based on total land use efficiency, we effectively select sites by prioritizing those with highest resource quality (highest capacity factor) and those closest to existing transmission infrastructure (reducing gen-tie costs), which are key siting criteria used by developers as they both lower development costs per unit of generation.

The sequence of steps were as follows for each case: 1) select geothermal CPAs, 2) remove selected geothermal CPAs from available wind CPAs, 3) select wind CPAs, 4) remove selected wind and geothermal CPAs from available solar CPAs, 5) select solar CPAs. The selection process for each technology simply involved ranking the CPAs by their total land use efficiency from highest to lowest, and selecting from this ranked "supply curve" the number of CPAs that would meet the expected amount of technology-specific generation as per the RESOLVE portfolio for each scenario or sensitivity case. Due to CPAs having discrete areas and sizes, CPAs selected at the margin will not meet the RESOLVE expected generation target exactly, but will exceed the target. That is, the decision to select a CPA is discrete—and marginal CPAs are not sized to precisely meet the RESOLVE generation target. Lastly, because the underlying spatially explicit site suitability dataset or Candidate Project Areas for out-of-state RESOLVE Zones used to create the RESOLVE Base supply curve do not exist in the public domain and the methods to replicate the process of creating the site suitability dataset are also not publicly available, we used Siting Level 1 CPAs to select project areas for all RESOLVE Base cases.

We made two exceptions to the CPA selection heuristic above—the first for allowing co-location of wind and solar resources in California, and the second to account for inadequate existing power plant footprint data in California. In the first exception, we did not remove selected wind CPAs from available solar CPAs before selecting solar CPAs—but only for the *Unconstrained* assumptions cases. This assumes that areas where selected wind and solar CPAs overlap, solar panels can be constructed between wind turbines. We made this exception in order to allow the maximum capacity to be selected in RESOLVE Zones where there is significant potential for both wind and solar energy—specifically, in the Tehachapi RESOLVE Zone in California. Because the site suitability analysis and supply curve creation steps could not account for the overlap of wind and solar CPAs, if the capacity expansion optimization does select the maximum amount of resource capacity in RESOLVE Zones with significant enough technology overlap, there would be an insufficient number of CPAs to meet the RESOLVE generation target for solar (i.e., this zone would be over-subscribed or have too much development). While this condition was only true in the *Unconstrained* assumptions case in the Tehachapi RESOLVE Zone in Siting Levels 3 and 4, for consistency, we made this exception for all *Unconstrained* cases.

The second exception was to address the fact that despite using the most recent and best available wind farm and turbine and solar array footprint data, we found that these datasets did not entirely encompass the renewable energy projects in the CPUC's database of Renewable Portfolio Standard (RPS) executed projects, which are point locations (SI Table S6). To address this issue, we identified all "RPS executed" projects locations that do not overlap with existing power plant footprint data and then labeled all CPAs within 2.5 km of these project locations to prioritize them in the site selection process (i.e., select these labeled CPAs first, in order of their land use efficiency, before selecting non-labeled CPAs). This approach assumes that proximity to these executed project locations is an adequate proxy for whether the CPA has already been developed or should be considered for development potential. Since these additional RPS executed project locations meant that we did not adequately account for the spatial footprints of existing power plants in California, we calculated more representative "selected" generation to model. We did this by subtracting the MWh estimated from existing power plants with footprint data (using RESOLVE's CFs) from RESOLVE's "baseline" and "selected" resources for California, or the "total" resource portfolio, for wind and solar and modeled the spatial build-out using these "net" selected resources. For other states and RESOLVE Zones, we used RESOLVE's "selected" resources directly, without further modification.

B. Gen-tie corridor modeling. Through the selection process described above, wind and solar resources selected by RESOLVE (total MWh per Zone) were assigned spatial project footprints. The approach generally assigned new renewable capacity to sites that were simultaneously economically attractive (having high capacity factor and low capital cost) and land use efficient (low total land area for the amount of generation, including straight-line-distance estimated gen-tie area).

Once the new resources were assigned to spatially explicit locations, it was possible to more accurately model the gen-tie route for connecting the Selected Project Areas to the existing transmission system. This then allowed a more accurate estimate of gen-tie area requirements and enabled a footprint-based strategic environmental assessment for modeled transmission projects. We modeled future gen-tie paths by performing a least cost path analysis. This analysis requires the following three inputs, described in detail below: a cost surface, a source dataset, and a destination dataset.

Cost surface The cost surface is comprised of WECC environmental data and topographic slope information (SI Table S5). The WECC environmental data was used because these layers were intentionally designed for the siting of linear features such as transmission lines (5). We used a weighted sum to combine the slope and environmental risk layers into a cost surface, assigning the following levels of influence to the two layers: 66% slope, 34% environmental risk, per methods described in the EPRI GTC paper (26). We intentionally set WECC Environmental Risk Category 4 values to "null" so that no gen-tie paths would be modeled across areas where development is prohibited (5).

Source dataset The source dataset was a combination of the existing and planned transmission lines (Ventyx and CEC existing transmission, planned transmission lines in advanced stages of permitting; see SI Table S6 for existing and planned energy infrastructure data sources).

Destination dataset The destination dataset was composed of wind and solar project areas that had been selected in the prior step for being economically attractive and in close proximity to existing transmission (estimated using Euclidean distance).

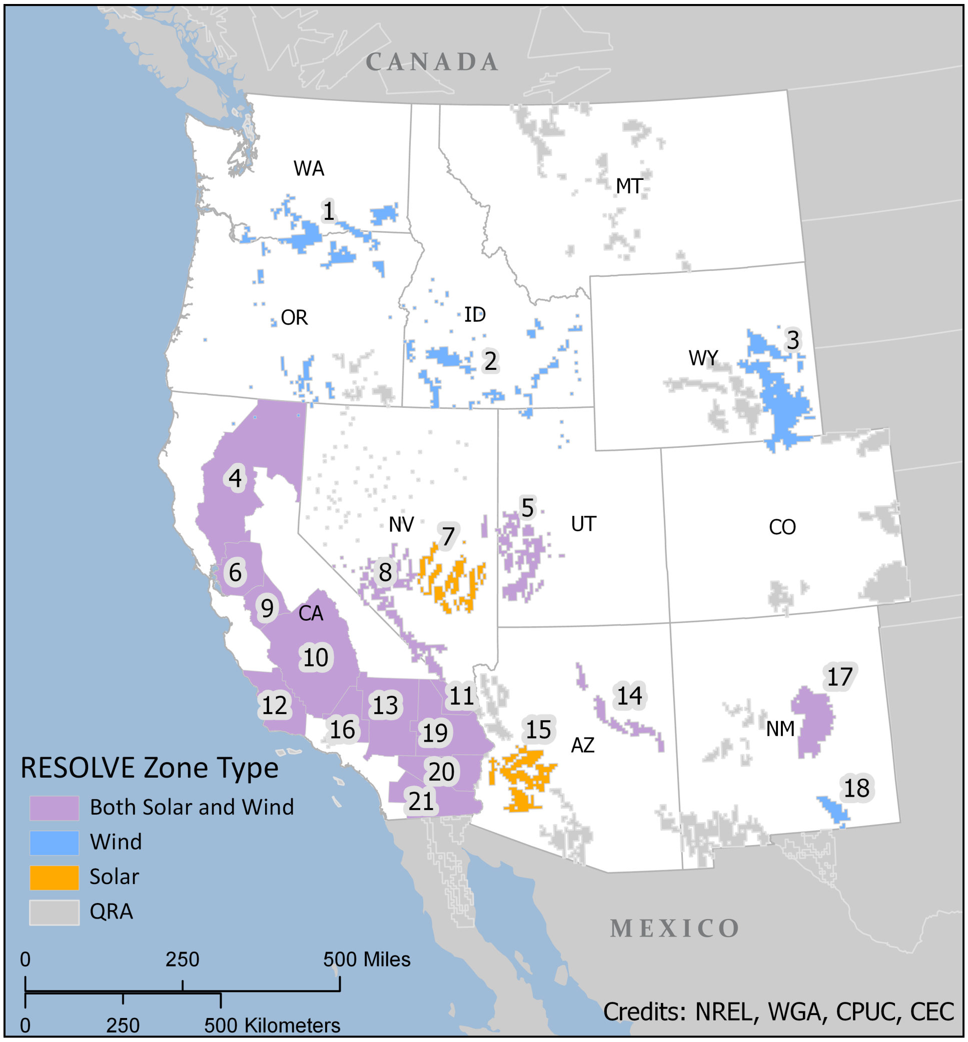
The resulting least cost path dataset contains drawn gen-tie lines for each Candidate Project Area or group of Candidate Project Areas (Fig. S17). We enabled the "each-zone" option so that shared interconnection paths would be identified for groups of projects. The final least cost gen-tie paths were included with the Selected Project Areas in the later step, strategic environmental assessment. In this way, we were able to assess the total impact of a new wind or solar project including the interconnection line, beyond just the area impacted by wind turbines or solar panels.

It should be noted that terrain multiplier criteria (such as landcover type, rolling hills, mountains) identified in the WECC TEPPC Transmission Cost Report (27) were not included, nor were other layers such as weighted values for residential and non-residential building densities, utility corridors, open land, forest, roads, mines, and quarries (identified in EPRI-GTC transmission line siting methods 2006). These could be added in future analyses.

9. Step 5. Strategic environmental assessment

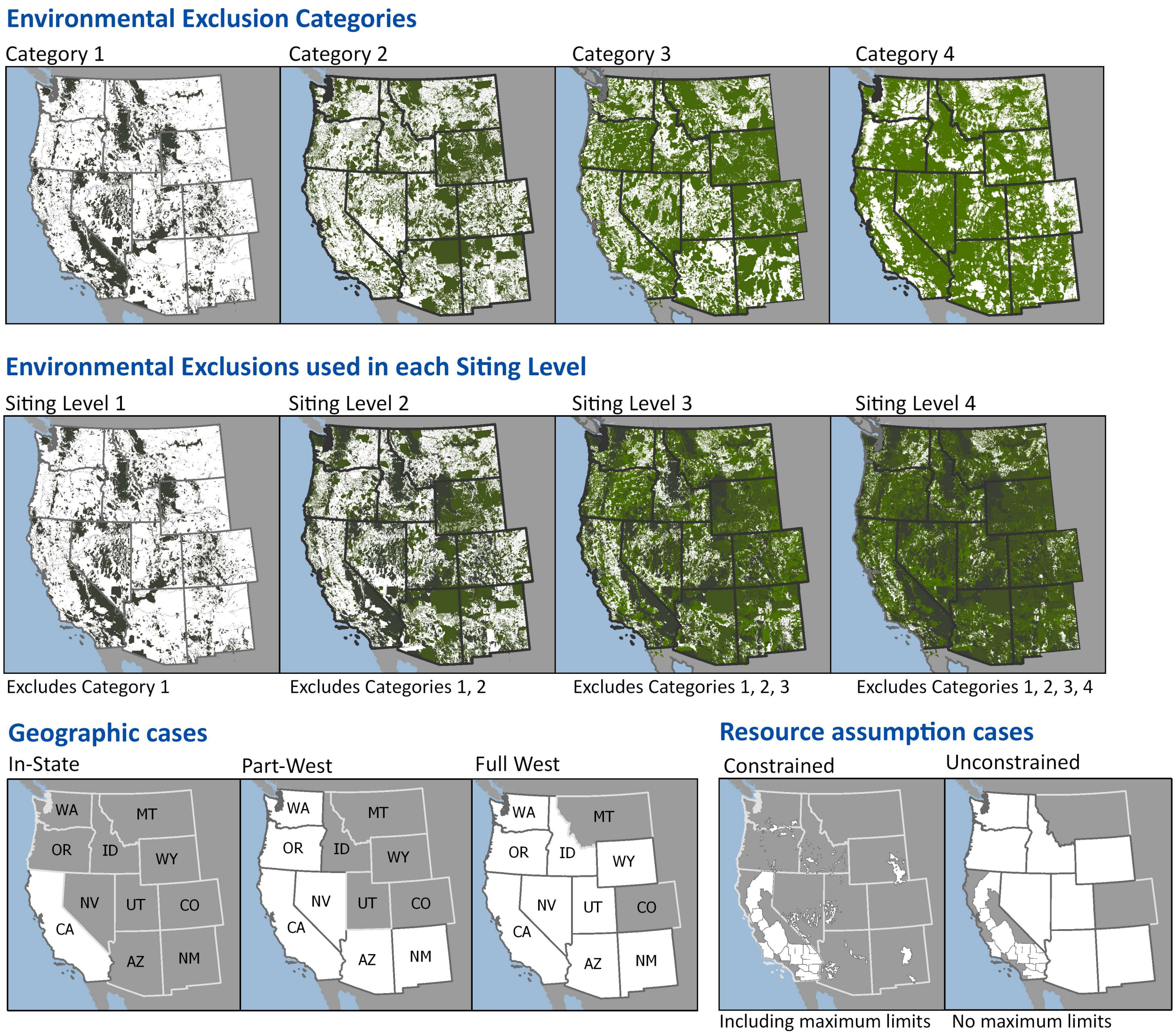
We conducted a land-area-based strategic environmental assessment using the modeled generation, gen-tie, and bulk transmission spatial build-out of portfolios created in Step 4 (Section 8). The purpose of the strategic environmental assessment is to anticipate the impact of energy development on lands with conservation value, and to examine whether siting protections can be effective in reducing development in areas with high conservation value. For bulk transmission lines with polyline spatial data, we approximated polygon corridor footprints using the average corridor width for each line reported in the BLM Record of Decision for each utility Right-of-Way Management Plan (see SI Table S7 for widths). For each infrastructure type (generation, gen-tie, bulk transmission) and each scenario, we calculated the amount of land area that overlaps with the four Environmental Exclusion Categories, 10 other environmental metrics, and the area-weighted average housing density. Ecological and landscape metrics included critical habitat for sensitive and listed species, sage grouse habitat, Important Bird Areas, wetlands, big game corridors, eagle habitat, and wildlife linkages (28). Working lands metrics include all agricultural land (crop and pasture land), prime farmland, and rangelands (29). For rangelands, we used the only known publicly available rangelands extent maps for the U.S. created by Reeves and Mitchell (29) and chose the map created using the National Resources Inventory (NRI) definition of rangelands mapped using the 2001 LANDFIRE landcover dataset. We use the rangelands definition adopted by the Natural Resources Conservation Service's NRI program, which states that rangelands are, "land on which the climax or potential plant cover is composed principally of native grasses, grass-like plants, forbs or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland" (29). Several environmental metrics are comprised of datasets that are also used in Environmental Exclusion Categories 2-4. See SI Table S8 for the underlying datasets, sources for each metric, and whether a metric was also included in an Environmental Exclusion Category.

The metrics for the strategic environmental assessment were chosen to represent two types of impacts—specific and generalized. The specific metrics (e.g., sage grouse habitat and wildlife linkages) were intended to explore areas of focus in current public discourse in energy planning forums. Thus, several specific metrics were chosen to explore trends and implications to key species. In contrast, the generalized metrics (e.g., impacts to Environmental Exclusion Category 3 lands) are meant to explore overall impacts to natural and working lands for a given resource portfolio.



Map Label	RESOLVE Zone	Map Label	RESOLVE Zone	Map Label	RESOLVE Zone
1	Pacific Northwest Wind	8	Southern Nevada Wind and Solar	15	Arizona Solar
2	Idaho Wind	9	Central Valley North Los Banos	16	Tehachapi
3	Wyoming Wind	10	Westlands	17	New Mexico Wind and Solar
4	Northern California	11	Mountain Pass El Dorado	18	New Mexico Wind
5	Utah Wind and Solar	12	Greater Carrizo	19	Southern California Desert
6	Solano	13	Kramer Inyokern	20	Riverside East Palm Springs
7	Southern Nevada Solar	14	Arizona Wind and Solar	21	Greater Imperial

Fig. S1. RESOLVE Zone names and locations for solar-only, wind-only, and both technologies. Other Qualifying Resource Areas (QRA) that were not used to create RESOLVE Zones are also shown in grey.



Battery Cost sensitivity cases

	Cost in 2050 ($/kWh-yr)
Base battery cost	$29.89
Low battery cost	$22.67

Distributed Energy Resources sensitivity cases

	GWh	GW	% of technical potential in CA
Base DER	49,207	24.7	19.2%
High DER	65,966	33.2	25.7%

Fig. S2. Summary of assumptions for the following cases and sensitivities examined: Siting Levels, Geographic cases, Resource Assumption cases, Battery Cost and Distributed Energy Resources sensitivity cases. Siting Levels (row 2) use the Environmental Exclusion Categories (row 1) cumulatively as indicated by the corresponding color in the maps of the Categories. The three Geographic cases (row 3) include resources identified within states indicated in white in addition to 1.5 GW and 0.5 GW of wind resources in the Pacific Northwest and New Mexico, respectively (see Table S2 for more details regarding Geographic cases). The *Constrained* Resource Assumption case restricts resource potential to within RESOLVE Zones and apply the RESOLVE Base as the maximum limit in each zone. The *Unconstrained* case expands resources to the rest of the state and do not impose maximum limits except for New Mexico Wind in the Part West Geography.

