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California Energy Commission

DRAFT STAFF REPORT

Land-Use Screens for Electric System Planning

Using Geographic Information Systems to Model Opportunities and Constraints for Renewable Resource Technical Potential in California

October 2022 | CEC-700-2022-006-SD

California Energy Commission

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ABSTRACT

This report, *Land-Use Screens for Electric System Planning: Using Geographic Information Systems to Model Opportunities and Constraints for Renewable Resource Technical Potential in California* (Land Use Screens Staff Report), describes updates to land-use screens for electric system planning. The staff report provides technical updates to the methodology for using biodiversity, habitat, and agricultural datasets to assess renewable resource technical potential for onshore wind, solar photovoltaic, and geothermal resources for electric system modeling and resource planning. The staff report summarizes the historical application and evolution of land-use screens developed and applied by the California Energy Commission and California Public Utilities Commission.

Keywords: Land-use screen, renewable resource technical potential, GIS, biodiversity, agriculture, cropland, SB 100, solar energy, onshore wind energy, geothermal energy, suitability modeling

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EXECUTIVE SUMMARY

Since 2008, the California Energy Commission (CEC), California Public Utilities Commission (CPUC), and California Independent System Operator (California ISO) have used spatial environmental and land-use data to guide their relevant energy resource planning. Over time, the methods and data used have evolved, reflecting the availability of new information and new planning initiatives related to biodiversity conservation, agricultural resource protection, and renewable resource development. In parallel, California's climate and clean energy mandates have increased. The 100 Percent Clean Energy Act of 2018 (Senate Bill 100, De León, Chapter 312, Statutes of 2018) sets a 2045 target of supplying all retail electricity sold in California and state agency electricity needs with renewable and zero-carbon energy resources. Senate Bill (SB) 100 also increased the state's Renewables Portfolio Standard (RPS) procurement target to 60 percent of retail sales by December 31, 2030, and requires all state agencies to incorporate the 2030 and 2045 targets into their relevant planning.

This report, *Land-Use Screens for Electric System Planning: Using Geographic Information Systems to Model Opportunities and Constraints for Renewable Resource Technical Potential in California* (Land Use Screens Staff Report), describes updates to land-use screens for electric system planning. Land-use screens are map-based footprints delineating important environmental, land-use, and physical characteristics of the land. The staff report provides technical updates to the methodology for using environmental and land-use datasets (such as, biodiversity, habitat, and cropland) to assess renewable resource technical potential for onshore wind, solar photovoltaic, and geothermal technologies for electric system planning. The renewable resource technical potential of a technology is its achievable energy generation given technoeconomic, topographic, environmental, and land-use constraints. CEC staff has created three models to provide a transparent and data-driven means for assessing a range of considerations in electric system planning, including renewable resource, biodiversity, and agricultural potential. Together, this information can be used to inform electric system planning and to help system planners focus on areas that have a greater potential for successful deployment of new utility-scale renewable energy capacity. The use of land-use screens in electric system planning has several benefits including increased transparency in decision making and early identification of issues or barriers to development, which supports long-term reliability in planning for long-lead time investments, such as transmission.

The models and land-use screens described in this report are for use in electric system planning and modeling. The geospatial land-use screens are intended to inform high-level estimates of renewable resource technical potential for electric system planning and should not be used, on their own, to guide siting of generation projects nor assess project-level impacts.

CHAPTER 1: Background

Senate Bill 100 of 2018

The 100 Percent Clean Energy Act of 2018 (Senate Bill 100, De León, Chapter 312, Statutes of 2018) sets a 2045 target of supplying all retail electricity sold in California and state agency electricity needs with renewable and zero-carbon resources.[1] SB 100 also increased the state's Renewables Portfolio Standard (RPS) procurement target to 60 percent of retail sales by December 31, 2030, and requires all state agencies to incorporate the 2030 and 2045 targets into their relevant planning. SB 100 requires the California Energy Commission (CEC), California Public Utilities Commission (CPUC), and California Air Resources Board (CARB) to use programs under existing laws to achieve 100 percent clean energy and issue a joint policy report on SB 100 by 2021 and every four years thereafter. The Clean Energy, Jobs, and Affordability Act of 2022 (Senate Bill 1020, Laird, Chapter 361, Statutes of 2022) revises SB 100 to instead provide that eligible renewable energy resources and zero-carbon resources supply 90 percent of all retail sales of electricity to California end-use customers by December 31, 2035, 95 percent of all retail sales of electricity to California end-customers by December 31, 2040, 100 percent of all retail sales of electricity to California end-use customers by December 31, 2045, and 100 percent of electricity procured to serve all states agencies by December 31, 2035.

The [2021 Joint Agency SB 100 Report](https://efiling.energy.ca.gov/EFiling/GetFile.aspx?tn=237167&DocumentContentId=70349) assessed various pathways to achieve the SB 100 target and an initial assessment of costs and benefits. One key finding from the report was that sustained record-setting renewable generation and energy storage build rates will be required to meet the target in a high electrification future, citing growing electricity demand as a significant driver.[2] The added electricity demand from the various modeled pathways to achieve economywide decarbonization created a significant resource need, regardless of the SB 100 portfolio studied. This added demand has implications for land use that must be considered for successful implementation of SB 100. Recognizing the potential implications for land use from the resource build necessary to achieve the SB 100 target, the report included several recommendations related to developing new methods to include land-use implications in electric system modeling.[3]

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1 Senate Bill 100 (De León, Chapter 312, Statutes of 2018).

2 CEC, CPUC, and CARB. 2021. *2021 SB 100 Joint Agency Report Achieving 100 Percent Clean Electricity in California: An Initial Assessment.* Publication Number: CEC-200-2021, https://efiling.energy.ca.gov/EFiling/GetFile.aspx?tn=237167&DocumentContentId=70349.

3 Ibid., page 18.

The updated land-use screens methods presented in this report reflect one approach for how the joint agencies are integrating land-use implications[4] in electric system modeling.

California's Biodiversity Conservation, Land Use, and Energy Planning Initiatives

California's vast array of natural and working landscapes all play important roles in the state's climate change strategy. Healthy landscapes can sequester and store carbon and build resilience to future impacts of climate change.[5] The state's natural areas are home to biodiversity found nowhere else on Earth and ecosystems that sustain communities, support the economy, and protect people and nature from the impacts of climate change. California's climate strategy further depends on reducing carbon pollution and shifting to clean energy resources. Integrated energy and land-use planning that identifies important locations for land conservation and those more suitable for renewable resource development will ensure the state conserves the health of its natural and working landscapes while achieving the state's climate targets, including carbon neutrality[6] and SB 100.