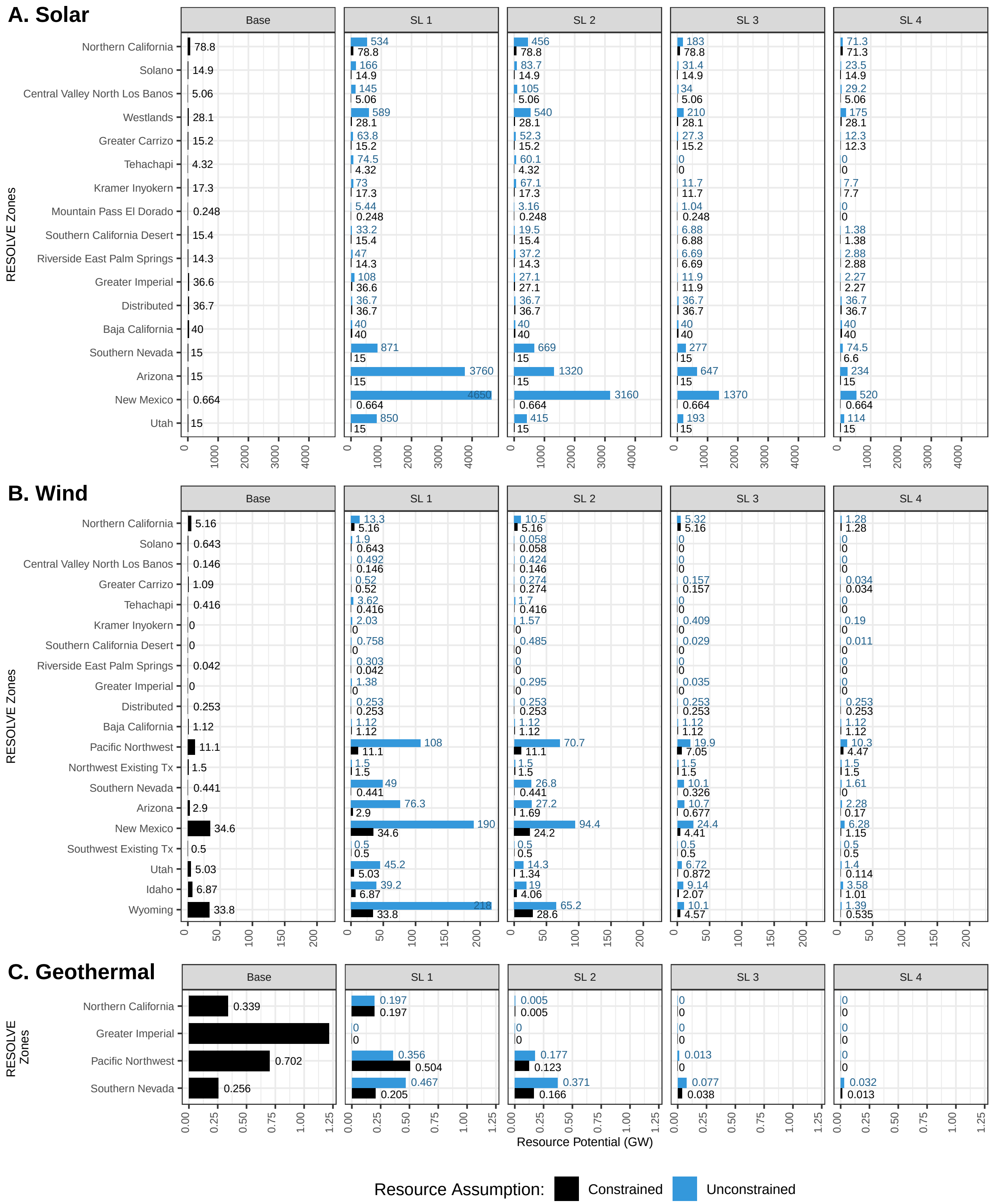


Fig. S3. Supply curves (resource potential assessment from site suitability analysis) for each Siting Level used as inputs to RESOLVE for solar (A), wind (B), and geothermal (C) technologies for the *Unconstrained* (bars and data values in blue) and *Constrained* (bars and data values in black) resource assumption case. No *Unconstrained* bars are in the Base panel plots because the RESOLVE Base case assumes *Constrained* resources.

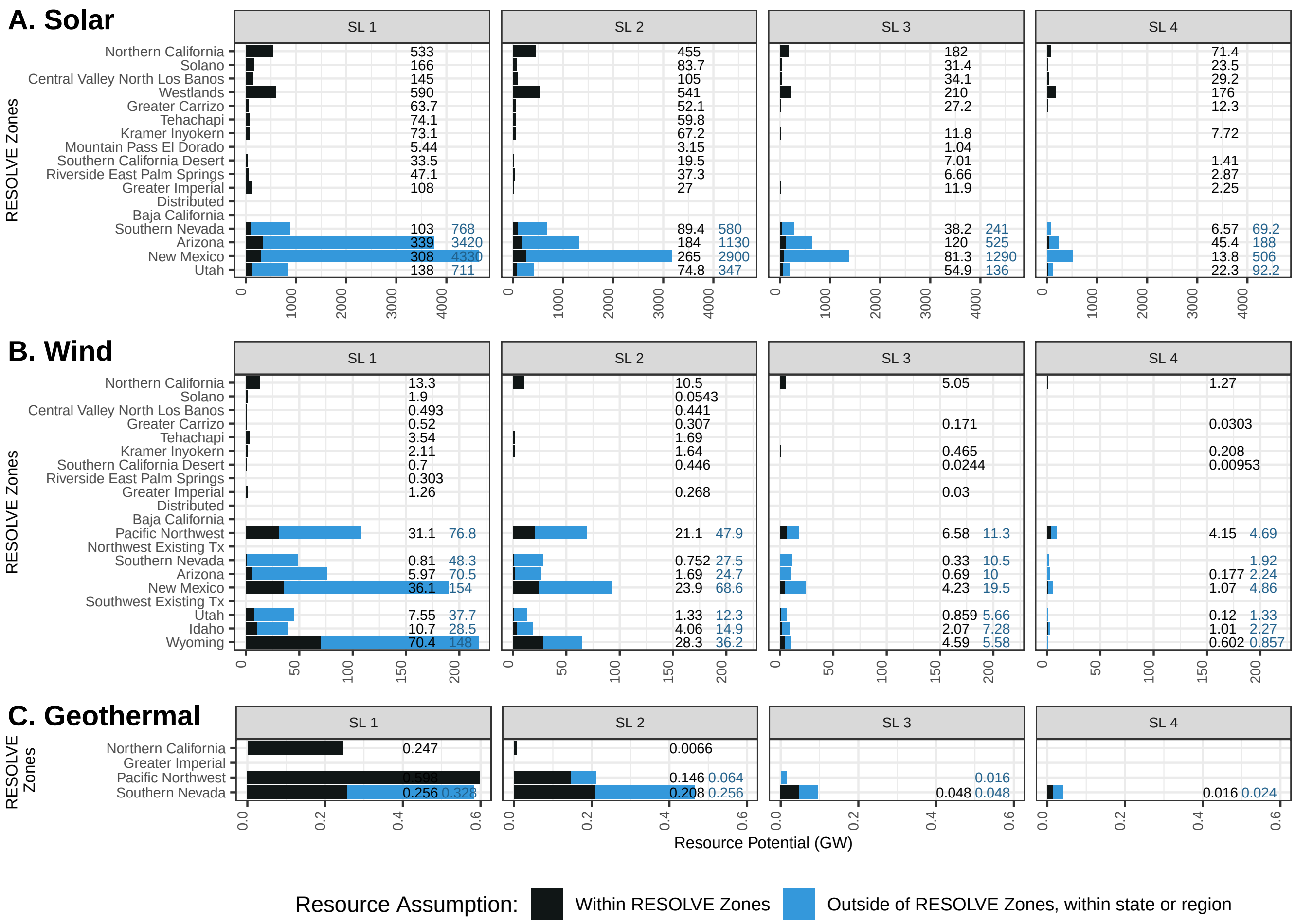


Fig. S4. Unadjusted supply curves under each Siting Level for solar (A), wind (B), and geothermal (C) technologies with stacked bars showing the amount of potential within RESOLVE Zones (black bars) and outside of RESOLVE Zones within the region or state for non-California regions (grey bars). The "within RESOLVE zones" data label is the left-most label and the "Outside of RESOLVE Zone" data labels is the far right label within each panel. The "Outside of RESOLVE Zone" data labels indicate the amount of potential within the grey bars, not of the absolute length of the bars. The absolute length of the bars is the sum of the two data labels, and it indicates the amount of resource potential in the *Unconstrained* case.

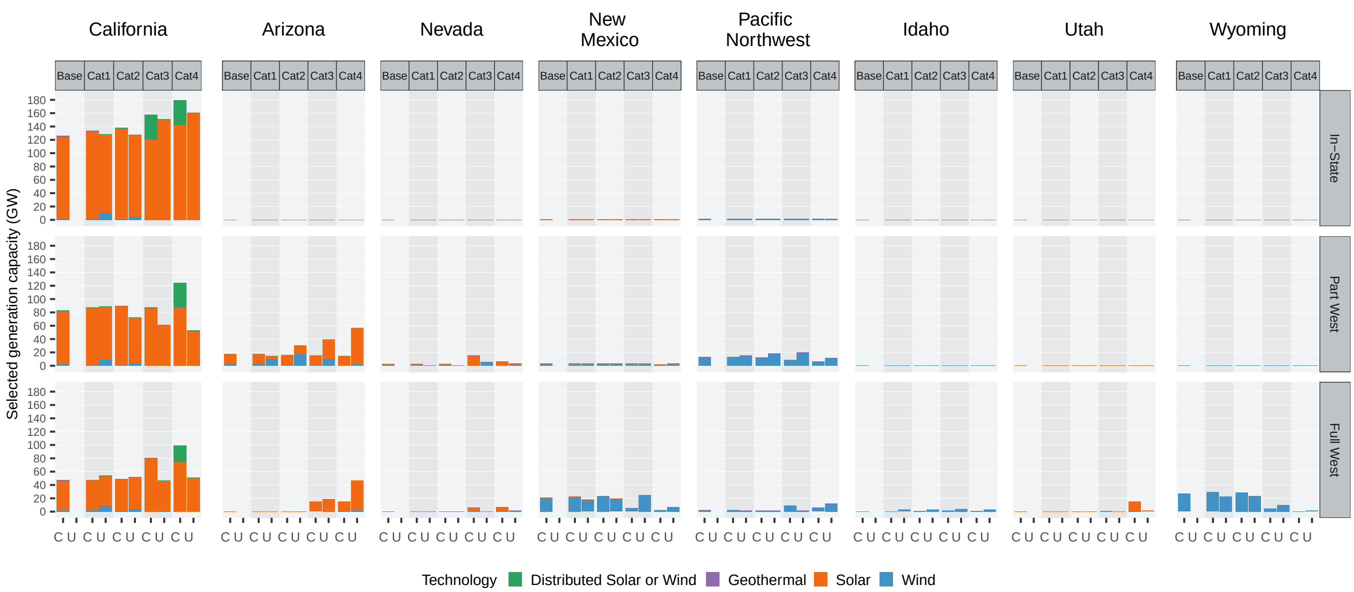


Fig. S5. Selected installed capacity of distributed resources, geothermal, solar, and wind by 2050 for each RESOLVE Zone for the three Geographic cases (*In-State*, *Part West*, and *Full West*), the four Siting Levels (1-4; grouped bars), and the *Constrained* and *Unconstrained* resource sensitivity assumptions (C and U, respectively, as the x-axis labels).

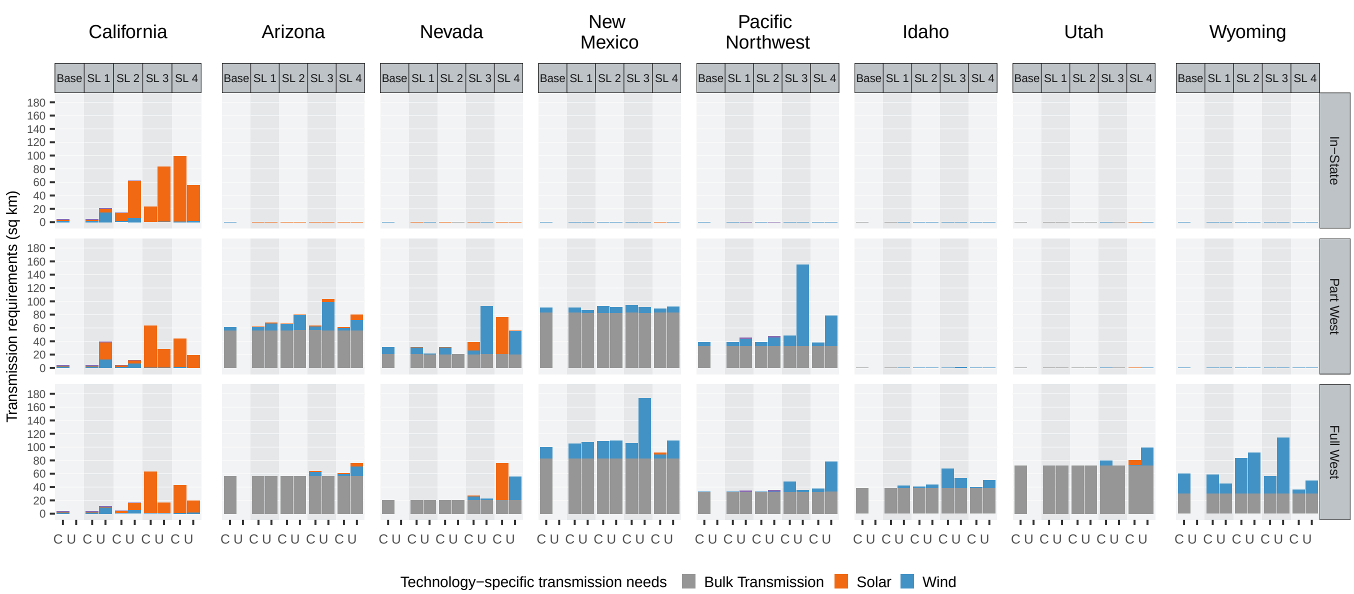


Fig. S6. Gen-tie and planned bulk transmission area requirements for each RESOLVE Zone (or state) for the three Geographic cases (*In-State, Part West*, and *Full West*), the four Siting Levels (grouped bars), and the *Constrained* and *Unconstrained* resource sensitivity assumptions (C and U, respectively, as the x-axis labels). Gen-tie areas are modeled using least cost analysis. Pacific Northwest includes Washington and Oregon.

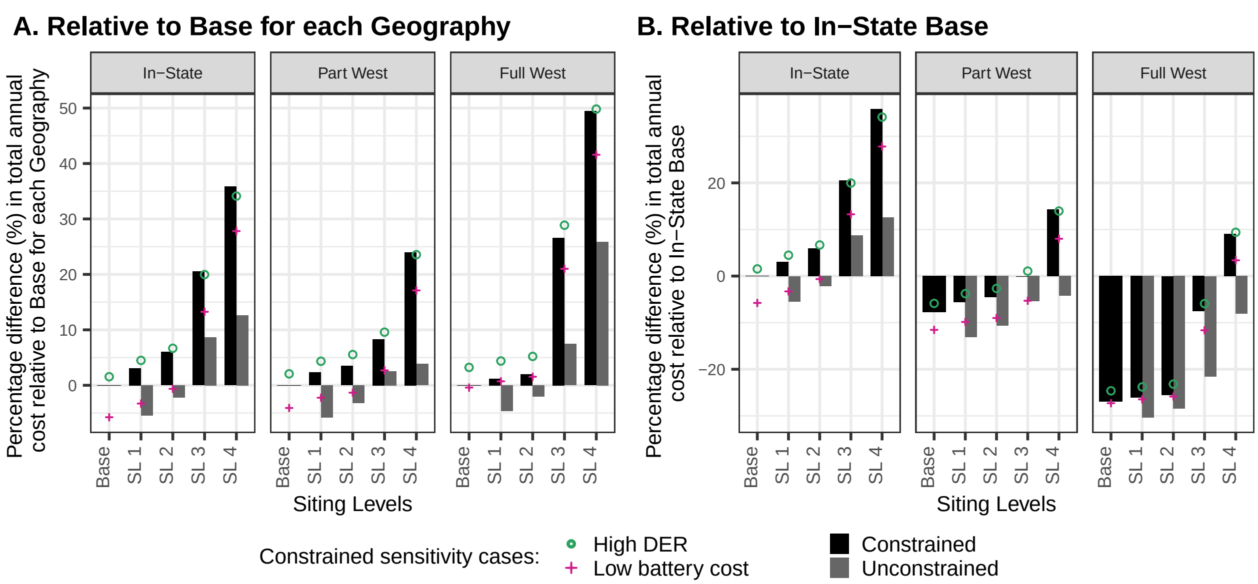


Fig. S7. Percentage cost differences of only modeled resource costs relative to the RESOLVE Base for each Geographic case (A) and relative to *In-State* RESOLVE Base (B) for all Siting Levels and *Constrained* and *Unconstrained* assumptions case. See Fig. **??** for percentage cost differences using total (modeled and non-modeled) costs.

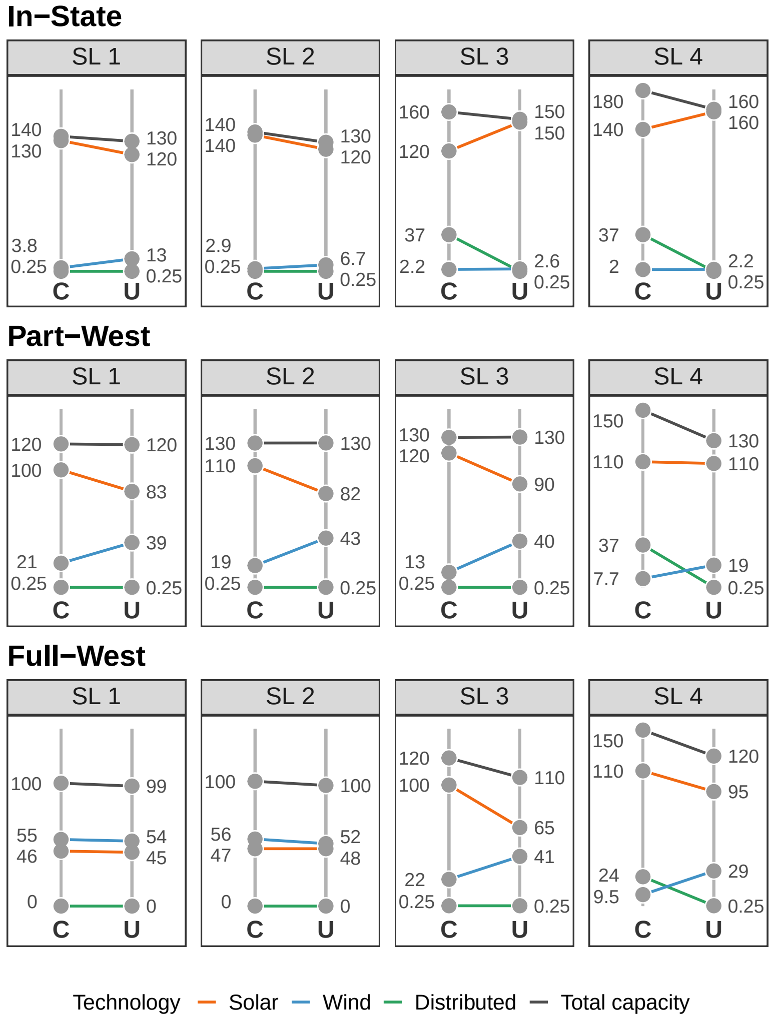


Fig. S8. Slope plots comparing *Constrained* and *Unconstrained* resource sensitivity results (C and U, respectively, as the x-axis labels) for selected technology-specific generation capacity (colored lines) and total generation capacity (grey lines) across the four Siting Levels and three Geographies. Labels indicate the amount of selected capacity in GW.

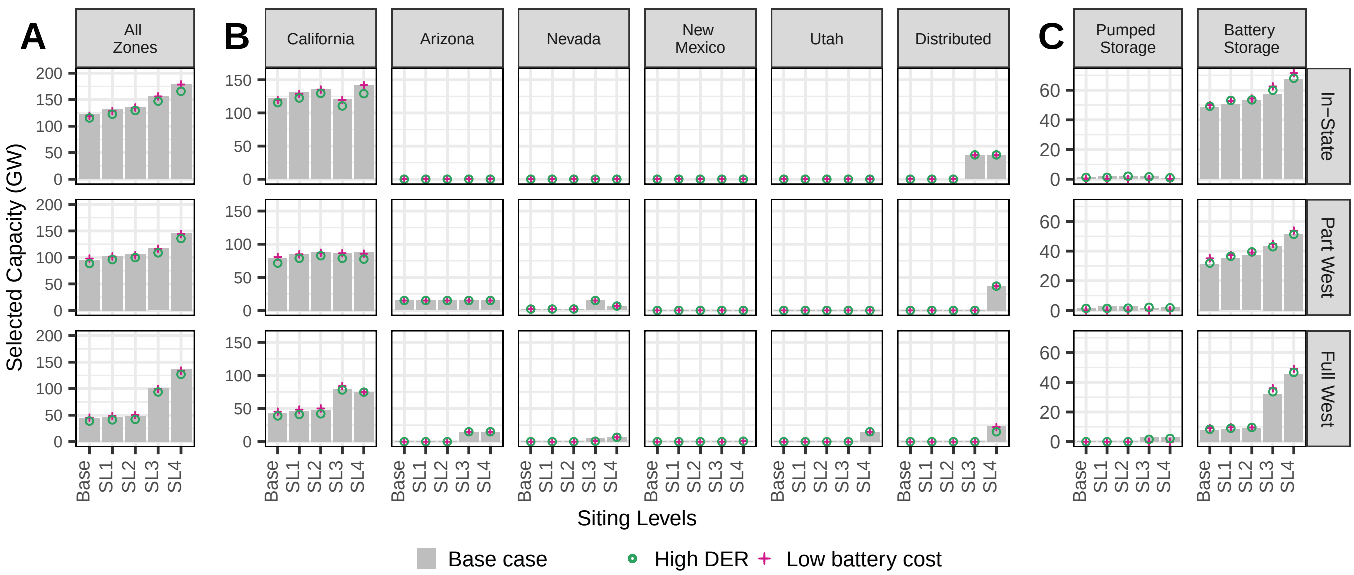


Fig. S9. Selected solar capacity comparing the Base case with Low Battery Cost and High DER sensitivity cases for the *Constrained* assumptions case.

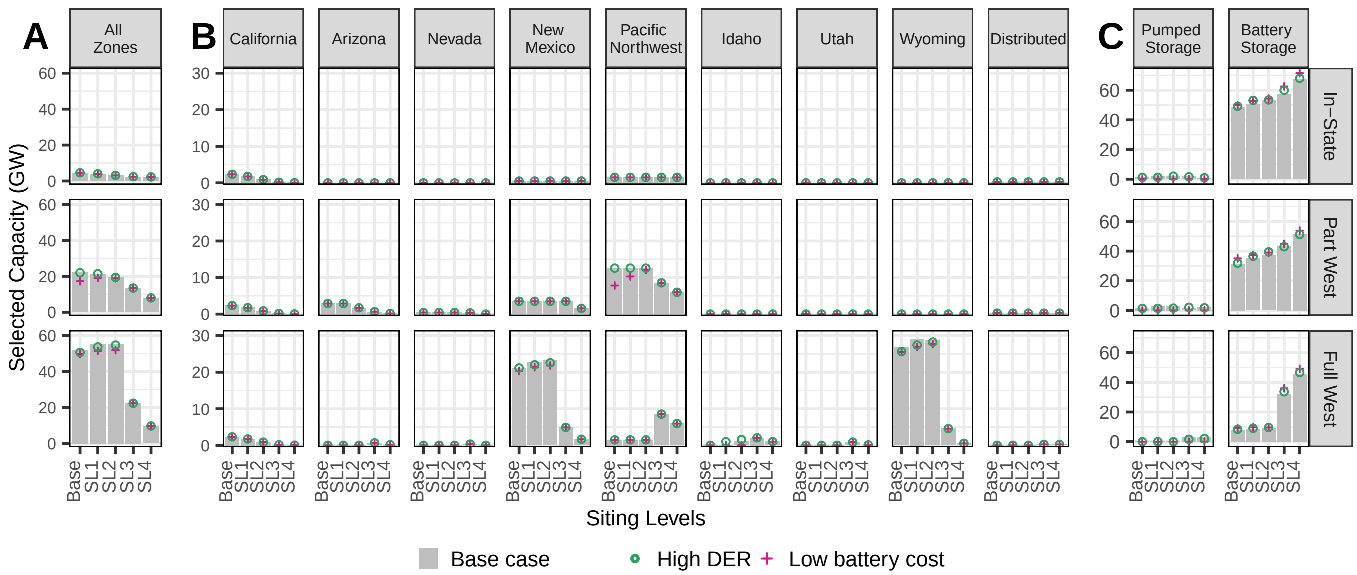


Fig. S10. Selected wind capacity comparing the Base case with Low Battery Cost and High DER sensitivity cases for the *Constrained* assumptions case.

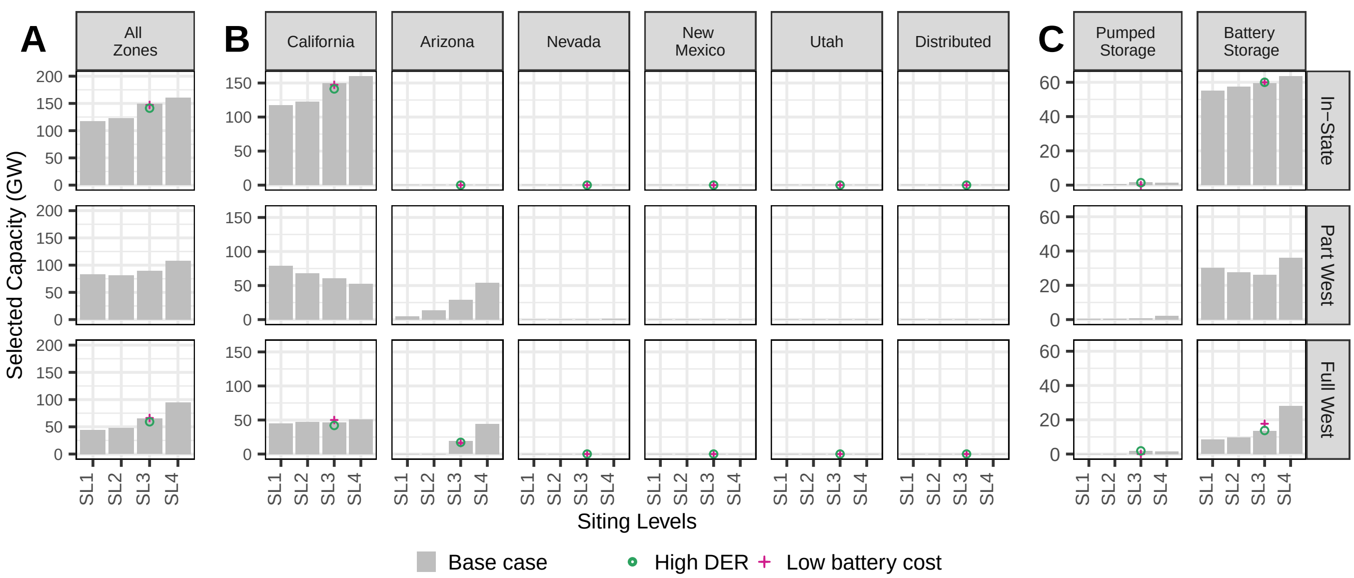


Fig. S11. Selected solar capacity comparing the Base case with Low Battery Cost and High DER sensitivity cases in the *Unconstrained* assumptions case. Note, since we did not expect sensitivities to affect results significantly, we only performed DER and Battery cost sensitivity analyses on Siting Level 3 for the *In-State* and *Full West* cases.

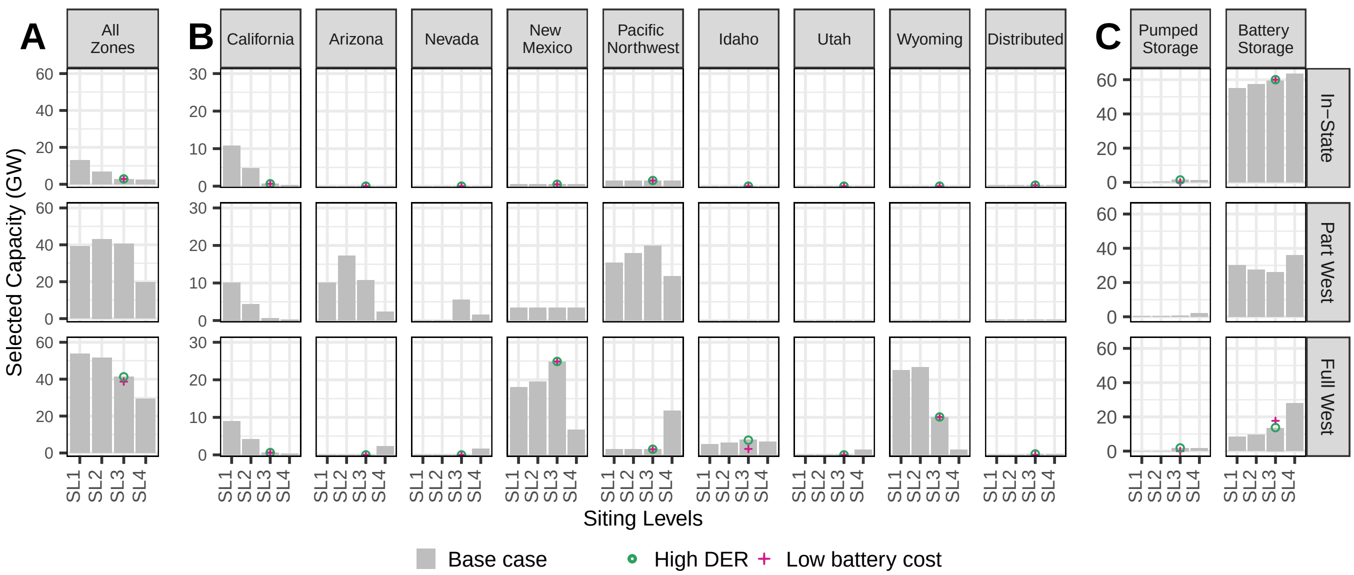


Fig. S12. Selected wind capacity comparing the Base case with Low Battery Cost and High DER sensitivity cases in the *Unconstrained* assumptions case.

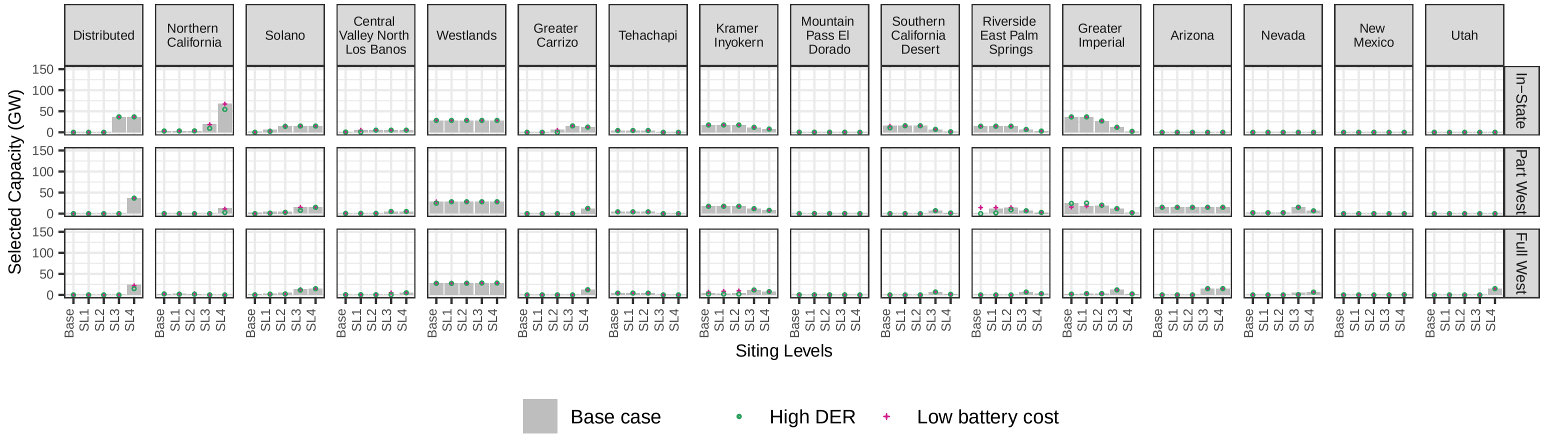


Fig. S13. Comparison between California solar RESOLVE Zones for the *Constrained* assumptions case— Selected solar capacity comparing the Base case with Low Battery Cost and High DER sensitivity cases. RESOLVE Zones within California have been included here (compared to Fig. S9) in order to show the effect on solar distribution within California.

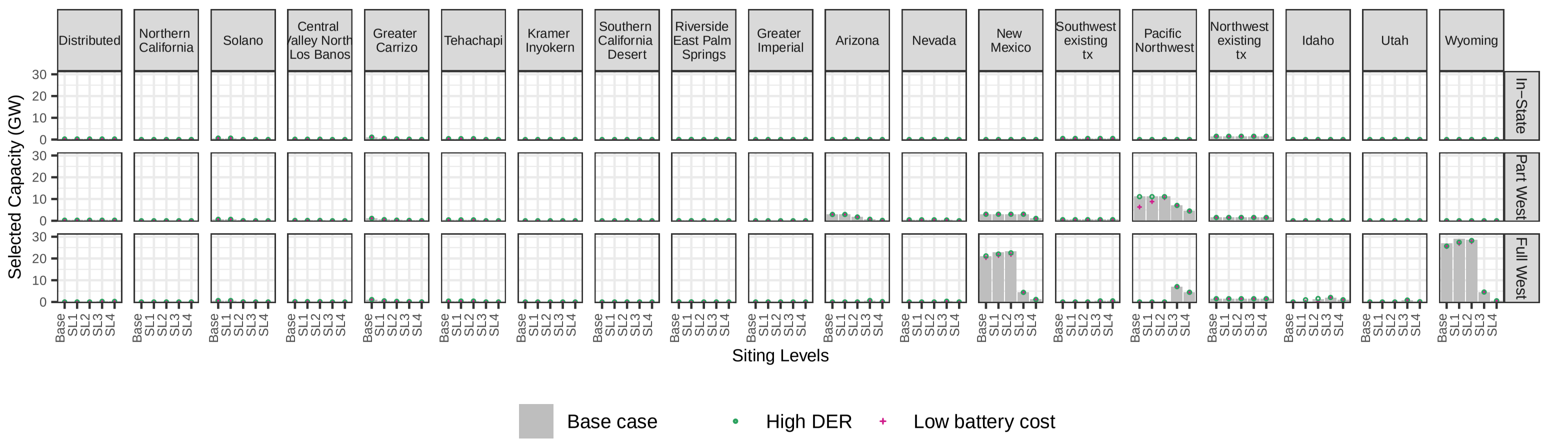


Fig. S14. Comparison between California wind RESOLVE Zones for the *Constrained* assumptions case— Selected wind capacity comparing the Base case with Low Battery Cost and High DER sensitivity cases. RESOLVE Zones within California have been included here (compared to Fig. S10) in order to show the effect on wind distribution within California.

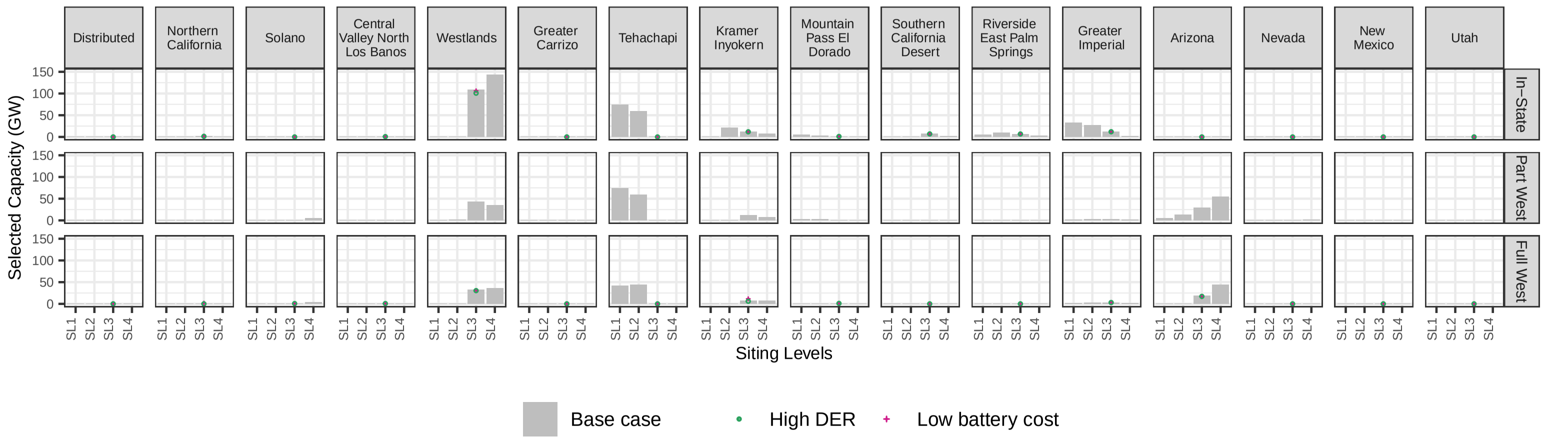


Fig. S15. Comparison between California solar RESOLVE Zones for the *Unconstrained* assumptions case—Selected solar capacity comparing the Base case with Low Battery Cost and High DER sensitivity cases. RESOLVE Zones within California have been included here (compared to Fig. S9) in order to show the effect on solar distribution within California.

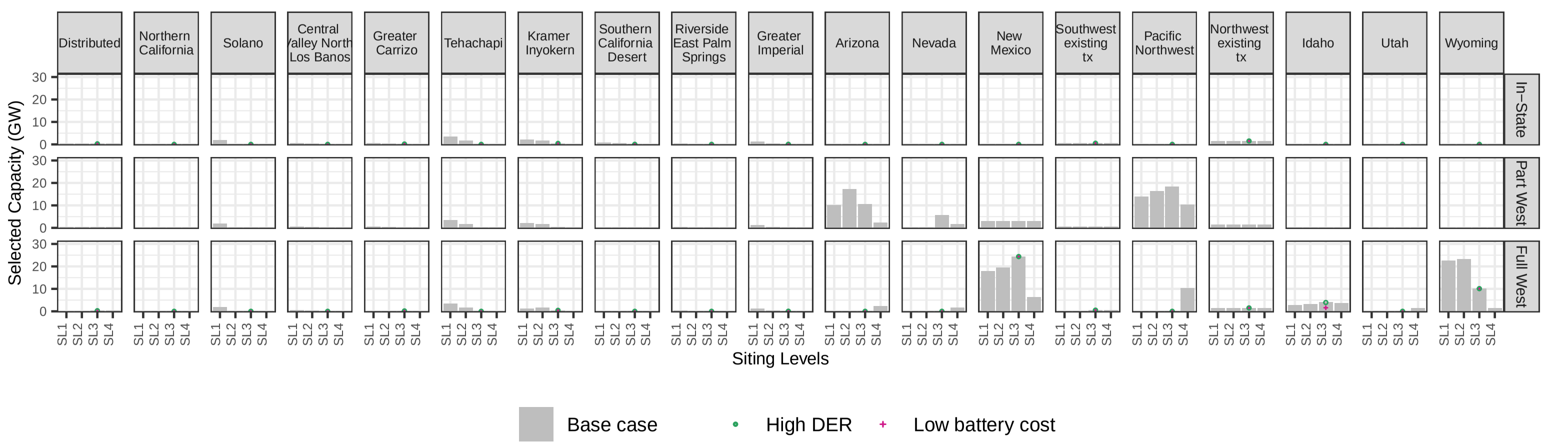


Fig. S16. Comparison between California wind RESOLVE Zones for the *Unconstrained* assumptions case—Selected wind capacity comparing the Base case with Low Battery Cost and High DER sensitivity cases. RESOLVE Zones within California have been included here (compared to Fig. S10) in order to show the effect on wind distribution within California.