California's state agencies have worked extensively with stakeholders and other agencies through science-based collaborative planning in several geographic areas of the state with renewable energy potential. Previous planning efforts include the first and second Renewable Energy Transmission Initiatives (RETI) processes,[7] the joint agency collaboration to develop the Desert Renewable Energy Conservation Plan (DRECP),[8] and the stakeholder-led San Joaquin Valley Identification of Least-Conflict Lands study.[9] Through these planning efforts, federal and state agencies, local governments, tribes, and stakeholders have gained experience with landscape-level approaches[10] that assess natural and working lands upfront in planning for large-scale future energy development (for example, onshore wind and utility-

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4 In this analysis, *implication* is defined as a possible significance or a likely consequence of an action, for example, planning for energy infrastructure development in area of higher biodiversity has *implications* for other land-use priorities.

5 California Natural Resources Agency. 2022. *Natural and Working Lands Climate Smart Strategy,* available at https://resources.ca.gov/Initiatives/Expanding-Nature-Based-Solutions.

6 Executive Order B-55-18, available at https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf.

7 Final RETI Phase 2A report, available at https://ww2.energy.ca.gov/2009publications/RETI-1000-2009-001/RETI-1000-2009-001-F-REV2.PDF. Final RETI 2.0 report, available at http://docketpublic.energy.ca.gov/PublicDocuments/15-RETI-02/TN216198_20170223T095548_RETI_20_Final_Plenary_Report.pdf.

8 *Desert Renewable Energy Conservation Plan,* available at https://www.energy.ca.gov/programs-and-topics/programs/desert-renewable-energy-conservation-plan.

9 See *A Path Forward: Identifying Least-Conflict Solar PV Development in California's San Joaquin Valley.* Available at https://sjvp.databasin.org/pages/least-conflict.

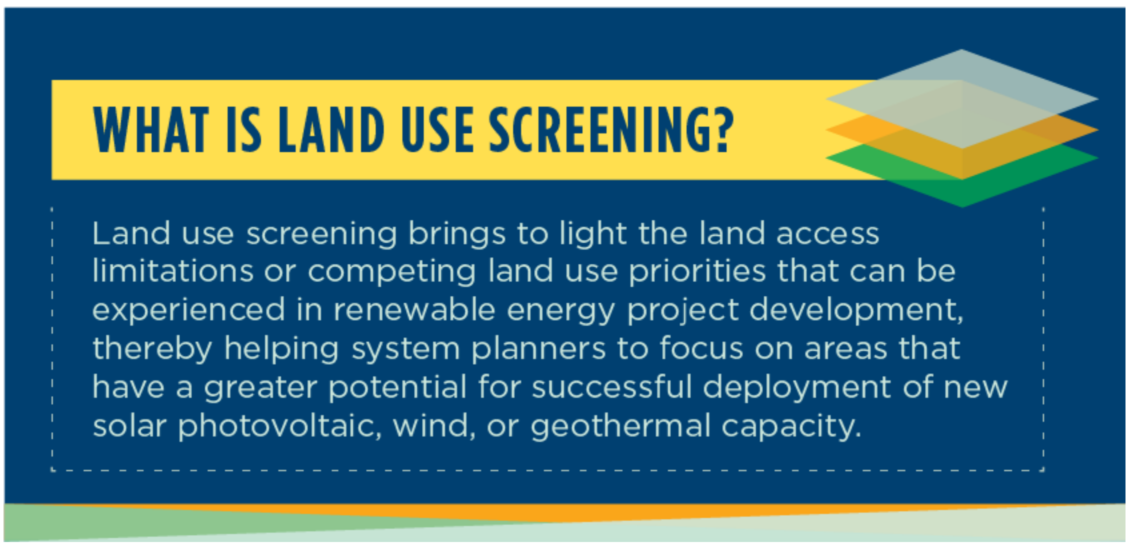
10 Landscape-level approaches, also known as landscape-scale planning, consider a wide range of potential constraints and conflicts, including environmental sensitivity, conservation and other land uses, tribal cultural resources, and more when considering future renewable energy development.

scale solar). This upfront planning aims to improve landscape resilience and function over the long term while delivering the significant clean energy generation and storage capacity needed to achieve the state's climate mandates.

There are several benefits to integrated energy and land use planning, such as the early identification of issues or barriers to development, increased transparency in decision making, limiting impacts, more rapid deployment of environmentally responsible renewable energy projects, and informing transmission planning. Integrated planning is most effective when employed early in planning, and one of the earliest opportunities is in California's electric system planning.

Land-Use Screens in California Electric System Planning

Since 2008, the CEC, CPUC, and California ISO have used spatial environmental and land-use data to guide their relevant energy resource planning. This geospatial analysis is commonly known as *land-use screening* or *resource mapping*. The geospatial datasets in a land-use screen may include technical, environmental, and land-use priorities and considerations.



In 2015, the CPUC implemented land-use screens in developing electric system planning portfolios. Two land-use screens were initially available in the CPUC's Renewable Portfolio Standard (RPS) Calculator (1) Environmental Baseline and (2) DRECP Development Focus Areas (DFAs). That same month, the CPUC released a staff paper titled *Energy Division's Staff Paper on Incorporating Land Use and Environmental Information into the RPS Calculator and Developing and Selecting RPS Calculator Portfolios.*[11]

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11 See *Energy Division's Staff Paper on Incorporating Land Use and Environmental Information into the RPS Calculator and Developing and Selecting RPS Calculator Portfolios*, available at available at https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2019-2020-irp-events-and-materials/rpscalc_landuseportselstaffpaper_20150825.pdf.

The RPS Calculator was a Microsoft Excel®-based renewable resource planning tool that developed plausible portfolios of RPS resources that meet a specific RPS procurement target. Portfolios from the RPS Calculator were used in several planning activities, including the CPUC's Long Term Procurement Plan (LTPP) scenario development and the California ISO's Transmission Planning Process (TPP).

Following the passage of Senate Bill 350 (SB 350, De León, Chapter 547, Statutes of 2015), the CPUC began implementing a process for integrated resource planning (IRP). The CPUC's IRP process seeks to reduce the cost of achieving greenhouse gas emission (GHG) reductions and other policy goals by looking across load-serving entity (LSE) boundaries and resource types to identify solutions to reliability, cost, or other concerns that might not otherwise be identified without an integrated planning process. The IRP process includes capacity expansion modeling, using the RESOLVE model, of the electric system, providing the analytical foundation for the CPUC to require LSEs to procure new energy resources, such as renewable generation and storage resources to achieve California's goals. RESOLVE co-optimizes investment and dispatch to identify least-cost resource portfolios that meet policy and reliability targets. The CPUC's IRP process includes land-use screens as part of the RESOLVE model. The land-use screens in RESOLVE are, on average, updated biennially.

Between 2018 and 2022, the RESOLVE model included six options for environmental screens. Each screen included a different combination of geospatial datasets, resulting in more or less land meeting the screening criteria and, therefore, different amounts of renewable resource technical potential[12] available for selection by the model:[13]

1. Base: includes RETI Category 1 exclusions only
2. Environmental Baseline (EnvBase): includes RETI Category 1 and 2 exclusions
3. NGO1: modified version of RETI Category 1 screen, developed by environmental nongovernmental organizations (NGOs)
4. NGO1&2: modified version of RETI Category 2 screen, developed by environmental NGOs
5. DRECP/SJV: applies RETI Categories 1 and 2 exclusions and focuses on preferred development areas only in the DRECP and San Joaquin Valley (SJV). Preferred development areas are defined as DRECP Development Focus Areas (DFAs) and least

12 The National Renewable Energy Laboratory defines the renewable resource technical potential of a technology as "its achievable energy generation given system performance, topographic, environmental, and land-use constraints," available at https://www.nrel.gov/gis/re-potential.html.