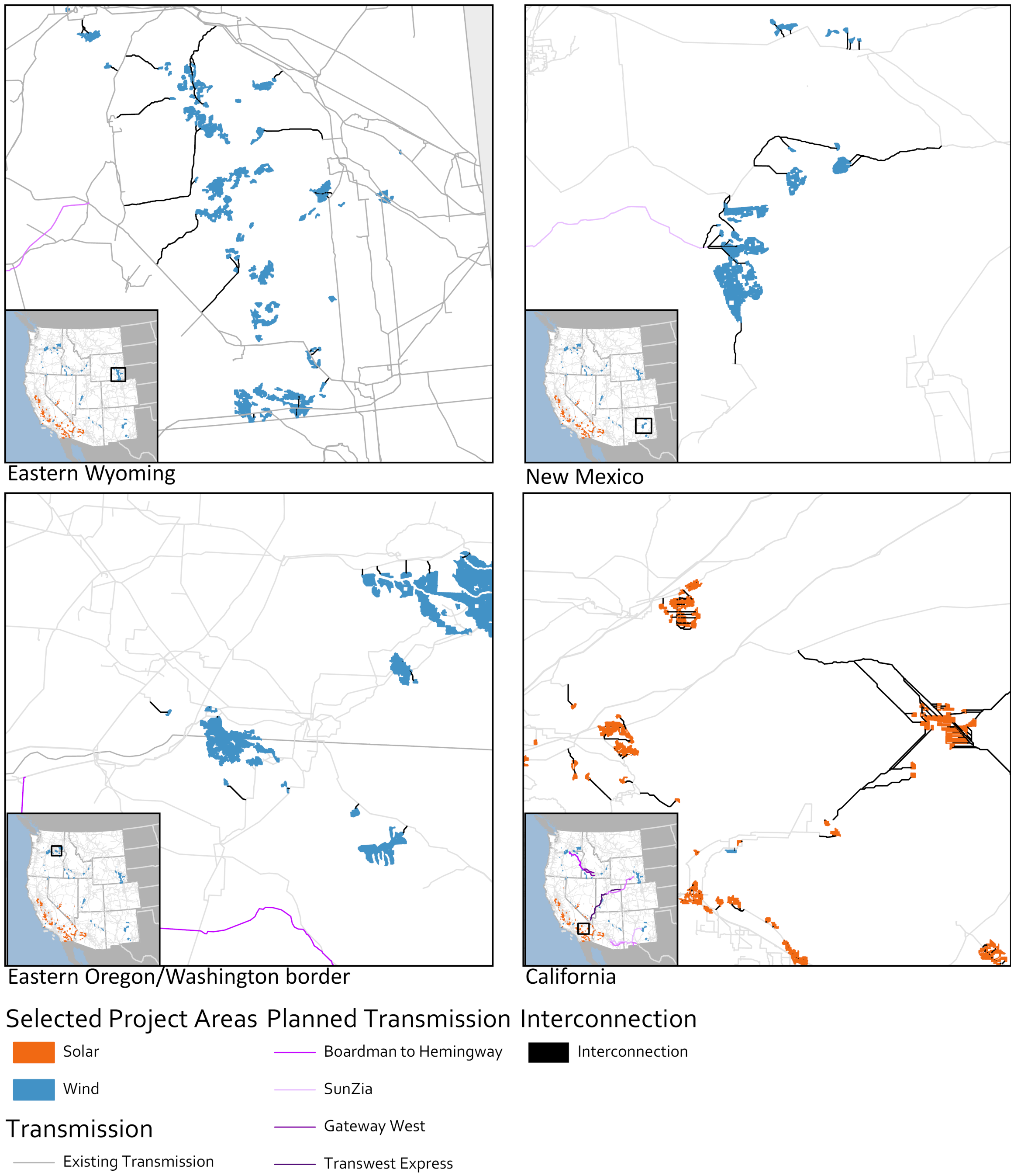


Fig. S17. Representative Selected Project Areas and least cost path gen-tie transmission corridors to serve selected generation project areas in the *Full West*, Siting Level 3, *Constrained* scenario.

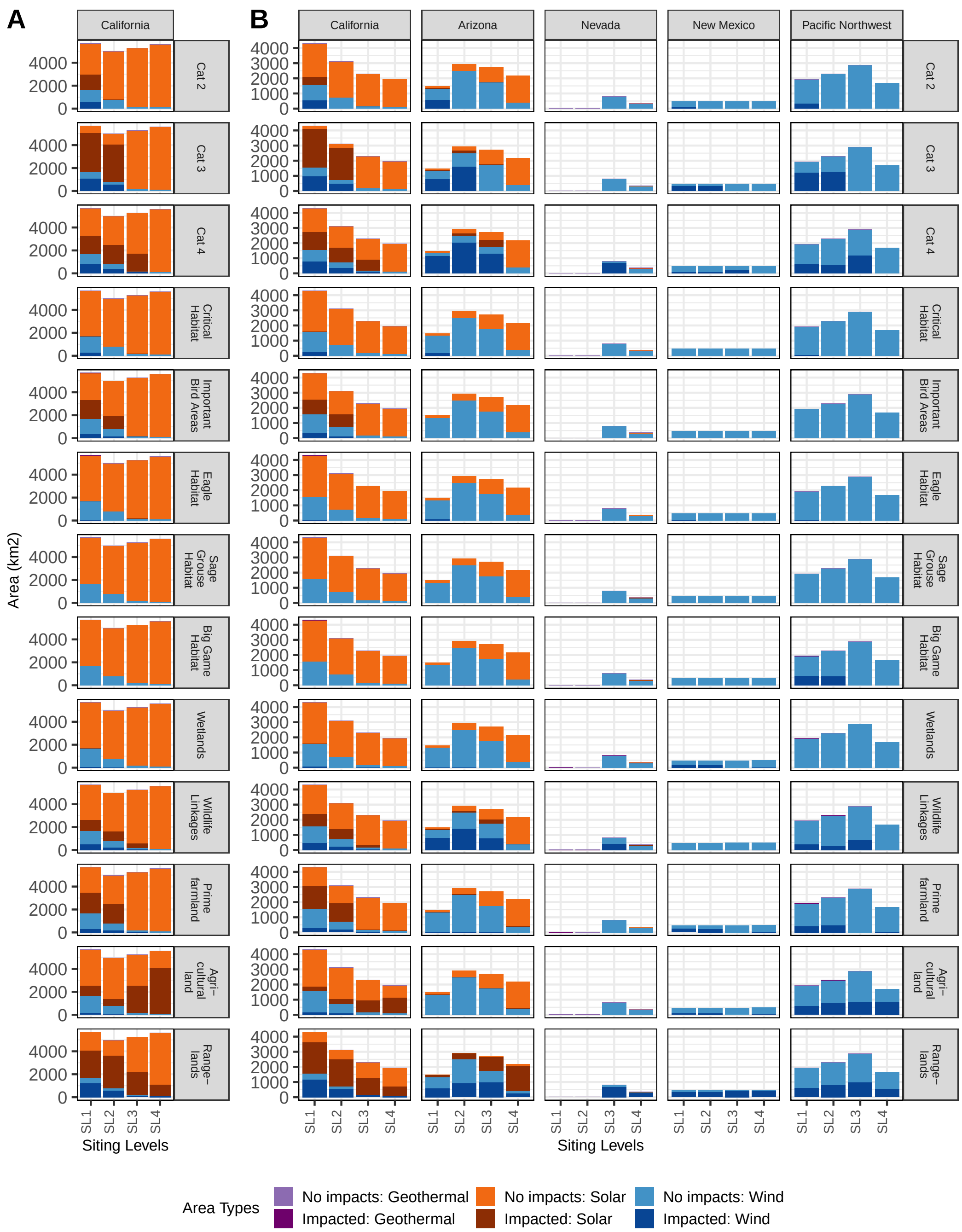


Fig. S18. Environmental impacts for selected generation project areas within each state for the *In-State* (A) and *Part West* (B) Geographic cases for the *Unconstrained* assumptions case.

Fig. S19. Environmental impacts for selected generation project areas in the *Full West* Geographic cases for the *Unconstrained* assumptions case.

Fig. S20. Environmental impacts for modeled gen-tie and planned bulk transmission corridors within each state for the *In-State* (A) and *Part West* (B) Geographic cases for the *Unconstrained* assumptions case.

Fig. S21. Environmental impacts for modeled gen-tie and planned bulk transmission corridors within each state in the *Full West* Geographic cases for the *Unconstrained* assumptions case.

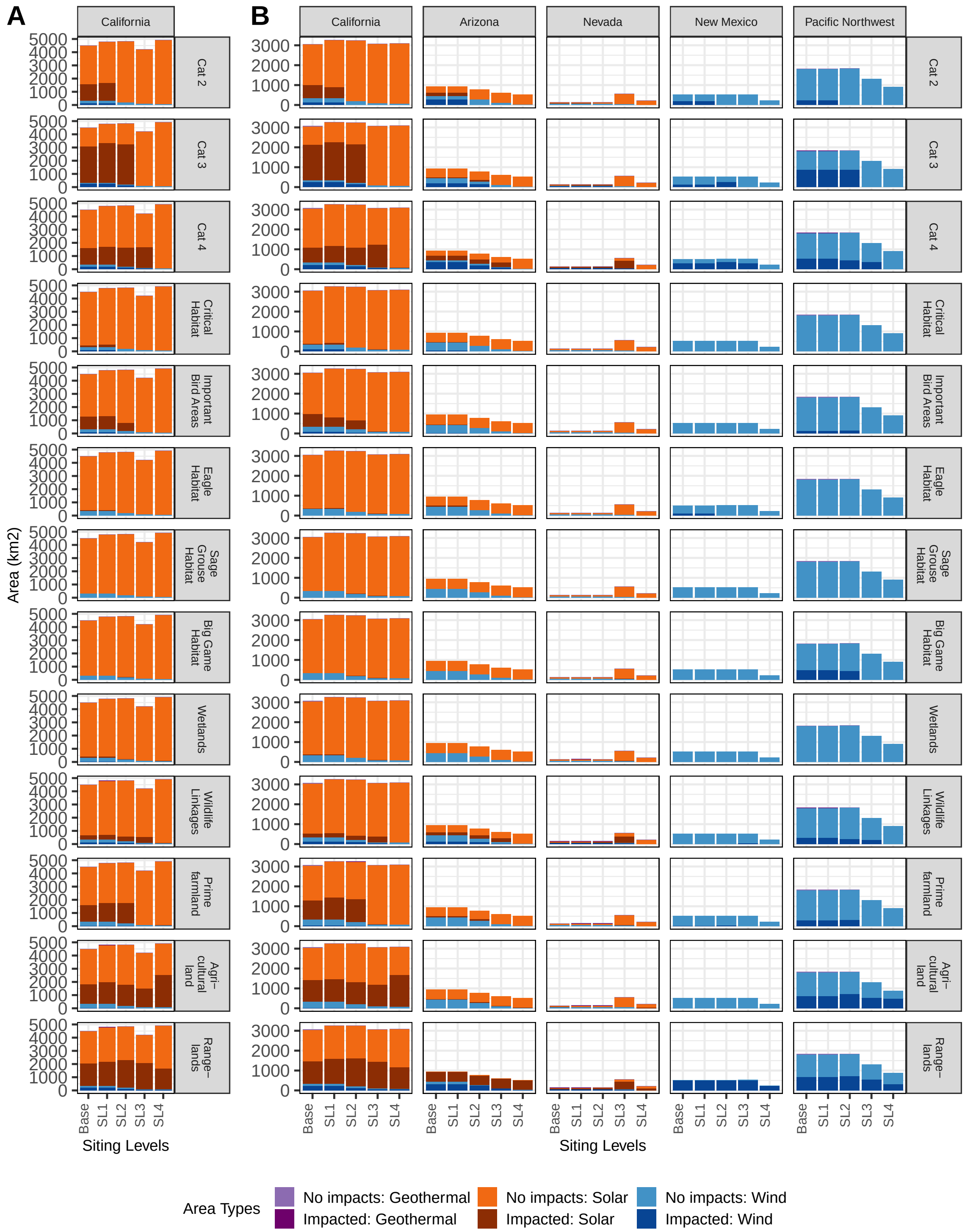


Fig. S22. Environmental impacts of selected generation projects within each state for the *In-State* (A) and *Part West* (B) Geographic cases in the *Constrained* assumptions case.

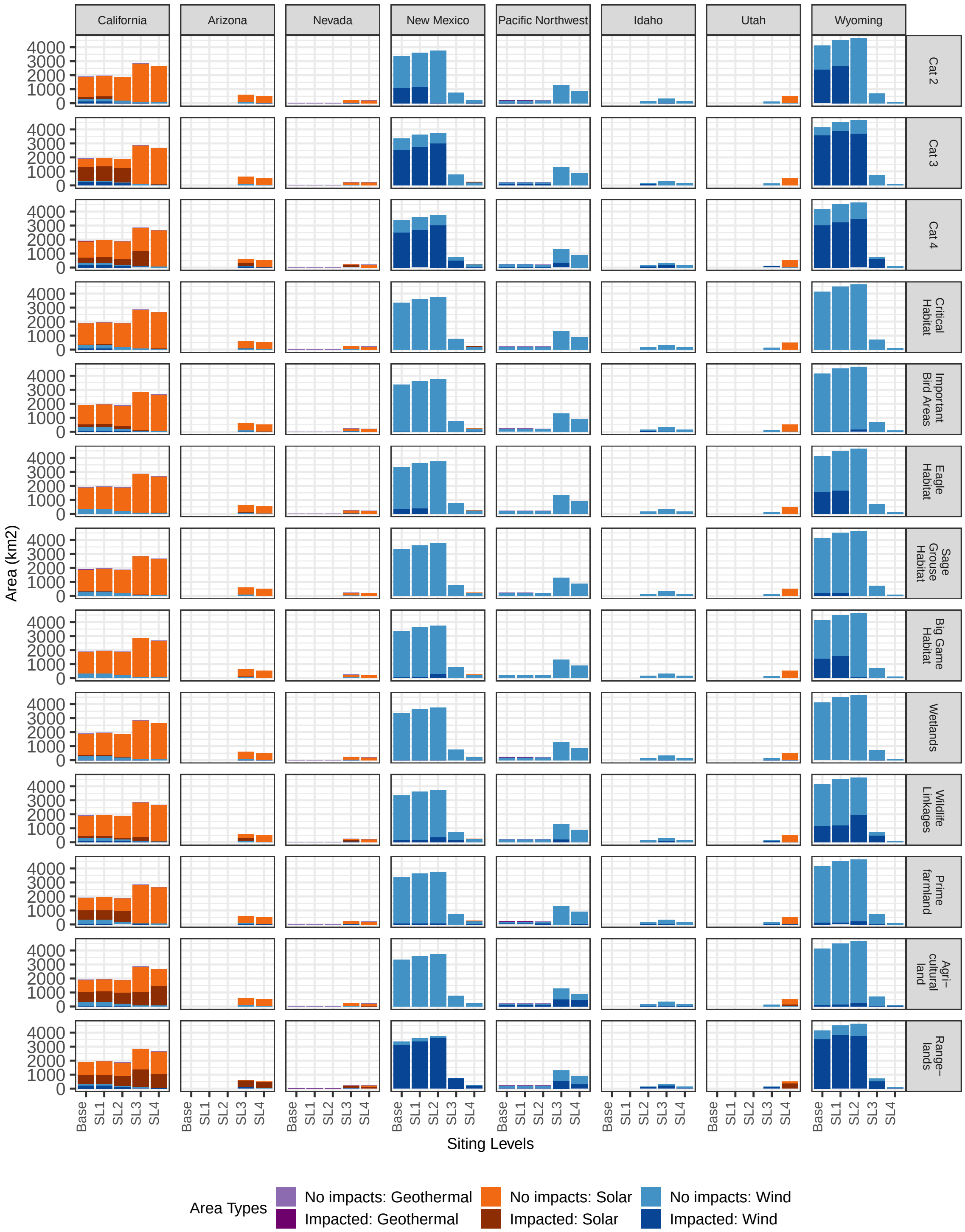


Fig. S23. Environmental impacts of selected generation projects within each state for the *Full West* Geographic cases and in the *Constrained* assumptions case.

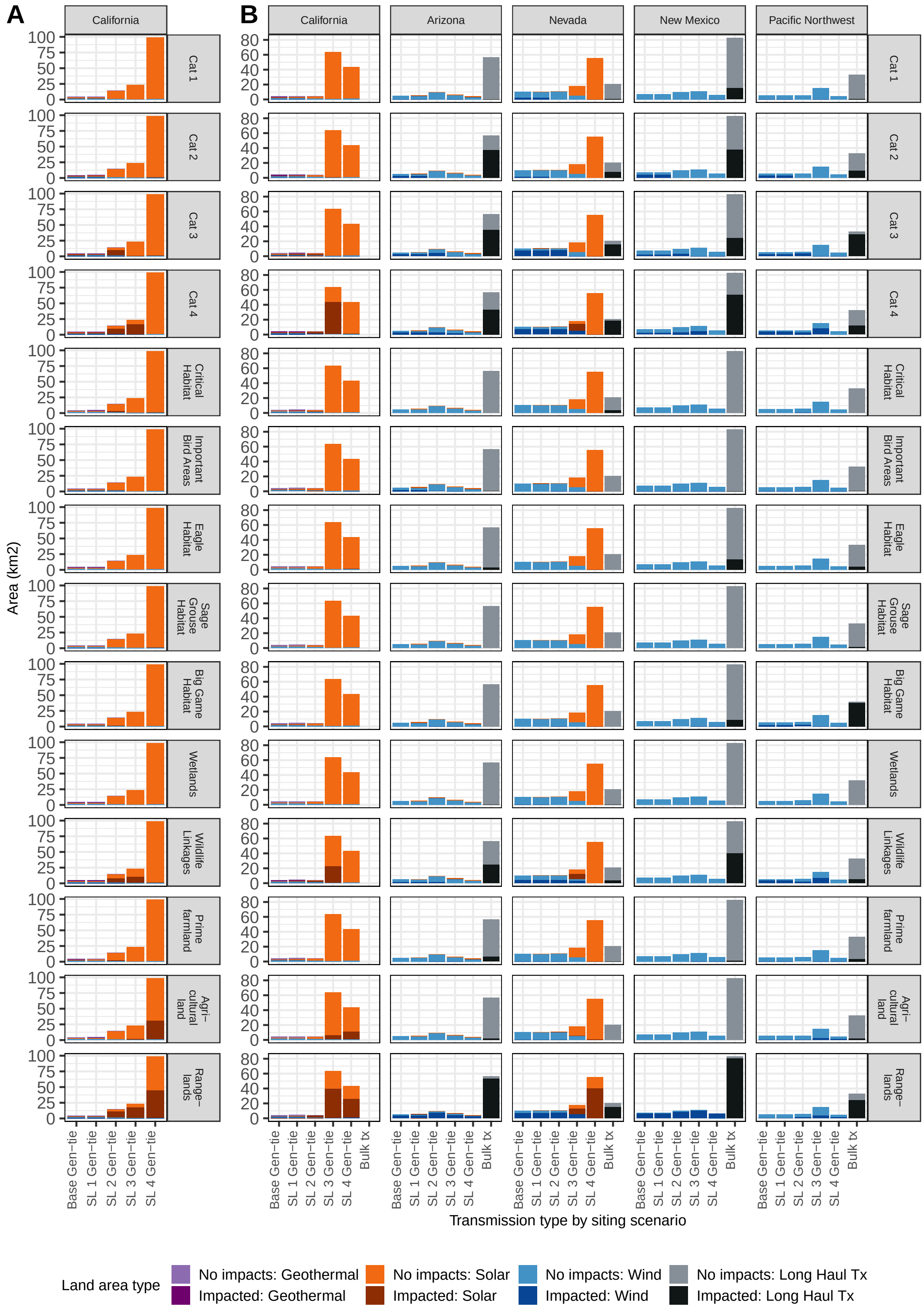


Fig. S24. Environmental impacts of gen-tie and bulk transmission corridors within each state for the *In-State* (A) and *Part West* (B) Geographic cases in the *Constrained* assumptions case.

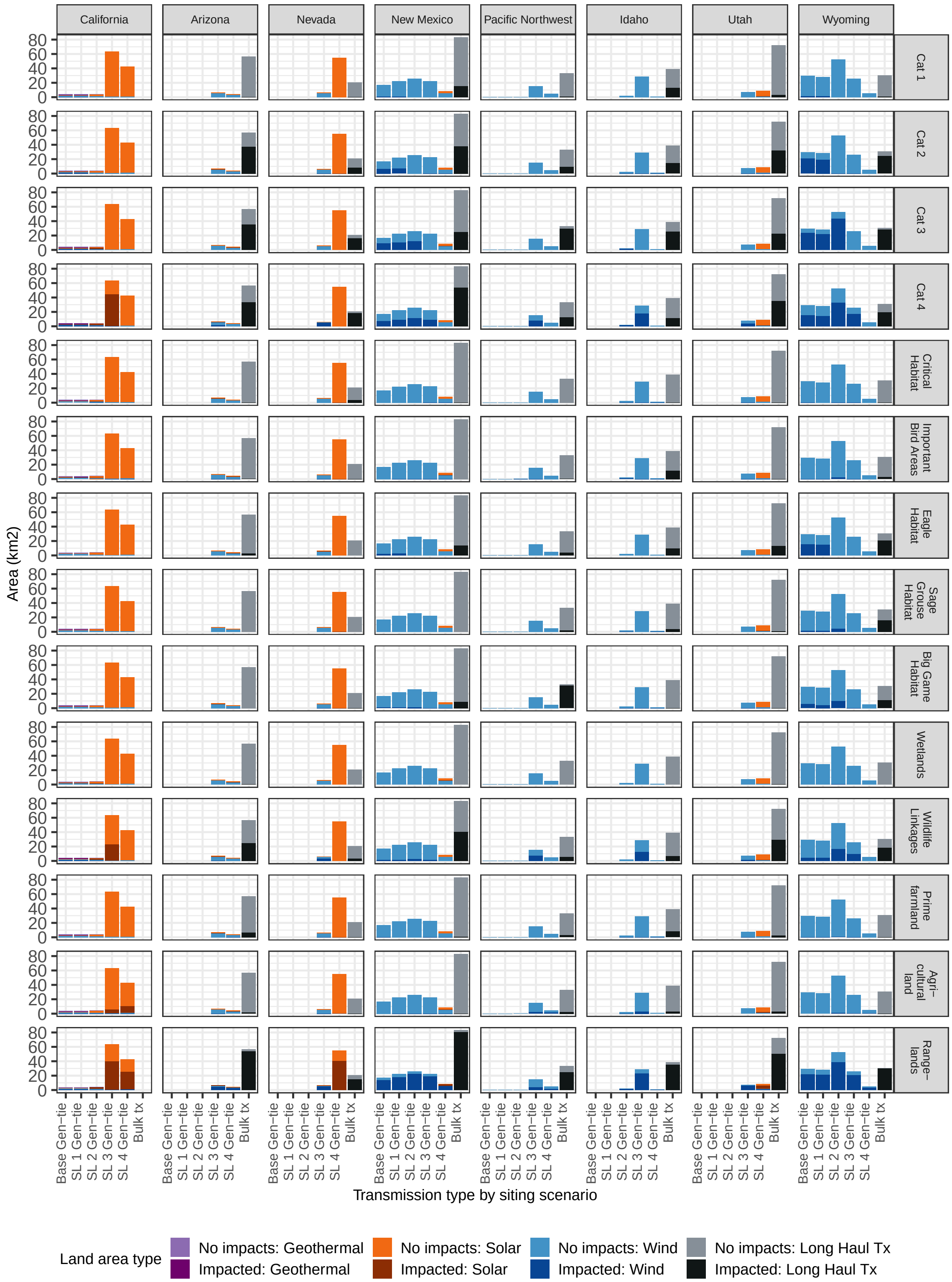


Fig. S25. Environmental impacts of gen-tie and bulk transmission corridors within each state for the *Full West* Geographic cases in the *Constrained* assumptions case.

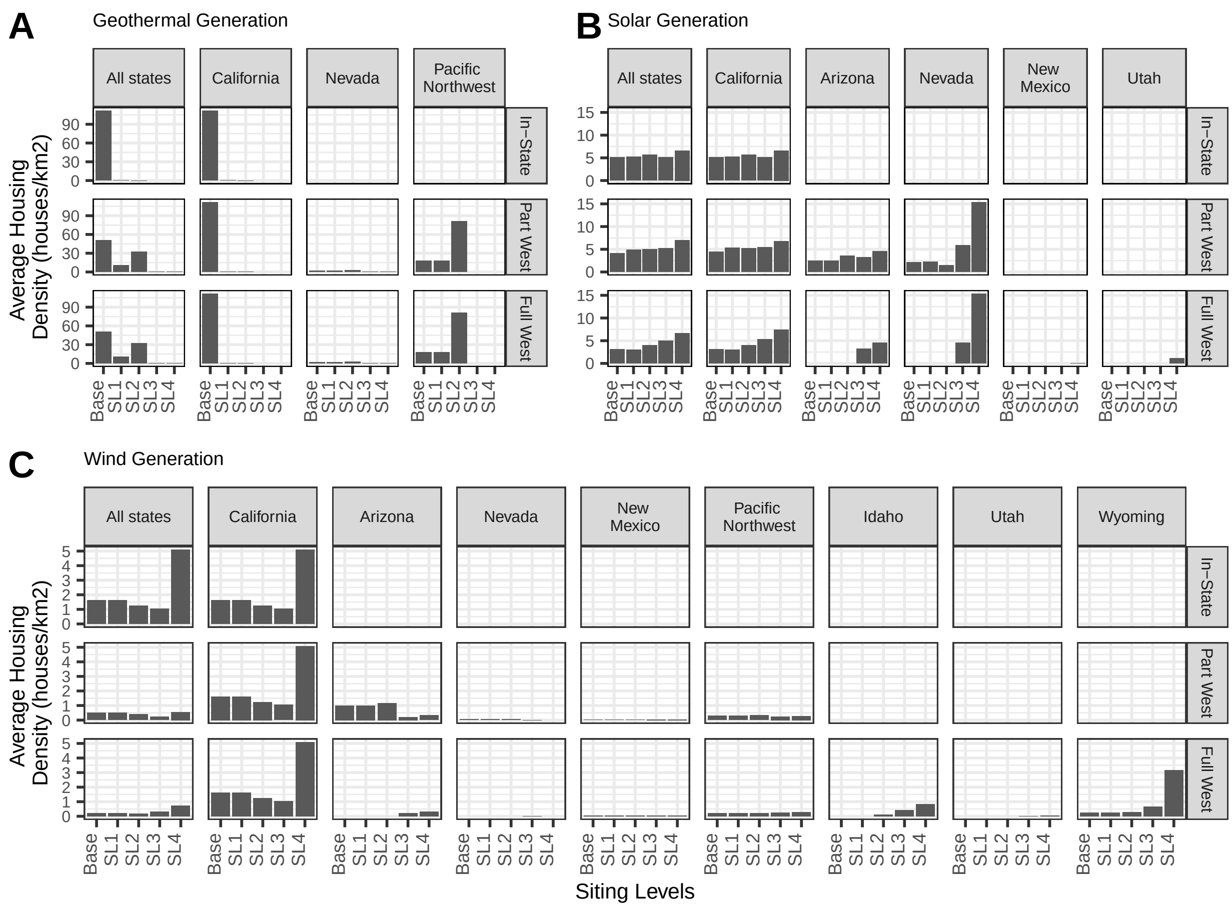


Fig. S26. Average housing density for selected generation project areas in the *Constrained* assumptions case.

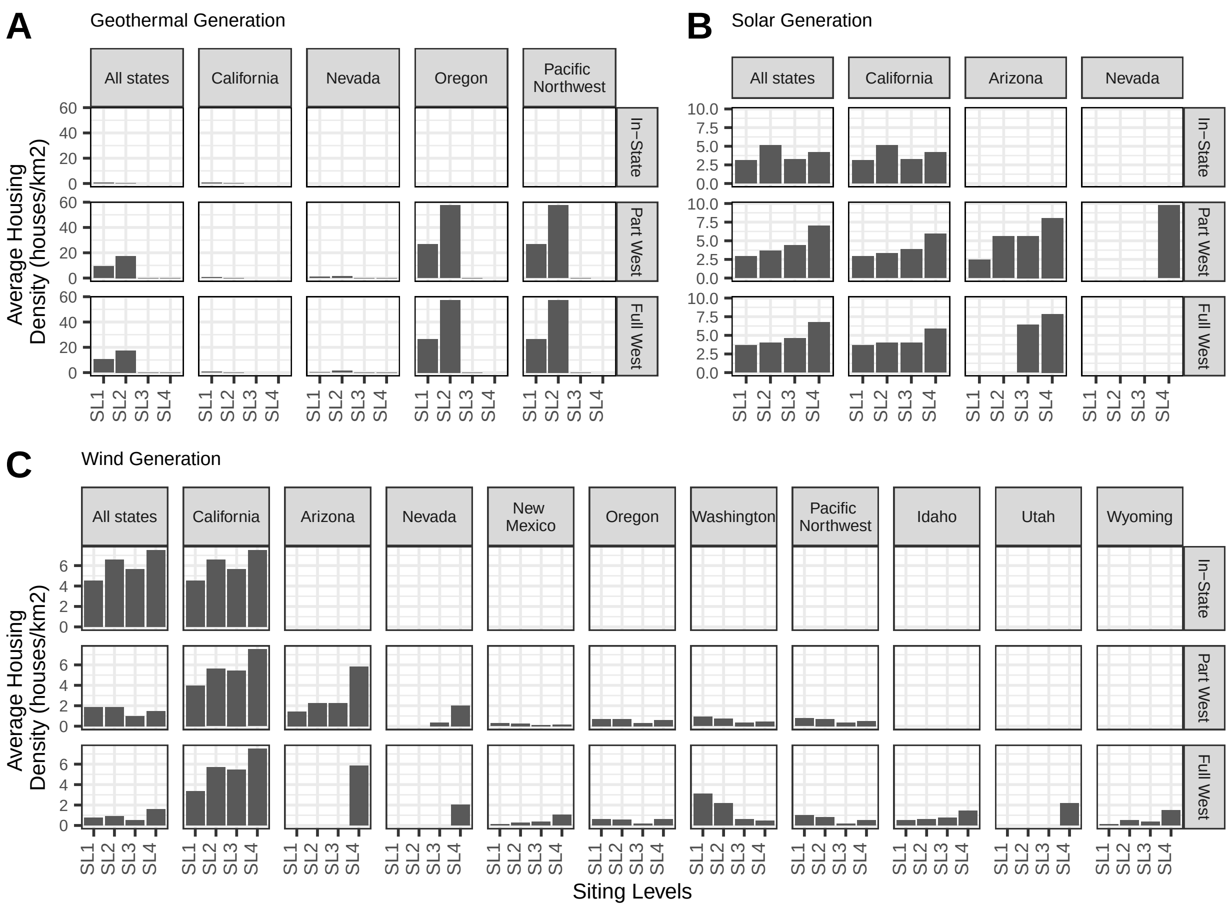


Fig. S27. Average housing density for selected generation project areas in *Unconstrained* assumptions case.

Table S1. Capital cost assumption comparisons between different RESOLVE versions

Capital Cost Comparison (2016 $/kW)						
Technology	CPUC IRP 2020	CPUC IRP 2050	CEC Study 2020	CEC Study 2050	This Study 2020	This Study 2050
Solar PV – 1-axis Tracking	$1,862	$1,692	$1,862	$1,692	$2,108	$1,916
Li-Ion Battery (4 hr duration)	$2,135	$1,407	$2,427	$1,874	$1,013	$815

Table S2. RESOLVE resources available by Geographic cases

Resource		Geographic cases	
Resource Zone	In-State	Part West	Full West
California Solar	X	X	X
California Wind	X	X	X
California Geothermal	X	X	X
Existing Northwest Transmission Wind	Constrained at 1500 MW	Constrained at 1500 MW	Constrained at 1500 MW
Existing Southwest Transmission Wind	Constrained at 500 MW	Constrained at 500 MW	Constrained at 500 MW
Utah Solar	-	-	X
Southern Nevada Solar	-	X	X
Arizona Solar	-	X	X
New Mexico Solar	-	-	X
Pacific Northwest Wind (new transmission)	-	-	X
Idaho Wind	-	-	X
Utah Wind	-	-	X
Wyoming Wind (new transmission)	-	-	X
Southern Nevada Wind	-	X	X
Arizona Wind	-	X	X
New Mexico Wind (new transmission)	-	Constrained at 3000 MW	X
Pacific Northwest Geothermal	-	X	X
Southern Nevada Geothermal	-	X	X

Table S3. Behind-the-meter PV forecast generation (GWh) and capacity (GW) assumptions for the base case and high distributed energy (High DER) sensitivity

BTM PV	2020	2025	2030	2035	2040	2045	2050
Base DER (GWh)	11,578	19,084	30,499	35,071	39,782	44,562	49,207
Base DER (GW)	5.82	9.60	15.3	17.6	20.0	22.4	24.7
High DER (GWh)	12,432	22,770	38,440	45,391	52,332	59,268	65,966
High DER (GW)	6.25	11.5	19.3	22.8	26.3	29.8	33.2

Table S4. Battery cost assumptions: All-In Fixed Cost, 4 hr Li-Ion Battery

Cost (2016 $/kWh-yr)	2020	2025	2030	2035	2040	2045	2050
Base Battery Cost	$38.08	$31.21	$29.88	$29.88	$29.88	$29.88	$29.887
Low Battery Cost	$27.48	$23.53	$22.67	$22.67	$22.67	$22.67	$22.67

Table S5. Techno-economic datasets for site suitability modeling

Broad category	Dataset name	Source	Website	Description	Data type/ resolution	Threshold or buffer
Renewable resource	WIND Toolkit dataset	NREL	https://data.nrel.gov/submissions/54 https://www.nrel.gov/grid/wind-toolkit.html	Point locations of simulated wind speeds and estimated annual average capacity factors of quality wind resource areas in the U.S.	CSV with geographic coordinates/ 2 km	Include all areas
Renewable resource	Solar PV capacity factors	NREL	https://sam.nrel.gov/	Point locations of estimated annual average capacity factors for fixed tilt solar PV calculated using SAM *	CSV with geographic coordinates/ 10 km	Include all areas
Renewable resource	Geothermal candidate locations	Black&Veatch	https://energyarchive.ca.gov/reti/documents/index.html	Point locations of candidate geothermal locations with estimated MW capacity for WesternU.S.as part of the Western Renewable Energy Zones study (4), and was also included in the Renewable Energy Transmission Initiative (RETI) 1.0 study (3). The data download link is called,"GIS Data for Phase 2B".	Geodatabase point feature classes	Include all areas, buffered points using a radius calculated using a land use efficiency of 25.5 MW km^{-2}
Technical constraint	Slope	CGIAR	http://www.cgiar-csi.org/data/srtm-90m-digital-elevation-database-v4-1	Calculated slope in percentage from STRM digital elevation model - Resampled 250 m SRTM 90m Digital Elevation Database v4.1	Raster/ 250m	Solar: exclude $>$5%, Wind: exclude $>$25%
Physical constraint	Water bodies and rivers	West-wide wind mapping project (WWWMP)	http://wwmp.anl.gov/maps-data/	Permanent water bodies in the U.S. (lakes and rivers)	Shapefile	Wind and solar: include areas $>$250m outside of water bodies
Socio-economic constraint	Census urban zones	2017 TIGER/ Line®	https://www.census.gov/geo/maps-data/data/tiger-line.html	Urban areas as defined by the U.S. Census	Shapefile	Solar: include areas $>$500m, Wind: include areas $>$1000m
Socio-economic constraint	Population density	ORNL Landscan	https://landscan.ornl.gov/	Persons per km^2	Raster/ 1km	Wind and solar: include areas $<$100 persons/km^2
Socio-economic constraint	Military areas	West-wide wind mapping project (WWWMP)	http://wwmp.anl.gov/maps-data/	Includes the following areas: DOD High Risk of Adverse Impact Zones, DOD Restricted Airspace and Military Training Routes, Utah Test and Training Range	Shapefile	Solar: include areas $>$1000m, Wind: include areas $>$5000m
Socio-economic constraint	Military areas	Protected Areas Database–U.S.	https://gapanalysis.usgs.gov/padus/	Filtered PAD-US feature class using: Des_Tp = 'MIL'	Geodatabase feature class	Solar: include areas $>$1000m, Wind: include areas $>$5000m
Hazardous constraint	Active mines	USGS Active mines and mineral plans in the U.S.	https://mrdata.usgs.gov/mineplant/	Mine plants and operations for commodities monitored by the National Minerals Information Center of the USGS. Operations included are those considered active in 2003 and surveyed by the USGS.	CSV of geographic coordinates	Wind and solar: include areas $>$1000m
Hazardous constraint	Airports and runways	National Transportation Atlas Database (NTAD) from the U.S. Department of Transportation (USDOT) and Bureau of Transportation Statistics	http://osav-usdot.opendata.arcgis.com/datasets?keyword=Aviation	The airports dataset including other aviation facilities is as of July 6, 2017, and is part of the U.S. Department of Transportation (USDOT)/Bureau of Transportation Statistics' (BTS') National Transportation Atlas Database (NTAD).	Shapefile	Solar: include areas $>$1000m, Wind: include areas $>$5000m
Hazardous constraint	Railways	National Transportation Atlas Database (NTAD) from the U.S.DOT and Bureau of Transporation Statistics	http://osav-usdot.opendata.arcgis.com/	The Rail Network is a comprehensive database of North America's railway system at 1:24,000 to 1:100,000 scale as of October 10, 2017.	Shapefile	Wind and Solar: include areas $>$250m
Hazardous constraint	Flood zones	National Flood Hazard (FEMA) in WECC Environmental Data Viewer Geodatabase	https://ecosystems.azurewebsites.net/WECC/Environmental/	SQL filtered feature class using: "ALLTYPES1" LIKE "Flood Zone" OR "ALLTYPES2" LIKE "Flood Zone" OR "ALLTYPES3" LIKE "Flood Zone" OR "ALLTYPES4" LIKE"Flood Zone"	Geodatabase feature class	Wind and Solar: include areas $>$0m