13 The model is available in *Inputs & Assumptions: 2019–2020 Integrated Resource Planning,* https://files.cpuc.ca.gov/energy/modeling/Inputs%20%20Assumptions%202019-2020%20CPUC%20IRP%202020-02-27.pdf.

conflict lands for solar photovoltaic (PV) as identified in *A Path Forward: Identifying Least-Conflict Solar PV Development in California's San Joaquin Valley*.[14]

6. Conservative: this screen applied the most conservative value from the above five screens

CPUC staff selected the DRECP/SJV screen for Integrated Resource Plan RESOLVE modeling for all cycles between 2018 and 2022.

The joint agencies selected the DRECP/SJV resource screen for the 2021 SB 100 analysis and joint agency report for consistency with the CPUC's IRP.

Between 2018 and 2021, CEC staff in collaboration with the CPUC, introduced new methods for land-use screening and resource mapping in resource-to-busbar mapping ("busbar mapping").[15] *Busbar mapping* is the process of refining the energy resource portfolios produced in the CPUC's IRP — which are at a geographic scale too broad for transmission planning to specific interconnection locations (that is, substations) for analysis in California ISO's TPP. The objective of introducing new methods for land-use screening was to incorporate additional statewide environmental information to better understand implications, from a landscape perspective, of mapped areas with renewable resource potential. The new methods included use of the following geospatial datasets[16] to explore environmental and land use implications:

- Energy resource potential and exclusion datasets provided by CPUC staff
- Areas of Conservation Emphasis (ACE), Version 3.0, Terrestrial Biodiversity and Terrestrial Connectivity[17]
- Terrestrial Landscape Intactness (California Energy Commission and Conservation Biology Institute, 2016)[18]

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14 See *A Path Forward: Identifying Least-Conflict Solar PV Development in California's San Joaquin Valley.* Available at https://sjvp.databasin.org/pages/least-conflict.

15 See *Energy Commission Staff Proof of Concept Report to CPUC Staff,* available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=222569&DocumentContentId=30438. See *Methodology for Resource-to-Busbar Mapping & Assumptions for the 2021–2022 TPP,* available at https://files.cpuc.ca.gov/energy/modeling/Busbar%20Mapping%20Methodology%20for%202021-2022%20TPP_V.2021-01-07.pdf. See *Methodology for Resource-to-Busbar Mapping & Assumptions for the Annual TPP*, available at Busbar Mapping Methodology for the TPP_V2021_12_21.pdf (ca.gov).

16 *Geospatial datasets* are digital representations of information specific to a location relative to the surface of the Earth that can be composed of separate elements but can be arranged as a unit.

17 "Areas of Conservation Emphasis." California Department of Fish and Wildlife. Available at https://wildlife.ca.gov/Data/Analysis/Ace.

18 "Landscape Intactness (1 km.), California." Data Basin. Available at https://databasin.org/datasets/e3ee00e8d94a4de58082fdbc91248a65.

- California Agricultural Value (California Energy Commission and Conservation Biology Institute, 2018)[19]

CEC staff applied the new land-use screening and resource mapping method in developing the *SB 100 Starting Point for the California ISO 20-Year Transmission Outlook.*[20] The land-use screening and resource mapping methodology was presented for public input at an August 12, 2021, workshop.[21]

On February 22, 2022, CEC, CPUC, and California ISO held a workshop to discuss approaches for examining the environmental and land-use implications of potential resource portfolios to meet SB 100.[22] This workshop included agency presentations and discussion on land-use screening and resource mapping.

The *2022 Integrated Energy Policy Report Update (2022 IEPR Update)* Scoping Order[23] noted that land-use screens would be enhanced and integrated into a California Planning Library. CEC staff sought input on the California Planning Library at the April 27, 2022, Integrated Energy Policy Report workshop.[24] The workshop included a panel of expert data users and discussed the most widely requested CEC analytical products.

Following the August 2021, February 2022, and April 2022 workshops, the CEC considered public comments and coordinated with state and federal agencies to review information used in land-use screening for electric system planning. As presented in this report, CEC staff propose updating the land-use screens used to support the IRP, SB 100 modeling, and busbar mapping. The revised methodology for the land-use screens aims to improve on past efforts by:

- Updating data to capture new information.
- Updating data to reflect new state conservation priorities and climate initiatives.

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19 "California Agricultural Value." 2018. Data Basin. Available at https://databasin.org/datasets/f55ea5085c024a96b5f17c7ddddd1147.

20 California Energy Commission staff. September 2021. *SB 100 Starting Point for the California ISO 20-Year Transmission Outlook*. California Energy Commission. Available at TN239685_20210913T160327_SB 100 Starting Point for the California ISO 20-Year Transmission Outlook (17).pdf.

21 Workshop materials available at https://www.energy.ca.gov/event/workshop/2021-08/joint-agency-workshop-next-steps-plan-senate-bill-100-resource-build.

22 Workshop materials available at https://www.energy.ca.gov/event/workshop/2022-02/joint-agency-workshop-plan-senate-bill-100-resource-build-analysis-land-use.

23 Scoping Order for the 2022 IEPR Update, https://efiling.energy.ca.gov/GetDocument.aspx?tn=242747&DocumentContentId=76300.

24 April 27, 2022, IEPR Commissioner Workshop on the California Planning Library. https://www.energy.ca.gov/event/workshop/2022-04/iepr-commissioner-workshop-california-planning-library.

- Updating the methodology to incorporate the latest agency and stakeholder input.

Based on the CEC staff's analysis of publicly available geospatial information as presented and evaluated in this report and feedback from agencies and the public, CEC staff recommends the following three revised land-use screens for electric system planning.

Table 1: Proposed Revised Land-Use Screens

Screen Name	Categories of Data Included
Land Use Screen 1	Base exclusions, biodiversity, cropland
Land Use Screen 2	Base exclusions, biodiversity, cropland, landscape intactness, proximity to protected areas
Land Use Screen 3	Base exclusions, biodiversity, cropland, terrestrial climate resilience

Source: CEC staff

The three land-use screens presented within this report build upon and update the land-use screens that are in use by the CEC and CPUC.

Land-Use Screen 1: This land-use screen addresses several state policy priorities, including sustaining agriculture and protecting natural lands that support biodiversity.[25] CEC staff recommends use of Land-Use Screen 1 as the primary screen for estimating renewable resource technical potential for onshore wind and solar PV for use in electric system planning (for example, capacity expansion modeling in SB 100 and CPUC IRP analysis.)

Land-Use Screen 2: This land-use screen addresses several state policy priorities, including sustaining agriculture and protecting natural lands that support biodiversity.[26] Further, this screen incorporates statewide information about intact landscapes (for example, lands with low levels of human disturbance) and adjacency to protected areas. CEC staff recommends using Land-Use Screen 2 in busbar mapping and exploring trade-offs in SB 100 land-use analysis.

Land-Use Screen 3: This land-use screen addresses several state policy priorities, including sustaining agriculture and protecting natural lands that support biodiversity.[27] Further, this screen incorporates statewide information about lands that have a higher probability of serving

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25 Executive Order N-82-20, available at https://www.gov.ca.gov/wp-content/uploads/2020/10/10.07.2020-EO-N-82-20-.pdf.

26 Ibid.

27 Ibid.

as refugia[28] for species adapting to climate change. Conserving refugia is an important part of adaptation planning and a means of building resilience to climate change. CEC staff recommends using Land-Use Screen 3 in busbar mapping and exploring trade-offs in SB 100 land-use analysis.

The use of these land-use screens in electric system planning, including SB 100, IRP, and busbar mapping for the TPP, has several benefits including increased transparency in decision making and early identification of issues or barriers to development, which supports long-term reliability in planning for long-lead time investments, such as transmission.

28 Refugia are areas relatively buffered from the effects of climate change, where conditions will likely remain suitable for the current array of plants and wildlife that reside within a location, and where ecological functions are more likely to remain intact. Available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=150836&inline.

CHAPTER 2: Methods Overview

This chapter describes the methods CEC staff used to construct a high-level land-use evaluation in California for electric system planning. The land-use evaluation identifies areas with renewable energy resource technical potential after considering technical and economic criteria commonly applied in energy infrastructure development,[29] legal restrictions, and planning considerations for biodiversity, lands used to produce crops, terrestrial landscape intactness, and terrestrial climate resilience. The information used in the evaluation is organized into three main categories: 1) lands where renewable resource potential is excluded based on technical or economic criteria, 2) legally protected areas,[30] and 3) land-use planning considerations related to biodiversity, croplands, landscape intactness, and terrestrial climate resilience. Geospatial data sets that represent these factors on a statewide scale are identified and compiled into a map so that the remaining areas can be quantified to estimate renewable resource technical potential for electric system modeling and energy resource planning.

The information described in the first two categories above are combined into a base exclusion layer that removes renewable resource potential on these lands from further consideration in energy resource planning. Lands with remaining renewable resource potential are further evaluated for planning considerations related to biodiversity, cropland, and terrestrial landscape intactness using three spatial models. The result of evaluating land in terms of planning considerations is defined as *land-use screening*, and the result of applying a land-use screen is an estimate of lands with renewable resource technical potential available in various regions throughout the state. The outputs are reported in acres and capacity (for example, megawatt [MW] or gigawatt [GW]).

For a detailed description of the technical geographic information systems (GIS) methods applied in land-use-screen development and analysis, see **Appendix C**. The process to revise the land-use screens included the following key steps.

1. Reviewed geospatial datasets used in previous land-use screenings to identify areas in California with renewable resource technical potential for energy resource planning.
2. Collected and updated, where necessary, geospatial datasets to reflect the availability of more recent information from state and federal agencies.

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29 Spatial datasets that capture technical (for example, competitive wind resource locations), physical (for example, slope, water bodies), and socio-economic or hazardous (for example, densely populated areas, railways, airports, mines, flood zones) criteria. This category also includes military lands. The data sets that were used in this exclusion category were provided by CPUC staff.

30 Areas where utility-scale renewable energy or transmission development is presently precluded by state or federal law, policy, or regulation.

3. Created renewable resource potential basemaps[26] for solar photovoltaic, onshore wind, and geothermal capacity by mapping areas of energy development restrictions into base exclusions.
4. Created three spatial models using the ArcGIS Pro Suitability Modeler[27] to evaluate several factors simultaneously in designated land-use categories (for example, cropland, biodiversity, and landscape intactness).
5. Constructed three new land-use screens that reflect the preference for new renewable resource potential from lower implication regions from the model results. The land-use screens are used in conjunction with the resource potential basemap to further refine the areas within California available for possible renewable resource potential.

The land-use evaluation summarized above attempts to objectively quantify the amount of land with renewable energy resource potential and general regions of availability. This process is described in the diagram below (Figure 1). Ultimately, the land-use screens provide a refined estimate of renewable resource technical potential that short-term forecasts and long-term energy planning processes can use to plan for the integration of new renewable energy resources necessary to achieve climate and clean energy targets.

Figure 1: Land-Use Evaluation Methods

Source: CEC staff

This diagram shows the procedure CEC staff used to incorporate land use screens to assess renewable resource technical potential for utility-scale solar and onshore wind.

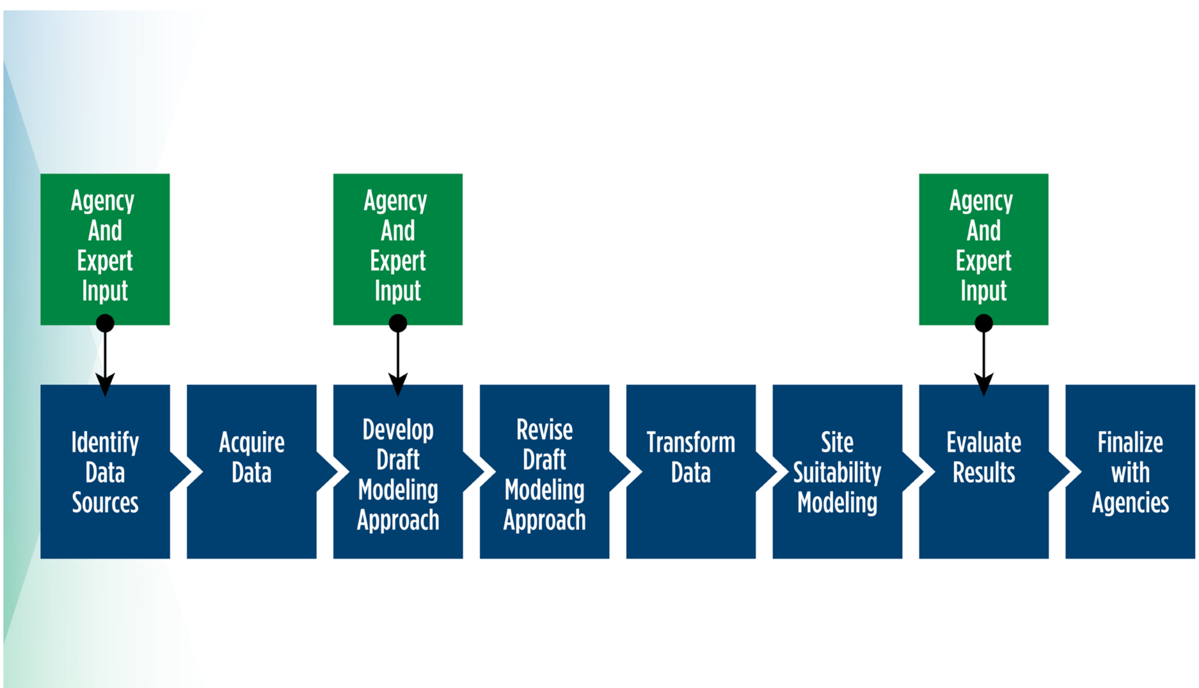
Workflow Overview

The updates to exclusion datasets, development of the spatial models, and development of the land-use screens were accomplished working through an iterative analysis process in coordination with CPUC, California Department of Fish and Wildlife (CDFW), Department of Conservation (DOC), California Department of Food and Agriculture (CDFA), Department of Water Resources (DWR), Natural Resources Conservation Service (NRCS), Bureau of Land Management (BLM), and United States Fish and Wildlife Service (USFWS).