* Solar PV capacity factor calculation assumptions for SAM: Ground Mount Fixed-tilt Racking Configuration, DC/AC Ratio = 1.35, Average Annual Soiling Losses = 3%, Module Mismatch Losses = 2%, Diode and Connection Losses = 0.5%, DC Wiring Losses = 2%, AC Wiring Losses = 1%, Availability Losses = 1%, Degradation = 0.35% in first year and 0.7%/year thereafter

Table S6. Existing and planned energy infrastructure datasets

Broad category	Dataset name	Source	Website	Description	Data type/ resolution	Usage in study
Existing power plant locations	United States Wind Turbine Database (USWTDB)	USGS, Berkeley Lab, AWEA	https://eerscmap.usgs.gov/uswtdb/data/	Point locations of on-shore and off-shore turbines in the U.S. It is updated quarterly. Accessed on 9/13/18	Shapefile or Geojson	Exclude from potential project areas
Existing power plant locations	Ventyx/ABB EV Energy Map - Existing wind farm boundaries	Ventyx/ABB	https://new.abb.com/enterprise-software/energy-portfolio-management/market-intelligence-services/velocity-suite	The Wind Farm Boundaries EV Energy Map layer depicts the land area for turbines for a particular wind plant site. This layer was developed from various sources such as maps filed with permit applications, FAA obstacle data or aerial imagery and includes both operational and proposed wind plants.	Shapefile	Exclude from potential project areas
Existing power plant locations	Surface area of solar arrays in the conterminous United States as of 2015	USGS (19)	https://www.sciencebase.gov/catalog/item/57a25271e4b006cb45553efa	Footprint area of solar arrays in the conterminous U.S. based on EIA utility-scale facilities data from 2015	Shapefile	Exclude from potential project areas
Existing power plant locations	Surface area of utility-scale solar arrays in California as of 2018	The Nature Conservancy (18)	Unpublished	Footprint area of solar arrays in California created using satellite imagery	Shapefile	Exclude from potential project areas
Existing power plant locations	California's commercial wind and solar project locations	DataBasin, Black & Veatch, Public Utilities Commission	https://databasin.org/maps/365216c4ead144718ec68294035a2646	Existing and commercial wind and solar project locations (those with power purchase agreements from RPS Calculator and the California Public Utilities Commission)	Shapefile (point locations)	Used in conjunction with footprint areas to exclude from potential project areas
Existing power plant locations	Renewable Portfolio Standard Executed Projects (California)	Public Utilities Commission	http://cpuc.ca.gov/RPS_Reports_Data/	Public information of investor owned utility renewable contracts under the RPS program include: contract summaries, contract counterparties, resource type, location, delivery point, expected deliveries, capacity, length of contract, and online date.	Spreadsheet with geographic coordinates of project locations	Used in conjunction with footprint areas to exclude from potential project areas
Transmission infrastructure	California electric transmission line	California Energy Commission	http://caenergy.maps.arcgis.com/home/item.html?id=260b4513acdb4a3a8e4d64e69fc84fee	Transmission line locations as polylines with attribute data on voltages. This data are usually updated quarterly. Accessed on 1/18/2018.	Geodatabase feature class	Selecting potential project areas and modeling transmission corridor needs. Used lines $>$ 69 kV
Transmission infrastructure	EV Energy Map - Transmission lines	Ventyx/ABB	https://new.abb.com/enterprise-software/energy-portfolio-management/market-intelligence-services/velocity-suite	Electric transmission lines EV energy map layer consists of market significant transmission lines generally greater than 115 kV.	Geodatabase feature class	Selecting potential project areas and modeling transmission corridor needs. Used lines $>$ 69 kV
Transmission infrastructure	BLM recently approved Transmission lines	Environmental Planning Group LLC, Bureau of Land Management, Argonne National Labs	View lines: https://bogi.evs.anl.gov/section368/portal/	We included the following six planned transmission corridors in "advanced development" and "recently approved": Gateway South, Gateway West, Southline, SunZia, TransWest Express, SWIP North, and Boardman to Hemingway. Spatial data can be requested from Argonne National Labs. These lines are listed as being in Phase 2 or 3 of the WECC Path Rating Process in the California Energy Commission's RETI 2.0 report "RETI 2.0 Western States Outreach Project Report" (https://www.energy.ca.gov/reti/reti2/documents/)	Geodatabase feature class	Selecting potential project areas and modeling transmission corridor needs. Buffered lines using project reports' planned corridor width

Table S7. Planned interstate bulk transmission data and corridor width assumptions

Transmission line name[†]	Average corridor width source	Spatial data format	Average corridor width
TransWest Express	https://eplanning.blm.gov/epl-front-office/projects/nepa/65198/92789/111798/AppB_TWE_POD.pdf	Polyline	250 ft
Boardman to Hemingway	https://boardmantohemingway.com/documents/11-26-18/USFS_ROD_Nov_2018.pdf	Polyline	250 ft
SunZia	https://openei.org/w/images/b/b7/SunZia_Southwest_Transmission_Project_FEIS_and_Proposed_RMP_Amendments.pdf	Polyline	400 ft
Southline	NA	Polygon	NA
Gateway South	https://eplanning.blm.gov/epl-front-office/projects/nepa/53044/92847/111847/EGS-RecordofDecision.pdf	Polyline	250 ft
Gateway West	https://eplanning.blm.gov/epl-front-office/projects/nepa/39829/95570/115576/GWW_Segments_8_and_9_FINAL_ROD_without_appendices.pdf	Polyline	250 ft

[†] SWIP North is included the Ventyx transmission dataset as an existing line.

Table S8. Datasets for environmental impact metrics

Metric	Dataset name	Source	Environmental Exclusion Category	Unique ID	Data type/ resolution
Critical habitat	Critical habitat		2	0051	Shapefile
Critical habitat	Desert tortoise critical habitat	WWWMP (high level)	2	0075	Shapefile
Critical habitat	Coastal critical habitat		2	0101	Shapefile
Critical habitat	Critical habitat	WWWMP (high level)	2	0262	Shapefile
Sage Grouse habitat	Priority habitat management area - exclusion	WWWMP - BLM	2	0257	Shapefile
Sage Grouse habitat	Priority habitat management area, high level siting considerations	WWWMP - BLM	2	0258	Shapefile
Sage Grouse habitat	General habitat management area, high level siting considerations	WWWMP - BLM	3	0259	Shapefile
Sage Grouse habitat	General habitat management area, moderate level siting considerations	WWWMP - BLM	3	0260	Shapefile
Sage Grouse habitat	Greater sage grouse priority areas for conservation	FWS	2	0266	Shapefile
Important Bird Areas	Important Bird Areas - state and globally important (Apr 2018)	Audubon Society	3	0110	Shapefile
Wetlands	National Wetlands Inventory	USFWS	2	0052	Shapefile
Wetlands	Priority Wetlands Inventory - Nevada	Nevada Natural Heritage Program	2	0054	Shapefile
Wetlands	Globally important wetlands	Site Wind Right (TNC)	2	0249	Shapefile
Wetlands	Playa wetland clusters	Site Wind Right (TNC)	3	0137	Shapefile
Wetlands	Vernal pools	USFWS	2	0077	Shapefile
Wetlands	Vernal pools - Great Valley, CA (Witham et al. 2014 update)	USFWS	2	0078	Shapefile
Wetlands	Vernal pools - San Diego	USGS	2	0079	Shapefile
Wetlands	Vernal pools - South Coast Range	California Department of Fish and Wildlife	2	0080	Shapefile
Wetlands	Vernal pools - Modoc National Forest	U.S.Forest Service	2	0081	Shapefile
Wetlands	California state wetlands	California Department of Fish and Game	2	0046	Shapefile
Big game corridors	Wyoming Big Game Crucial Habitat (Elk, Mule Deer, Bighorn Sheep, Pronghorn, White-tailed Deer)	Wyoming Game and Fish	2	0100	Shapefile
Big game corridors	WECC Big Game (ALLTYPES3 LIKE '%Big Game Winter Range%')	WECC	3	0105	Shapefile
Big game corridors	Washington Deer areas	Washington Department of Fish and Wildlife	3	0123	Shapefile
Big game corridors	Washington Elk areas	Washington Department of Fish and Wildlife	3	0124	Shapefile
Big game corridors	Oregon Elk and Deer Winter Range	Oregon Department of Fish and Wildlife	3	0149	Shapefile
Big game corridors	Columbian White-tailed deer range	USFWS	3	0155	Shapefile
Wildlife linkages	Wildlife linkages with corridor values $>$ 34.3428	The Wilderness Society (28)	4	0172	Shapefile
Eagle habitat	Bald Eagle habitat	WWWMP - BLM	2 (wind only)	0076	Shapefile
Eagle habitat	West-wide eagle risk data using the 2 of quantile bins (top 30% of eagle habitat)	USFWS (Bedrosian et al. 2018)	2 (wind only)	0102	Shapefile
Eagle habitat	Golden Eagle habitat	WWWMP	2 (wind only)	0228	Shapefile
Prime farmland	Prime farmland based on high quality soils	Natural Resources Conservation Service	3	0267	Shapefile
Agricultural land	Crop and pasturelands (used class #556-Cultivated Cropland and #557-Pasture/Hay)	National GAP Landcover https://gapanalysis.usgs.gov/gaplandcover/data/download/	NA	NA	raster/ 30m
Rangelands	U.S.rangelands extent using NRI-LANDFIRE model	(29)	NA	NA	raster/ 30m
Housing density	Housing density (2010)	USFS http://silvis.forest.wisc.edu/data/housing-block-change/	NA	NA	geodatabase

Table S9. Datasets for Environmental Exclusion Category 1 (site suitability). Definitions: Exclude development (EX), Avoid development (AV), WECC Environmental Risk Class (RC 1, 2, 3, 4), BLM High Level Siting Considerations (HLSC), BLM Moderate Level Siting Considerations (MLSC), Information not available (NA). Study abbreviation and names: ORB 2015 (Optimal Renewable Energy Build-out), BLM WSEP (BLM Western Solar Energy Program), BLM WWW-MP (BLM West-wide Wind Mapping Program), WECC (Western Electricity Coordinating council Environmental Data Viewer), WREZ (Western Renewable Energy Zones), RETI CPUC (Renewable Energy Transmission Initiative of the California Public Utilities Commission)

Unique Data ID	Environmental Category	Technology	Data Publisher Organization	Dataset Name	ORB 2015 (1)	BLM WSEP (30)	BLM WWW-MP (8)	BLM DRECP (7)	WECC (5)	WREZ (4)	RETI CPUC (3)
1	1	All	National Park Service	NPS boundaries - National Historic Trails	EX	EX	EX	EX	RC 2	EX	EX
2	1	All	BLM - WWWMP	National Scenic Trails	NA	EX	EX	EX	NA	EX	NA
3	1	All	BLM - WWWMP	National Historic Landmarks	NA	NA	EX	NA	NA	NA	NA
4	1	All	BLM - WWWMP	National Natural Landmarks	NA	NA	EX	NA	NA	NA	NA
5	1	All	United States Geological Survey	Wild and Scenic Rivers	NA	EX	EX	NA	RC 3	EX	EX
6	1	All	Natural Resources Conservation Service	Easements	EX	NA	NA	NA	RC 3	EX	EX
8	1	All	National Conservation Easement Database	Conservation Easements	NA	NA	NA	NA	NA	NA	NA
9	1	All	Bureau of Land Management	BLM Solar Energy Program SEZ non-dev	NA	EX	NA	NA	NA	NA	NA
10	1	All	BLM - WWWMP	Visual Resource Management	NA	EX	EX	NA	NA	AV	NA
11	1	All	Bureau of Land Management	BLM Solar Energy Program exclusions	NA	NA	NA	NA	NA	NA	NA
12	1	All	USGS PAD-US	National Primitive Area	EX	NA	NA	NA	RC 4	EX	NA
13	1	All	USGS PAD-US	National Wildlife Refuge	EX	NA	NA	NA	RC 4	EX	EX
14	1	All	USGS PAD-US	Units of the National Parks System (excluding National Recreation Areas and National Trails)	EX	EX	NA	NA	RC 4	EX	EX
15	1	All	USGS PAD-US	Wilderness Area	EX	EX	EX	NA	RC 4	EX	EX
16	1	All	USGS PAD-US	Wilderness Area (Recommended)	NA	NA	NA	NA	RC 4	EX	NA
17	1	All	USGS PAD-US	Wilderness Study Area	EX	EX	EX	NA	RC 4	EX	EX
20	1	All	BLM - WWWMP	National Conservation Area	EX	EX	EX	NA	RC 3	EX	EX
21	1	All	USGS PAD-US	National Monument	EX	EX	EX	NA	RC 3	EX	EX
22	1	All	USGS PAD-US	National Recreation Area	EX	NA	NA	NA	RC 3	EX	EX
23	1	All	USGS PAD-US	Research Natural Area – Proposed	EX	NA	NA	NA	RC 3	NA	NA
24	1	All	BLM - WWWMP	Desert Renewable Energy Conservation Plan Special Recreation Management Area	EX	EX	EX in CA; MLSC elsewhere.	EX	NA	AV	EX in DRECP area
25	1	All	USGS PAD-US	State Park	EX	NA	NA	NA	RC 3	EX	EX
26	1	All	USGS PAD-US	State Wildlife Management Areas	EX	NA	NA	NA	RC 3	AV	NA
28	1	All	BLM - WWWMP	National Register Historic Places		NA	EX	NA	NA	NA	NA
29	1	All	USGS PAD-US	State Wilderness Areas	EX	NA	NA	NA	NA	EX	EX
30	1	All	USGS PAD-US	DFW Wildlife Areas and Ecological Reserves	EX	NA	NA	NA	NA	NA	NA
31	1	All	USGS PAD-US	Existing Conservation and Mitigation Bank	EX	NA	NA	NA	NA	EX	EX
32	1	All	USGS PAD-US	Watershed Protection Area	EX	NA	NA	NA	NA	EX	NA
33	1	All	USGS PAD-US	Marine Protected Area	EX	NA	NA	NA	NA	EX	NA
34	1	All	USGS PAD-US	Historic or Cultural Area	EX	EX	NA	NA	NA	AV	EX
35	1	All	California State Agencies	Habitat Conservation Plan	AV	NA	NA	NA	Non-preferred dataset	AV	EX
36	1	All	California State Agencies	Natural Community Conservation Plan	AV	NA	NA	NA	Non-preferred dataset	AV	EX
38	1	All	BLM - WWWMP	DRECP NCL	NA	NA	NA	EX	NA	NA	NA
39	1	All	BLM - WWWMP	Park boundaries	NA	NA	NA	NA	NA	NA	NA
43	1	All	BLM - WWWMP	vrmII	NA	NA	NA	NA	NA	NA	NA
190	1,2	Cat1(s); Cat2 (w,g)	USGS PAD-US	Right of Way exclusion	NA	NA	NA	NA	RC 3	NA	NA
240	1,2	All	Colorado Natural Heritage Program	Colorado protected lands	NA	NA	NA	NA	NA	NA	NA
252	1	All	BLM - WWWMP	conservation	NA	NA	EX	NA	NA	NA	NA
256	1	All	BLM - WWWMP	Right of Way exclusion	NA	NA	EX	NA	NA	NA	NA

Table S10. Datasets for Environmental Exclusion Category 2. Definitions: Exclude development (EX), Avoid development (AV), WECC Environmental Risk Class (RC 1, 2, 3, 4), BLM High Level Siting Considerations (HLSC), BLM Moderate Level Siting Considerations (MLSC), Information not available (NA). Study abbreviation and names: ORB 2015 (Optimal Renewable Energy Build-out), BLM WSEP (BLM Western Solar Energy Program), BLM WWW-MP (BLM West-wide Wind Mapping Program), WECC (Western Electricity Coordinating council Environmental Data Viewer), WREZ (Western Renewable Energy Zones), RETI CPUC (Renewable Energy Transmission Initiative of the California Public Utilities Commission)