To create the three spatial models, CEC staff implemented the following workflow.

1. Identified source datasets for consideration.
2. Developed a draft modeling approach.
3. Consulted source data owners, associated subject matter experts, and partnering agencies. Gathered best practices for using source data, including how to interpret raw data values in terms of suitability categories for renewable resource technical potential.
4. Revised draft modeling approach.
5. Transformed each dataset from the source per the revised modeling approach.
6. Combined all input data sets into a single model output by summing each input component and associated weight in the suitability modeling tool.
7. Evaluated model results against similar models and basic statistical measures.
8. Worked with agency staff to review model result and modify, as recommended.

Figure 2: Workflow Diagram



Source: CEC staff

Workflow for developing spatial models and updating exclusion datasets for land-use screens for electric system planning

An initial step in revising the land-use screens was defining the geographic scope of the analysis. CEC staff elected to create statewide geospatial models and land-use screens. A statewide approach allows the results to be used across several electric system planning processes, which may have different approaches to geographically aggregating attributes of the electric system (for example, transmission, substations, generation resource areas). For example, prior land-use screening methods focused within geographic transmission zones previously used by CPUC and California ISO in resource and transmission planning. In 2021, CPUC and California ISO updated their resource and transmission planning processes to move away from a modeling approached based on geographic zones to a modeling approach based on transmission constraints.[31]

At this time, the land-use analysis does not apply to out-of-state renewable resource potential that may be used to serve California load. Consistent with the approach currently used in busbar mapping and proposed for use in the CPUC's Inputs & Assumptions for the 2022-23 IRP Cycle, CEC staff recommends using publicly available spatial datasets from the Western Electricity Coordinating Council (WECC) Environmental Risk Dataset[32] to map resources outside of California.

Input Data

Input data for revising the land use screens used in electric system planning were acquired from many authoritative sources, including the CPUC, CDFW, DOC, CDFA, NRCS, DWR, BLM, USFWS, and the National Renewable Energy Laboratory (NREL). There are three categories of input datasets used to develop the land use screens for electric system planning:

- Energy resource potential datasets (derived from raw resource estimates from NREL)
- Exclusion datasets (which are combined to form the base exclusion layer)
- Modeling input datasets (datasets that are the result of or inputs to a modeling framework that evaluates a state policy priority)

Energy resource potential datasets came from CPUC staff. Exclusion datasets came from past land-use screens. Where applicable, the exclusion datasets were updated to reflect the availability of newer information from state and federal agencies. Modeling input datasets

31 See *Transmission Capability Estimates for use in the CPUC's Resource Planning Process*, available at http://www.caiso.com/Documents/WhitePaper-2021TransmissionCapabilityEstimates-CPUCResourcePlanningProcess.pdf. See *Resolve Updates for 2021 PSP / 2022-2023 TPP*, available at https://files.cpuc.ca.gov/energy/modeling/PSP%20RESOLVE%20Updates.pdf.

32 "WECC Environmental Data Viewer," available at https://ecosystems.azurewebsites.net/WECC/Environmental/.

came from past land-use screens and acquired from state and federal agencies. See **Appendix D** for tables showing input data for the exclusion datasets and the models.

Once exclusion data were acquired and updated, where necessary, the datasets were combined into a single GIS layer for solar PV and a single GIS layer for onshore wind exclusions. The approach of combining exclusion datasets into a base exclusion layer is consistent with past land-use screening approaches. The area of California remaining after removing the base exclusions for solar PV and onshore wind technologies is shown below in Figure 3. This area is called the **resource potential basemap** and is the basis of much of the CEC staff analysis in this update to the land-use screens.

Consistent with past approaches, the land-use screens include renewable resource potential from the BLM DRECP Land Use Plan Amendment (LUPA) Development Focus Areas (DFAs). In this update, CEC staff proposes to include renewable resource potential from Variance Process Lands (VPLs).[33]

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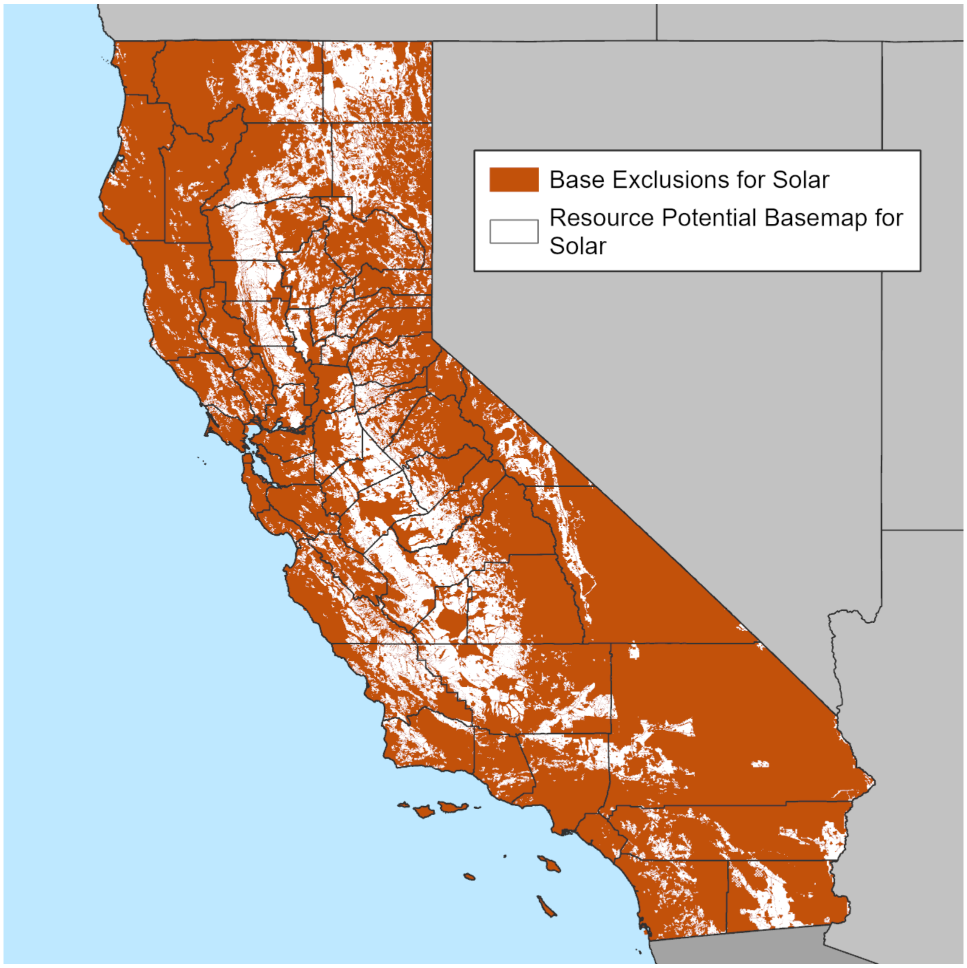
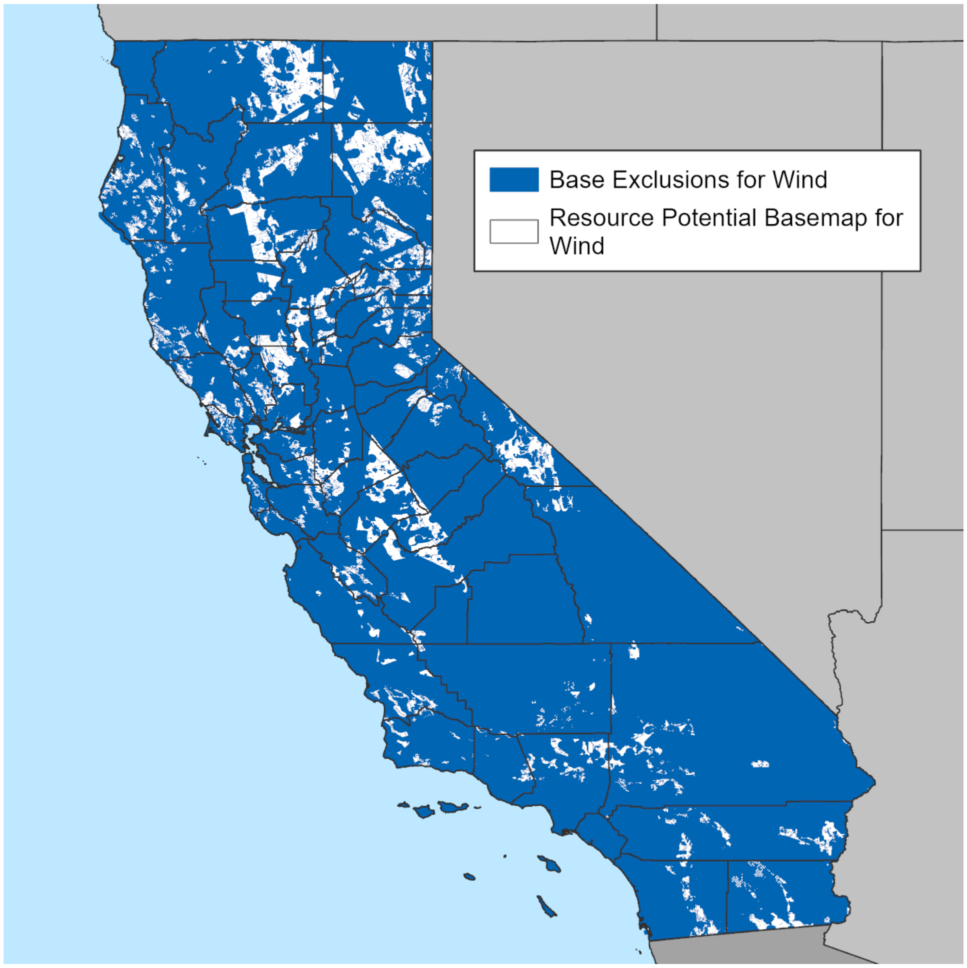
33 Record of Decision for the Land Use Plan Amendment to the California Desert Conservation Plan, Bishop Resource Management Plan, and Bakersfield Resource Management Plan. 2016. U.S. Bureau of Land Management. Available at https://eplanning.blm.gov/public_projects/lup/66459/133460/163124/DRECP_BLM_LUPA_ROD.pdf.

Spatial data retrieved from: *BLM LUPA Renewable Energy Designations*. 2016. Data Basin. Accessed: October 3, 2022 https://databasin.org/datasets/c61b0e256e494fc5b6958d6c3999a19a/.

Figure 3: Resource Potential Basemaps and Base Exclusions for Onshore Wind and Solar Technologies





Source: CEC staff

Base exclusion areas are shaded in color for solar (top) and onshore wind (bottom). The white areas remaining make up the resource potential basemaps for each technology. These areas are the starting point for any for resource potential estimates in California.

The geothermal resource potential basemap was constructed using areas of the state known to contain significant energy resources. CEC staff compiled footprints of known geothermal resource areas (KGRAs), locations of geothermal fields that have sufficient information known (such as temperature, dimensions, porosity, and recovery factor) to estimate utility-grade generation, and lands leased by BLM for geothermal development. KGRAs are areas designated by the United States Geological Survey (USGS) as having the possibility of beneficial extraction of the geothermal resource that is suspected to exist in the area[34] and

34 Lovekin, James W., Subir K. Sanyal, Christopher W. Klein. 2004. "New Geothermal Site Identification and Qualification." Richmond, California: California Energy Commission: Public Interest Energy Research Program. Accessed September 14, 2022.

were digitized by the CEC.[35] Lovekin et al.[36] provided a comprehensive list of 22 geothermal areas in the state that had enough information known about them to estimate a generation capacity. Truckhaven, North Brawley, Superstition Mountain, and Mount Signal geothermal fields were added to consideration from this source. A complete list of sources used to define the geothermal fields is given in **Table D-9** of **Appendix D.**

CEC staff recognizes that geothermal resource potential can be found outside of known geothermal fields, but the majority of resource potential is contained within them. A USGS estimate from identified geothermal systems within the state indicates that a total of 6 percent of the electrical power generation potential can be found from all sites outside the KGRAs.[37] Most of the sites outside of the known geothermal fields contain small magnitude estimates of resource potential. Exploring, confirming, and securing financial backing for development of a new geothermal reserve is a lengthy and costly process for a small magnitude resource. The decision to limit the geothermal resource potential to known areas with the majority of the state's estimated geothermal resource is reasonable considering the time frame for energy planning in this report.

The only component of exclusions that is factored into the land-use evaluation for geothermal technology is the legally protected areas. It was applied differently than solar and onshore wind. If the geothermal field lies entirely within the protected areas, it was not considered part of the resource potential. CEC staff either included the geothermal area and the full assessment of electrical generation capacity or did not include it at all. This method excluded Randsburg, Bodie, Sespe Hot Springs, and Dunes KGRAs. It also excluded Superstition Mountain and Mount Signal geothermal fields, which are located in a National Conservation Area and Area of Critical Environmental Concern, respectively. Lassen KGRA was excluded from consideration because of a lack of knowledge to properly assess the respective resource potential. Figure 4 shows all the geothermal fields used in this report after application of the protected areas filter and exclusions. These regions make up the resource potential basemap for geothermal technology.