Unique Data ID	Environmental Category	Technology	Data Publisher Organization	Dataset Name	ORB 2015 (1)	BLM WSEP (30)	BLM WWW-MP (8)	BLM DRECP (7)	WECC (5)	WREZ (4)	RETI CPUC (3)
18	2	All	BLM - WWWMP	Areas of Critical Environmental Concern	EX	EX	EX	EX	RC 3	EX	EX
27	2	All	New Mexico County governments	New Mexico County wind ordinances	NA	NA	NA	NA	NA	NA	NA
42	2	All	U.S.Census Bureau	Tribal Lands	NA	NA	NA	NA	RC 2	NA	NA
43	2	All	BLM - WWWMP	Visual Resource Management II	NA	NA	HLSC	NA	NA	NA	NA
44	2	All	USGS PAD-US	State Forest	EX	NA	NA	NA	RC 3	EX	EX
45	2	All	BLM - WWWMP	National Park Service Areas of High Potential Resource Conflict	NA	NA	MLSC	NA	NA	NA	AV
46	2	All	California Department of Fish and Game	Central Valley Wetland and Riparian Areas	EX	NA	NA	NA	RC 3	EX	EX
47	2	All	BLM - WWWMP	No Surface Occupancy	EX	EX	HLSC	NA	NA	NA	NA
51	2	All	United States Fish and Wildlife Service	Critical Habitat for Threatened and Endangered Species Composite Layer	AV	EX	HLSC	NA	RC 3	NA	AV
52	2	All	United States Fish and Wildlife Service	Wetlands - prc	EX	NA	NA	NA	RC 2	EX	NA
53	2	All	United States Forest Service	National Inventoried Roadless Areas	EX	NA	NA	NA	RC 3	EX	EX
54	2	All	Nevada Natural Heritage Program	Priority Wetlands Inventory	NA	NA	NA	NA	RC 2	NA	NA
55	2	All	Wyoming Game and Fish	crucial winter areas	NA	NA	NA	NA	RC 3	NA	NA
56	2	All	Wyoming Game and Fish	crucial winter areas	NA	NA	NA	NA	RC 3	NA	NA
57	2	All	USGS PAD-US	Special Interest Area	AV	NA	NA	NA	RC 3	AV	NA
58	2	All	BLM - WWWMP	Desert Renewable Energy Conservation Plan Extensive Recreation Management Area	NA	NA	HLSC	AV	NA	NA	NA
59	2	All	BLM - WWWMP	Desert Renewable Energy Conservation Plan Wildlife Allocation	NA	NA	EX	AV	NA	NA	EX in DRECP
60	2	All	BLM - WWWMP	Desert Renewable Energy Conservation Plan Off Highway Vehicles	NA	NA	EX	EX	NA	AV	NA
61	2	All	BLM - WWWMP	Off Highway Vehicle	NA	NA	MLSC	NA	NA	AV	NA
62	2	Wind	BLM - WWWMP	Development Focus Area - solar and geothermal only (excluding wind)	NA	NA	EX	Prioritize (varies by technology)	NA	NA	NA, except in SJV/ DRECP screen
63	2	All	USGS PAD-US	U.S. Army Corps of Engineers Land	NA	NA	NA	NA	RC 2	NA	NA
64	2	All	USGS PAD-US	Native Allotments	NA	NA	NA	NA	RC 2	NA	NA
65	2	All	USGS PAD-US	Other private non-profit land	EX	NA	NA	NA	RC 2	NA	NA
66	2	All	TNC WAFO	TNC_Lands_Features	EX	NA	NA	NA	NA	NA	EX
67	2	All	WA DNR	Spotted Owl Management Units	NA	NA	NA	NA	NA	EX	EX
68	2	All	WA DNR	Habitat Conservation Plan Lands	NA	NA	NA	NA	NA	EX	EX
71	2	All	USGS PAD-US	State Reserves	AV	NA	NA	NA	NA	NA	NA
72	2	All	USGS PAD-US	Other wildlife areas and ecological reserves	AV	NA	NA	NA	NA	NA	NA
73	2	All	Los Angeles County	Significant ecological areas	AV	NA	NA	NA	NA	NA	AV
75	2	All	BLM - WWWMP	Desert Tortoise Critical Habitat	AV	NA	HLSC	NA	NA	NA	NA
76	2	Wind	BLM - WWWMP	Bald Eagle	NA	NA	MLSC	NA	NA	NA	NA
77	2	All	USFWS	Vernal pools	NA	NA	NA	NA	NA	NA	AV
78	2	All	USFWS	2012RemapVernalPoolsFINAL.zip	NA	NA	NA	NA	NA	NA	AV
79	2	All	CDFW	SANGIS_ECO_VERNAL_POOLS.shp	NA	NA	NA	NA	NA	NA	AV
80	2	All	CDFW	ds948.shp	NA	NA	NA	NA	NA	NA	AV
81	2	All	USDA Forest Service, Modoc National Forest.	Vernal pools, Modoc. ds949.zip	NA	NA	NA	NA	NA	NA	AV
82	2	All	BLM	BLM Lands with Wilderness Characteristics (DRECP)	NA	EX	EX	See CMAs	NA	AV	NA
83	2	All	BLM - WWWMP	BLM Lands with Wilderness Characteristics (WWWMP)	NA	EX	EX	See CMAs	NA	AV	NA
85	2	All	Bureau of Land Management DRECP	National Landscape Conservation Survey Preferred Subareas	NA	EX	EX	EX	NA	EX	NA
91	2	Wind	TNC "Site Wind Right" study	Cooperative Whooping Crane Tracking Project database Pearse et al. (2015) National Wetlands Inventory	NA	NA	NA	NA	NA	NA	NA
92	2	Wind	University of Kansas, Kansas Biological Survey	SGPCHAT	NA	NA	NA	NA	NA	NA	NA
96	2	All	Colorado Parks and Wildlife	Preble S Jumping Mouse	NA	NA	NA	NA	NA	NA	NA
97	2	All	Colorado Parks and Wildlife	Mule deer	NA	NA	NA	NA	NA	NA	NA

Table S10. Datasets for Environmental Exclusion Category 2. Definitions: Exclude development (EX), Avoid development (AV), WECC Environmental Risk Class (RC 1, 2, 3, 4), BLM High Level Siting Considerations (HLSC), BLM Moderate Level Siting Considerations (MLSC), Information not available (NA). Study abbreviation and names: ORB 2015 (Optimal Renewable Energy Build-out), BLM WSEP (BLM Western Solar Energy Program), BLM WWW-MP (BLM West-wide Wind Mapping Program), WECC (Western Electricity Coordinating council Environmental Data Viewer), WREZ (Western Renewable Energy Zones), RETI CPUC (Renewable Energy Transmission Initiative of the California Public Utilities Commission)

Unique Data ID	Environmental Category	Technology	Data Publisher Organization	Dataset Name	ORB 2015 (1)	BLM WSEP (30)	BLM WWW-MP (8)	BLM DRECP (7)	WECC (5)	WREZ (4)	RETI CPUC (3)
100	2	Wind	Wyoming Game and Fish	Big Game Crucial Habitat	NA	NA	NA	NA	RC 3	NA	NA
101	2	All	NOAA/USFWS	Critical Habitat Designations (map service layer)	AV	NA	NA	NA	NA	NA	NA
102	2	Wind	FWS	West-Wide Eagle Risk Data	NA	NA	NA	NA	NA	NA	NA
185	2	All	USGS PAD-US	Research Natural Area	EX/AV	NA	NA	NA	RC 3	AV	EX
194	2	All	USGS PAD-US	Native American Lands	NA	NA	NA	NA	RC 2	NA	NA
225	2	All	WSDOT	WSDOT - Tribal Reservation and Trust Lands	NA	NA	NA	NA	RC 2	NA	NA
228	2	Wind	BLM - WWWMP	Golden Eagle suitable habitat	NA	NA	MLSC	NA	NA	NA	NA
234	2	Wind	Colorado Parks and Wildlife	Bald Eagle nest sites, roosting sites, concentration areas	NA	NA	NA	NA	NA	NA	NA
239	2	Wind	Colorado Parks and Wildlife	Colorado Least Tern nesting and foraging sites	NA	NA	NA	NA	NA	NA	NA
240	1,2	All	Colorado Natural Heritage Program	Colorado protected lands	NA	NA	NA	NA	NA	NA	NA
248	2	All	Contact TNC MT chapter for more information.	Montana Wetland Areas	NA	NA	NA	NA	NA	NA	NA
249	2	All	WHSRN	Globally important wetlands	NA	NA	NA	NA	NA	NA	NA
257	2	Wind	BLM - WWWMP	Sage Grouse Priority Habitat Management Area exclusion	NA	NA	EX	NA	NA	NA	NA
258	2	Wind	BLM - WWWMP	Sage Grouse Priority Habitat Management Area, High Level Siting Requirements	NA	NA	HLSC	NA	NA	NA	NA
262	2	All	BLM - WWWMP	critical habitat	NA	NA	HLSC	NA	NA	NA	NA
263	2	All	BLM - WWWMP	Special Recreation Management Area	NA	NA	HLSC	EX	NA	NA	NA
266	2	Wind	TNC	GreaterSageGrousePACs.gdb	NA	NA	NA	NA	NA	NA	NA
271	2	Wind and solar only, geothermal is an exception	County government	Imperial County: areas outside Renewable Energy Overlay	NA	NA	NA	NA	NA	NA	NA
272	2	All	County government	Inyo County: areas outside Solar Energy Development Areas (SEDAs)	NA	NA	NA	NA	NA	NA	NA

Table S11. Datasets for Environmental Exclusion Category 3. Definitions: Exclude development (EX), Avoid development (AV), WECC Environmental Risk Class (RC 1, 2, 3, 4), BLM High Level Siting Considerations (HLSC), BLM Moderate Level Siting Considerations (MLSC), Information not available (NA). Study abbreviation and names: ORB 2015 (Optimal Renewable Energy Build-out), BLM WSEP (BLM Western Solar Energy Program), BLM WWW-MP (BLM West-wide Wind Mapping Program), WECC (Western Electricity Coordinating council Environmental Data Viewer), WREZ (Western Renewable Energy Zones), RETI CPUC (Renewable Energy Transmission Initiative of the California Public Utilities Commission)

Unique Data ID	Environmental Category	Technology	Data Publisher Organization	Dataset Name	ORB 2015 (1)	BLM WSEP (30)	BLM WWW-MP (8)	BLM DRECP (7)	WECC (5)	WREZ (4)	RETI CPUC (3)
49	3	All	Montana Dept of Fish Wildlife and Parks: Crucial Areas Planning System (CAPS)	Bighorn Sheep & Mountain Goat Habitat	AV	NA	NA	NA	RC 3	NA	NA
103	3	All	BLM - WWWMP	Visual Resource Management lands level III	NA	NA	MLSC	NA	NA	NA	NA
104	3	All	Colorado Division of Wildlife	Species Activitiy Data: Severe Winter Range, Winter Concentration, Winter Range, Migration Patters, and Migration Corridor	NA	NA	NA	NA	RC 3	NA	NA
105	3	All	Montana Dept of Fish Wildlife and Parks: Crucial Areas Planning System (CAPS)	Big Game Winter Range Habitat	NA	NA	NA	NA	RC 3	NA	NA
111	3	All	Federal Highway Administration	America's Byways	NA	NA	NA	NA	RC 2	NA	NA
112	3	All	Caltrans	California Scenic Highways	NA	NA	NA	NA	RC 2	NA	NA
113	3	All	Idaho Department o Transportation	Scenic Byways of Idaho	NA	NA	NA	NA	RC 2	NA	NA
114	3	All	Colorado Department of Transportation	Colorado Scenic and Historic Byways	NA	NA	NA	NA	RC 2	NA	NA
115	3	All	Washington State Department of Transportation	Washington Scenic Highways	NA	NA	NA	NA	RC 2	NA	NA
118	3	All	Wyoming Game and Fish	Shapefile: WYPrairieDogComplexes_WGFDWAFWA.	NA	NA	NA	NA	NA	NA	NA
121	3	Wind	Wyoming Natural Heritage Program	WYGrasslandBirds	NA	NA	NA	NA	NA	NA	NA
123	3	All	WDFW	Deer Areas (Polygons)	NA	NA	NA	NA	NA	NA	NA
124	3	All	WDFW	Elk Areas (Polygons)	NA	NA	NA	NA	NA	NA	NA
125	3	All	U.S. Fish and Wildlife Service	USFWS Upland Species Recovery Units	AV	NA	NA	NA	NA	NA	NA
126	3	All	California Department of Conservation	Williamson act –Farmland Mapping and Monitoring Program (FMMP) in CA	Cat3	NA	NA	NA	EX	EX	EX
127	3	All	The Nature Conservancy	Mojave Ecorgeional Assessment	Cat3	NA	NA	NA	NA	NA	NA
129	3	All	Herpetological Conservation and Biology	Mojave Desert Tortoise Linkages	Cat3	NA	MLSC	NA	NA	NA	NA
133	3	All	BLM - WWWMP	Desert Tortoise Connectivity	NA	NA	MLSC	NA	NA	NA	NA
136	3	All	TNC	High integrity grasslands	NA	NA	NA	NA	NA	NA	NA
137	3	Wind	Playa Lakes Joint Venture	Playa clusters	NA	NA	NA	NA	NA	NA	NA
138	3	Wind	Colorado Parks and Wildlife	Greater prairie-chicken optimal habitat	NA	NA	NA	NA	NA	NA	NA
139	3	All	Colorado Natural Heritage Program	Potential Conservation Areas	NA	NA	NA	NA	NA	NA	NA
140	3	Wind	Colorado Parks and Wildlife	Columbian sharptail grouse production areas and winter range	NA	NA	NA	NA	NA	NA	NA
141	3	Wind	Colorado Parks and Wildlife	Plains sharptail grouse concentration areas, winter concentration areas, migratino corridors, severe winter range	NA	NA	NA	NA	NA	NA	NA
142	3	All	Colorado Parks and Wildlife	Pronghorn	NA	NA	NA	NA	NA	NA	NA
143	3	Wind	Colorado Parks and Wildlife	Least tern production areas and foraging areas	NA	NA	NA	NA	NA	NA	NA
144	3	Wind	Colorado Parks and Wildlife	Piipng plover production areas and foraging areas	NA	NA	NA	NA	NA	NA	NA
145	3	Wind	Colorado Parks and Wildlife	CPW Nest area and potential nesting area	NA	NA	NA	NA	NA	NA	NA
146	3	Wind	Wyoming Natural Heritage Program	Tree roosting bats (Silver-haired bat, Hoary, Eastern Red)	NA	NA	NA	NA	NA	NA	NA
148	3	All	New Mexico Department of Game and Fish	Big Game Priority Habitat	NA	NA	NA	NA	RC 3	NA	NA
149	3	All	Oregon Department of Fish and Wildlife	Elk and Deer Winter Range	NA	NA	NA	NA	RC 3	NA	NA
150	3	All	New Mexico Department of Transportation	New Mexico State and National Scenic Byways	NA	NA	NA	NA	RC 2	NA	NA
151	3	All	Oregon Department of Transportation	Oregon Scenic Byways	NA	NA	NA	NA	RC 2	NA	NA
152	3	All	Wyoming Department of Transportation	Wyoming Scenic Highways and Byways	NA	NA	NA	NA	RC 2	NA	NA
155	3	All	USFWS	Columbian white-tailed deer	NA	NA	NA	NA	NA	NA	NA
156	3	All	BLM	BLM Nominated ACECs	NA	NA	NA	NA	NA	NA	NA
157	3	All	TNC	TNC Nominated ACECs. Areas with high conservation value as determined through TNC ecoregional analysis (if/when they become ACEC they would move up to Cat 2).	NA	NA	NA	NA	NA	NA	NA
158	3	All	TNC	Ecologically core areas. Contact TNC NV chapter for more information,	NA	NA	NA	NA	NA	NA	NA
159	3	All	TNC OR	The Nature Conservancy Portfolio Areas	Cat3	NA	NA	NA	NA	NA	NA
160	3	All	ODFW	Oregon Conservation Strategy	NA	NA	NA	NA	NA	NA	NA
161	3	All	TNC	TNC Nevada priority landscapes layer	NA	NA	NA	NA	NA	NA	NA
162	3	All	NDOW	Critical habitat rank 1 or 2	NA	NA	NA	NA	NA	NA	NA

Table S11. Datasets for Environmental Exclusion Category 3. Definitions: Exclude development (EX), Avoid development (AV), WECC Environmental Risk Class (RC 1, 2, 3, 4), BLM High Level Siting Considerations (HLSC), BLM Moderate Level Siting Considerations (MLSC), Information not available (NA). Study abbreviation and names: ORB 2015 (Optimal Renewable Energy Build-out), BLM WSEP (BLM Western Solar Energy Program), BLM WWW-MP (BLM West-wide Wind Mapping Program), WECC (Western Electricity Coordinating council Environmental Data Viewer), WREZ (Western Renewable Energy Zones), RETI CPUC (Renewable Energy Transmission Initiative of the California Public Utilities Commission)

Unique Data ID	Environmental Category	Technology	Data Publisher Organization	Dataset Name	ORB 2015 (1)	BLM WSEP (30)	BLM WWW-MP (8)	BLM DRECP (7)	WECC (5)	WREZ (4)	RETI CPUC (3)
164	3	All	Arizona Department of Roads	Arizona Scenic Roads	NA	NA	NA	NA	RC 2	NA	NA
170	3	All	CEC and USGS, Las Vegas Field Station	Mohave Ground Squirrel (candidate species) Maxent site suitability model at 0.438 cutoff	Cat4	NA	NA	NA	NA	NA	NA
187	3, 4	All	TNC	The Nature Conservancy Portfolio Areas	NA	NA	NA	NA	NA	NA	NA
241	3	All	Colorado natural Heritage Program	Potential Conservation Areas (CO)	NA	NA	NA	NA	NA	NA	NA
259	3	All	BLM - WWWMP	Sage Grouse General Habitat Management Area, High Level Siting Requirements	NA	NA	HLSC	NA	NA	NA	NA
260	3	All	BLM - WWWMP	Sage Grouse General Habitat Management Area, Moderate Level Siting Requirements	NA	NA	MLSC	NA	NA	NA	NA
261	3	All	BLM - WWWMP	Sagebrush Focal Area	NA	NA	EX	NA	NA	NA	NA
267	3	All	NRCS	Westwide Prime farmland classification	NA	NA	NA	NA	NA	NA	EX
268	3	All	TNC	Priority Conservation Areas	NA	NA	NA	NA	NA	NA	NA
269	3	All	NatureServe	Mojave Desert Tortoise Species Distribution Model - Threshold	NA	NA	NA	NA	NA	NA	NA

Table S12. Datasets for Environmental Exclusion Category 4. Definitions: Exclude development (EX), Avoid development (AV), WECC Environmental Risk Class (RC 1, 2, 3, 4), BLM High Level Siting Considerations (HLSC), BLM Moderate Level Siting Considerations (MLSC), Information not available (NA). Study abbreviation and names: ORB 2015 (Optimal Renewable Energy Build-out), BLM WSEP (BLM Western Solar Energy Program), BLM WWW-MP (BLM West-wide Wind Mapping Program), WECC (Western Electricity Coordinating council Environmental Data Viewer), WREZ (Western Renewable Energy Zones), RETI CPUC (Renewable Energy Transmission Initiative of the California Public Utilities Commission)

Unique Data ID	Environmental Category	Technology	Data Publisher Organization	Dataset Name	ORB 2015 (1)	BLM WSEP (30)	BLM WWW-MP (8)	BLM DRECP (7)	WECC (5)	WREZ (4)	RETI CPUC (3)
165	4	All	Conservation Science Partners Inc.	Landscape intactness	NA	NA	NA	NA	NA	NA	NA
166	4	All	TNC	The Nature Conservancy Ecologically Intact for CA deserts	Cat4	NA	NA	NA	NA	NA	NA
169	4	All	CDOT, CDFG, and FHA	Essential Connectivity areas of California	Cat4	NA	NA	NA	RC 3	NA	NA
172	4	All	The Wilderness Society	Least cost linkages	NA	NA	NA	NA	NA	NA	NA
173	4	All	AGFD	AZ multi-species corridors	NA	NA	NA	NA	NA	NA	NA