The decision not to exclude or adjust the energy potential coming from geothermal fields that lie partially within a protected area is due to the small direct land use footprint of this

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35 Youngs, S. *California Low-Temperature Geothermal Resources Update -1993*. State of California Department of Conservation, 1994.

36 Lovekin, James W., Subir K. Sanyal, Christopher W. Klein. 2004. "New Geothermal Site Identification and Qualification." Richmond, California: California Energy Commission: Public Interest Energy Research Program. Accessed September 14, 2022.

37 Williams, Colin F., Reed, Marshall J., Mariner, Robert H., DeAngelo, Jacob, Galanis, S. Peter, Jr., 2008, Assessment of moderate- and high-temperature geothermal resources of the United States: U.S. Geological Survey Fact Sheet 2008-3082, 4 p. Data accessed at: https://certmapper.cr.usgs.gov/server/rest/services/geothermal/westus_favoribility_systems/MapServer/0

technology.[38] The spatial extent of the geothermal formation beneath the earth's surface is typically large and not well constrained. Thus, there is flexibility in the placement of wells and power plants to access the reservoir. This is also the reason that technoeconomic feasibility of geothermal energy development was not considered as first-order exclusions for this technology type. Any limitations in the physical features of the land could be bypassed by smart placement of the wellheads and power plant.

Figure 4: Geothermal Resource Potential Basemap

Source: CEC staff

The resource potential basemap consists of the geothermal fields that are not entirely within a legally protected area. Their characteristics must also be known with sufficient certainty to warrant a reasonable and spatially explicit estimate of generation capacity.

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38 McDonald RI, Fargione J, Kiesecker J, Miller WM, Powell J (2009) "Energy Sprawl or Energy Efficiency: Climate Policy Impacts on Natural Habitat for the United States of America." PLOS ONE 4(8): e6802. https://doi.org/10.1371/journal.pone.0006802.

In Appendix C, CEC staff performed a comparative analysis of the revised resource potential basemaps to past agency and nongovernmental organization (NGO) studies that have used similar approaches to construct resource potential basemaps for solar. A comparison of the total land areas from these studies is available in Table C-1. The comparative analysis reveals that the approach to creating base exclusions and the resource potential basemaps in this report produced a total footprint area within the range of other efforts.

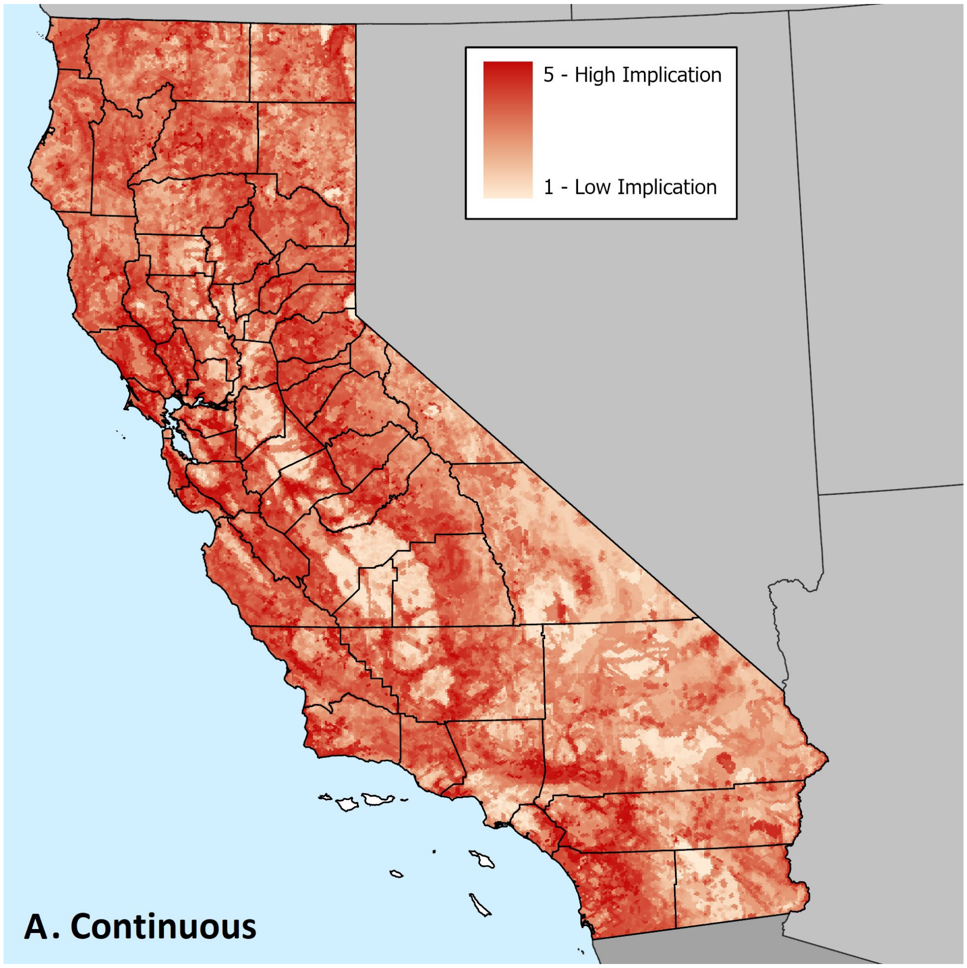
Geographic Information Systems (GIS) Modeling Overview