Table S13. Scenario List

Number	Name
1	In-State Base
2	In-State Base High DER
3	In-State Base Low Battery Cost
4	In-State Siting Level 1 Constrained Base
5	In-State Siting Level 1 Constrained High DER
6	In-State Siting Level 1 Constrained Low Battery Cost
7	In-State Siting Level 1 Unconstrained Base
8	In-State Siting Level 2 Constrained Base
9	In-State Siting Level 2 Constrained High DER
10	In-State Siting Level 2 Constrained Low Battery Cost
11	In-State Siting Level 2 Unconstrained Base
12	In-State Siting Level 3 Constrained Base
13	In-State Siting Level 3 Constrained High DER
14	In-State Siting Level 3 Constrained Low Battery Cost
15	In-State Siting Level 3 Unconstrained Base
16	In-State Siting Level 3 Unconstrained High DER
17	In-State Siting Level 3 Unconstrained Low Battery Cost
18	In-State Siting Level 4 Constrained Base
19	In-State Siting Level 4 Constrained High DER
20	In-State Siting Level 4 Constrained Low Battery Cost
21	In-State Siting Level 4 Unconstrained Base
22	Part West Base
23	Part West Base High DER
24	Part West Base Low Battery Cost
25	Part West Siting Level 1 Constrained Base
26	Part West Siting Level 1 Constrained High DER
27	Part West Siting Level 1 Constrained Low Battery Cost
28	Part West Siting Level 1 Unconstrained Base
29	Part West Siting Level 2 Constrained Base
30	Part West Siting Level 2 Constrained High DER
31	Part West Siting Level 2 Constrained Low Battery Cost
32	Part West Siting Level 2 Unconstrained Base
33	Part West Siting Level 3 Constrained Base
34	Part West Siting Level 3 Constrained High DER
35	Part West Siting Level 3 Constrained Low Battery Cost
36	Part West Siting Level 3 Unconstrained Base
37	Part West Siting Level 4 Constrained Base
38	Part West Siting Level 4 Constrained High DER
39	Part West Siting Level 4 Constrained Low Battery Cost
40	Part West Siting Level 4 Unconstrained Base
41	Full West Base
42	Full West Base High DER
43	Full West Base Low Battery Cost
44	Full West Siting Level 1 Constrained Base
45	Full West Siting Level 1 Constrained High DER
46	Full West Siting Level 1 Constrained Low Battery Cost
47	Full West Siting Level 1 Unconstrained Base
48	Full West Siting Level 2 Constrained Base
49	Full West Siting Level 2 Constrained High DER
50	Full West Siting Level 2 Constrained Low Battery Cost
51	Full West Siting Level 2 Unconstrained Base
52	Full West Siting Level 3 Constrained Base
53	Full West Siting Level 3 Constrained High DER
54	Full West Siting Level 3 Constrained Low Battery Cost
55	Full West Siting Level 3 Unconstrained Base
56	Full West Siting Level 3 Unconstrained High DER
57	Full West Siting Level 3 Unconstrained Low Battery Cost
58	Full West Siting Level 4 Constrained Base
59	Full West Siting Level 4 Constrained High DER
60	Full West Siting Level 4 Constrained Low Battery Cost
61	Full West Siting Level 4 Unconstrained Base

Table S14. Generation land area (km^2) for each technology for each scenario

	Technology	Geographic scenario	RESOLVE sensitivity	Base	Cat1	Cat2	Cat3	Cat4
1	Geothermal	Full West	Constrained Basecase	54	43	14	2	1
2	Geothermal	Full West	Constrained High DER	54	43	14	2	1
3	Geothermal	Full West	Constrained Low Battery Cost	54	43	14	2	1
4	Geothermal	Full West	Unconstrained Basecase		41	27	4	2
5	Geothermal	Full West	Unconstrained High DER				4	
6	Geothermal	Full West	Unconstrained Low Battery Cost				4	
7	Geothermal	Part West	Constrained Basecase	54	43	14	2	1
8	Geothermal	Part West	Constrained High DER	54	43	14	2	1
9	Geothermal	Part West	Constrained Low Battery Cost	54	43	14	2	1
10	Geothermal	Part West	Unconstrained Basecase		49	27	4	2
11	Geothermal	InState	Constrained Basecase	20	10	0	0	0
12	Geothermal	InState	Constrained High DER	20	10	0	0	0
13	Geothermal	InState	Constrained Low Battery Cost	20	10	0	0	0
14	Geothermal	InState	Unconstrained Basecase		10	0	0	0
15	Geothermal	InState	Unconstrained High DER				0	
16	Geothermal	InState	Unconstrained Low Battery Cost				0	
17	Solar	Full West	Constrained Basecase	1545	1611	1676	3434	3821
18	Solar	Full West	Constrained High DER	1392	1461	1497	3215	3821
19	Solar	Full West	Constrained Low Battery Cost	1605	1708	1763	3407	3821
20	Solar	Full West	Unconstrained Basecase		1591	1690	2255	3236
21	Solar	Full West	Unconstrained High DER				2067	
22	Solar	Full West	Unconstrained Low Battery Cost				2292	
23	Solar	Part West	Constrained Basecase	3264	3483	3610	3978	3724
24	Solar	Part West	Constrained High DER	3042	3276	3415	3708	3388
25	Solar	Part West	Constrained Low Battery Cost	3343	3476	3560	3967	3661
26	Solar	Part West	Unconstrained Basecase		2882	2818	3070	3660
27	Solar	InState	Constrained Basecase	4152	4455	4626	4107	4844
28	Solar	InState	Constrained High DER	3937	4172	4394	3767	4398
29	Solar	InState	Constrained Low Battery Cost	4070	4367	4575	4061	4827
30	Solar	InState	Unconstrained Basecase		4003	4184	5080	5468
31	Solar	InState	Unconstrained High DER				4801	
32	Solar	InState	Unconstrained Low Battery Cost				5001	
33	Wind	Full West	Constrained Basecase	8056	8682	8979	3512	1517
34	Wind	Full West	Constrained High DER	7861	8421	8822	3512	1517
35	Wind	Full West	Constrained Low Battery Cost	7698	8094	8362	3512	1517
36	Wind	Full West	Unconstrained Basecase		7681	7457	6500	4545
37	Wind	Full West	Unconstrained High DER				6478	
38	Wind	Full West	Unconstrained Low Battery Cost				6144	
39	Wind	Part West	Constrained Basecase	3170	3170	2910	2092	1235
40	Wind	Part West	Constrained High DER	3170	3170	2910	2092	1235
41	Wind	Part West	Constrained Low Battery Cost	2456	2822	2834	2092	1235
42	Wind	Part West	Unconstrained Basecase		5285	5972	6098	2996
43	Wind	InState	Constrained Basecase	341	341	207	95	82
44	Wind	InState	Constrained High DER	341	341	207	95	82
45	Wind	InState	Constrained Low Battery Cost	341	341	207	95	82
46	Wind	InState	Unconstrained Basecase		1678	798	183	119
47	Wind	InState	Unconstrained High DER				183	
48	Wind	InState	Unconstrained Low Battery Cost				183	

Table S15. Gen-tie transmission land area (km2) for each technology for each scenario

	Technology	Geographic scenario	RESOLVE sensitivity	Base	Cat1	Cat2	Cat3	Cat4
1	Geothermal	Full West	Constrained Basecase	1	1.1	0.0	0.0	0.0
2	Geothermal	Full West	Constrained High DER	1	1.1	0.0	0.0	0.0
3	Geothermal	Full West	Constrained Low Battery Cost	1	1.1	0.0	0.0	0.0
4	Geothermal	Full West	Unconstrained Basecase		2.9	1.8	0.0	0.0
5	Geothermal	Full West	Unconstrained High DER				0.0	
6	Geothermal	Full West	Unconstrained Low Battery Cost				0.0	
7	Geothermal	Part West	Constrained Basecase	1	1.1	0.0	0.0	0.0
8	Geothermal	Part West	Constrained High DER	1	1.1	0.0	0.0	0.0
9	Geothermal	Part West	Constrained Low Battery Cost	1	1.1	0.0	0.0	0.0
10	Geothermal	Part West	Unconstrained Basecase		2.9	1.8	0.0	0.0
11	Geothermal	InState	Constrained Basecase	1	1.1	0.0	0.0	0.0
12	Geothermal	InState	Constrained High DER	1	1.1	0.0	0.0	0.0
13	Geothermal	InState	Constrained Low Battery Cost	1	1.1	0.0	0.0	0.0
14	Geothermal	InState	Unconstrained Basecase		1.1	0.0	0.0	0.0
15	Geothermal	InState	Unconstrained High DER				0.0	
16	Geothermal	InState	Unconstrained Low Battery Cost				0.0	
17	Solar	Full West	Constrained Basecase	1	0.7	2.6	64.1	107.5
18	Solar	Full West	Constrained High DER	1	0.9	2.9	62.9	107.5
19	Solar	Full West	Constrained Low Battery Cost	1	0.8	2.6	64.0	107.5
20	Solar	Full West	Unconstrained Basecase		0.2	10.0	15.2	23.1
21	Solar	Full West	Unconstrained High DER				15.7	
22	Solar	Full West	Unconstrained Low Battery Cost				25.2	
23	Solar	Part West	Constrained Basecase	1	2.1	2.7	76.1	98.8
24	Solar	Part West	Constrained High DER	1	2.1	0.1	74.3	98.5
25	Solar	Part West	Constrained Low Battery Cost	2	2.0	2.6	62.7	98.8
26	Solar	Part West	Unconstrained Basecase		26.7	5.2	30.9	26.5
27	Solar	InState	Constrained Basecase	1	1.6	12.9	22.5	97.5
28	Solar	InState	Constrained High DER	1	1.3	12.8	18.0	61.7
29	Solar	InState	Constrained Low Battery Cost	1	1.6	12.8	83.2	94.7
30	Solar	InState	Unconstrained Basecase		4.8	55.3	82.0	53.5
31	Solar	InState	Unconstrained High DER				79.4	
32	Solar	InState	Unconstrained Low Battery Cost				81.4	
33	Wind	Full West	Constrained Basecase	49	52.7	82.2	112.3	22.8
34	Wind	Full West	Constrained High DER	49	49.7	81.7	112.3	22.8
35	Wind	Full West	Constrained Low Battery Cost	47	48.9	81.3	112.3	22.8
36	Wind	Full West	Unconstrained Basecase		52.3	99.7	194.2	179.2
37	Wind	Full West	Unconstrained High DER				190.3	
38	Wind	Full West	Unconstrained Low Battery Cost				181.1	
39	Wind	Part West	Constrained Basecase	30	30.1	37.5	38.8	15.1
40	Wind	Part West	Constrained High DER	30	30.1	37.5	38.8	15.1
41	Wind	Part West	Constrained Low Battery Cost	28	29.2	36.9	38.8	15.1
42	Wind	Part West	Unconstrained Basecase		38.8	51.6	246.3	104.5
43	Wind	InState	Constrained Basecase	2	2.2	1.5	0.9	1.3
44	Wind	InState	Constrained High DER	2	2.2	1.5	0.9	1.3
45	Wind	InState	Constrained Low Battery Cost	2	2.2	1.5	0.9	1.3
46	Wind	InState	Unconstrained Basecase		14.7	6.9	1.4	1.8
47	Wind	InState	Unconstrained High DER				1.4	
48	Wind	InState	Unconstrained Low Battery Cost				1.4	

Table S16. Gen-tie transmission land area percentage (%) out of total area (gen-tie transmission and generation) for each technology for each scenario

	Technology	Geographic scenario	RESOLVE sensitivity	Base	Cat1	Cat2	Cat3	Cat4
1	Geothermal	Full West	Constrained Basecase	2	2.6	0.0	0.0	0.0
2	Geothermal	Full West	Constrained High DER	2	2.6	0.0	0.0	0.0
3	Geothermal	Full West	Constrained Low Battery Cost	2	2.6	0.0	0.0	0.0
4	Geothermal	Full West	Unconstrained Basecase		6.6	6.2	0.0	0.0
5	Geothermal	Full West	Unconstrained High DER				0.0	
6	Geothermal	Full West	Unconstrained Low Battery Cost				0.0	
7	Geothermal	Part West	Constrained Basecase	2	2.6	0.0	0.0	0.0
8	Geothermal	Part West	Constrained High DER	2	2.6	0.0	0.0	0.0
9	Geothermal	Part West	Constrained Low Battery Cost	2	2.6	0.0	0.0	0.0
10	Geothermal	Part West	Unconstrained Basecase		5.6	6.2	0.0	0.0
11	Geothermal	InState	Constrained Basecase	5	10.5	0.0		
12	Geothermal	InState	Constrained High DER	5	10.5	0.0		
13	Geothermal	InState	Constrained Low Battery Cost	5	10.5	0.0		
14	Geothermal	InState	Unconstrained Basecase		10.5	0.0		
15	Geothermal	InState	Unconstrained High DER					
16	Geothermal	InState	Unconstrained Low Battery Cost					
17	Solar	Full West	Constrained Basecase	0	0.0	0.2	1.8	2.7
18	Solar	Full West	Constrained High DER	0	0.1	0.2	1.9	2.7
19	Solar	Full West	Constrained Low Battery Cost	0	0.0	0.1	1.8	2.7
20	Solar	Full West	Unconstrained Basecase		0.0	0.6	0.7	0.7
21	Solar	Full West	Unconstrained High DER				0.8	
22	Solar	Full West	Unconstrained Low Battery Cost				1.1	
23	Solar	Part West	Constrained Basecase	0	0.1	0.1	1.9	2.6
24	Solar	Part West	Constrained High DER	0	0.1	0.0	2.0	2.8
25	Solar	Part West	Constrained Low Battery Cost	0	0.1	0.1	1.6	2.6
26	Solar	Part West	Unconstrained Basecase		0.9	0.2	1.0	0.7
27	Solar	InState	Constrained Basecase	0	0.0	0.3	0.5	2.0
28	Solar	InState	Constrained High DER	0	0.0	0.3	0.5	1.4
29	Solar	InState	Constrained Low Battery Cost	0	0.0	0.3	2.0	1.9
30	Solar	InState	Unconstrained Basecase		0.1	1.3	1.6	1.0
31	Solar	InState	Unconstrained High DER				1.6	
32	Solar	InState	Unconstrained Low Battery Cost				1.6	
33	Wind	Full West	Constrained Basecase	1	0.6	0.9	3.1	1.5
34	Wind	Full West	Constrained High DER	1	0.6	0.9	3.1	1.5
35	Wind	Full West	Constrained Low Battery Cost	1	0.6	1.0	3.1	1.5
36	Wind	Full West	Unconstrained Basecase		0.7	1.3	2.9	3.8
37	Wind	Full West	Unconstrained High DER				2.9	
38	Wind	Full West	Unconstrained Low Battery Cost				2.9	
39	Wind	Part West	Constrained Basecase	1	0.9	1.3	1.8	1.2
40	Wind	Part West	Constrained High DER	1	0.9	1.3	1.8	1.2
41	Wind	Part West	Constrained Low Battery Cost	1	1.0	1.3	1.8	1.2
42	Wind	Part West	Unconstrained Basecase		0.7	0.9	3.9	3.4
43	Wind	InState	Constrained Basecase	1	0.6	0.7	0.9	1.6
44	Wind	InState	Constrained High DER	1	0.6	0.7	0.9	1.6
45	Wind	InState	Constrained Low Battery Cost	1	0.6	0.7	0.9	1.6
46	Wind	InState	Unconstrained Basecase		0.9	0.9	0.8	1.5
47	Wind	InState	Unconstrained High DER				0.8	
48	Wind	InState	Unconstrained Low Battery Cost				0.8	

Table S17. Gen-tie transmission land area percentage (%) out of total area (gen-tie transmission and generation) summed across technologies for each scenario

	Geographic scenario	RESOLVE sensitivity	Base	Cat1	Cat2	Cat3	Cat4
1	Full West	Constrained Basecase	1	0.5	0.8	2.5	2.4
2	Full West	Constrained High DER	1	0.5	0.8	2.5	2.4
3	Full West	Constrained Low Battery Cost	1	0.5	0.8	2.5	2.4
4	Full West	Unconstrained Basecase		0.6	1.2	2.3	2.5
5	Full West	Unconstrained High DER				2.4	
6	Full West	Unconstrained Low Battery Cost				2.4	
7	Part West	Constrained Basecase	0	0.5	0.6	1.9	2.2
8	Part West	Constrained High DER	1	0.5	0.6	1.9	2.4
9	Part West	Constrained Low Battery Cost	1	0.5	0.6	1.6	2.3
10	Part West	Unconstrained Basecase		0.8	0.7	2.9	1.9
11	InState	Constrained Basecase	0	0.1	0.3	0.6	2.0
12	InState	Constrained High DER	0	0.1	0.3	0.5	1.4
13	InState	Constrained Low Battery Cost	0	0.1	0.3	2.0	1.9
14	InState	Unconstrained Basecase		0.4	1.2	1.6	1.0
15	InState	Unconstrained High DER				1.6	
16	InState	Unconstrained Low Battery Cost				1.6	

Additional data table S1 (EnvironmentalExclusionCategoryDataSources.xlsx)
Data sources and links for each Environmental Exclusion Category (Step 1). Extended versions of Tables S9–S12.

Additional data table S2 (ResourceAssessment.xlsx)
Unadjusted resource potential results (capacity in megawatts, MW) from resource assessment for states used in RESOLVE (used to make SI Fig. S4)

Additional data table S3 (ResourceAssessment.xlsx)
Adjusted resource potential results (capacity in megawatts, MW) from resource assessment for states used in RESOLVE, supply curve inputs for RESOLVE modeling (used to make SI Fig. S3)

Additional data table S4 (CapacityExpansionResults_RESOLVEportfolios.xlsx)
Total resource cost of each portfolio

Additional data table S5 (CapacityExpansionResults_RESOLVEportfolios.xlsx)
Cost breakdown of each portfolio

Additional data table S6 (CapacityExpansionResults_RESOLVEportfolios.xlsx)
Selected capacity (MW) by RESOLVE Zone by 2050 for all portfolios

Additional data table S7 (CapacityExpansionResults_RESOLVEportfolios.xlsx)
Generation (MWh) of selected capacity (MW) by RESOLVE Zone by 2050 for all portfolios

Additional data table S8 (CapacityExpansionResults_RESOLVEportfolios.xlsx)
Total (selected + existing and contracted) Capacity (MW) across all RESOLVE Zones by 2050 for all portfolios

Additional data table S9 (CapacityExpansionResults_RESOLVEportfolios.xlsx)
Selected capacity (MW) across all RESOLVE Zone by 2050 for all portfolios

Additional data table S10 (CapacityExpansionResults_RESOLVEportfolios.xlsx)
Generation (MWh) across all RESOLVE Zones by 2050 for all portfolios

Additional data table S11 (StrategicEnvAssessment.xlsx)
Strategic Environmental Assessment results for generation aggregated across all RESOLVE Zones or regions

Additional data table S12 (StrategicEnvAssessment.xlsx)
Strategic Environmental Assessment results for generation by RESOLVE Zone or region

Additional data table S13 (StrategicEnvAssessment.xlsx)
Strategic Environmental Assessment results for transmission aggregated across all RESOLVE Zones or region

Additional data table S14 (StrategicEnvAssessment.xlsx)
Strategic Environmental Assessment results for transmission by RESOLVE Zone or region

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