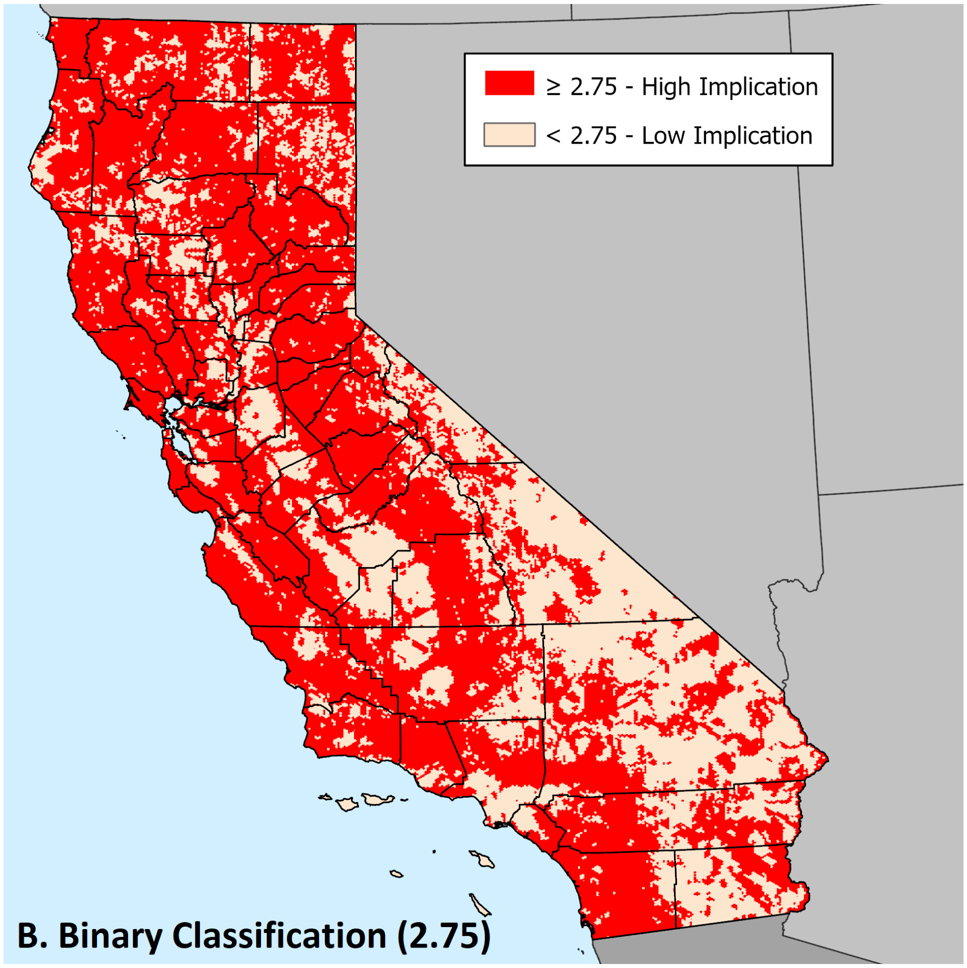
To explore planning considerations related to biodiversity, lands used to produce crops, and terrestrial landscape intactness, CEC staff developed three models: Biodiversity Index, Cropland Index, and Intactness and Proximity to Protected Areas using the ArcGIS Pro Suitability Modeler. The suitability modeling set of tools is a multicriteria evaluation method common in geospatial analyses when multiple inputs affect an overall value decision for an area. It uses a weighted raster overlay (WRO) to combine input data layers to produce a map showing the resulting summation value. For a detailed description of model development, **see Appendix C**.

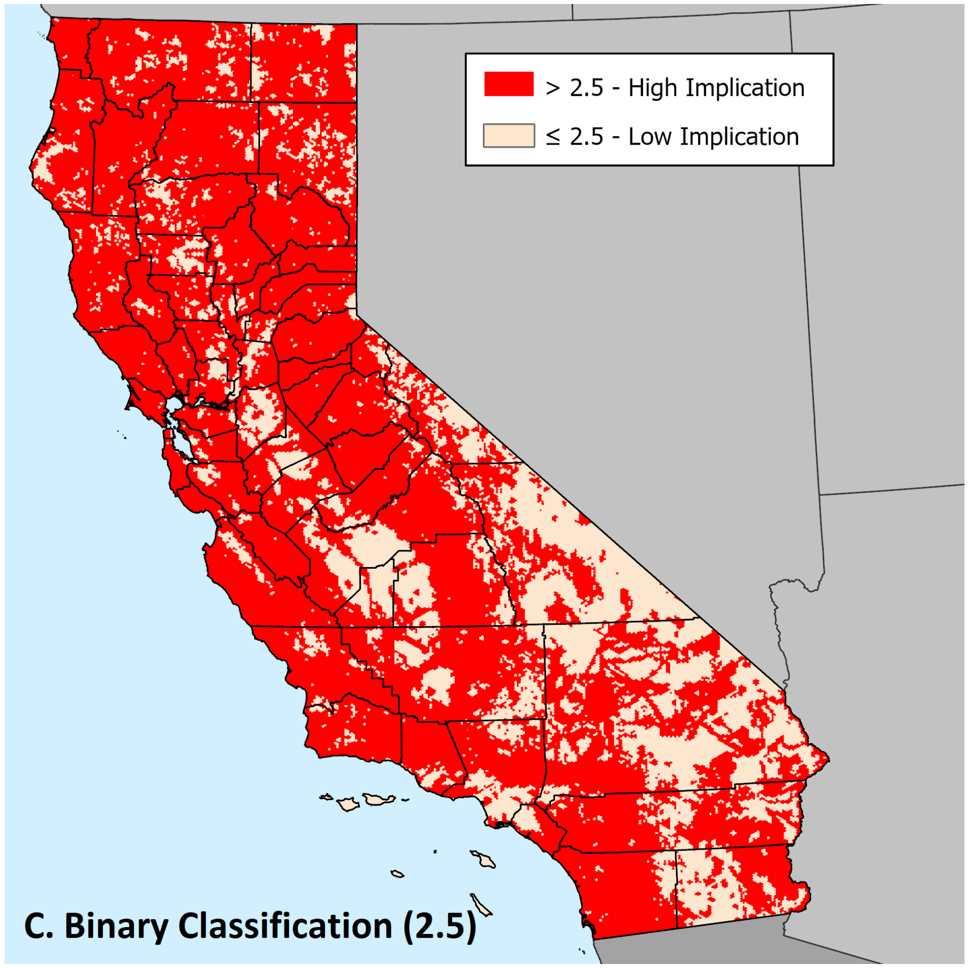
The purpose of modeling the Biodiversity Index, the Cropland Index, and the Intactness and Proximity to Protected Areas Index is to identify the suitable areas with technical feasibility for onshore wind and utility-scale solar PV based on an evaluation of the variables used in each of these models. The result of modeling is a spatial dataset that numerically represents the land-use implication level when considering all the input variables combined in each of the important land-use categories in California.

Biodiversity Index Model — This model represents a numerically weighted index of biodiversity at a given location, drawing from the Terrestrial Biodiversity and Connectivity data products of the CDFW ACE project. ACE Terrestrial Biodiversity is an index derived from multiple species richness metrics, including all regularly occurring California terrestrial vertebrate and plant species (Native Species Richness), special status species (Rare Species Richness), and geographically weighted endemism (Irreplaceability).

Figure 5: Biodiversity Index Results




≥ 2.75 - High Implication
< 2.75 - Low Implication
B. Binary Classification (2.75)



Source: CEC staff

The Biodiversity Index model results are shown in Panel A. Areas of higher biodiversity appear in red, while areas of lower biodiversity lighten to white. Panel B depicts the binary classification of the model results using a threshold of 2.75. Panel C depicts the binary classification of the model results using a threshold of 2.5.

The model results are shown in Figure 5A. Higher scores are shown in red, and lower scores lighten to white. A cutoff value of 2.75 was used to categorize these results into regions of lower and higher biodiversity implication[39] for Land-Use Screen 1. A slightly lower cutoff value of 2.5 was used to partition these results into higher and lower categories for Land-Use Screens 2 and 3. Areas of higher biodiversity implication are incorporated as an exclusion in resource potential estimates. These categorized areas under the two different thresholds are shown in panels B and C of Figure 5. Further explanation of the chosen cutoff values are provided in Appendix C.

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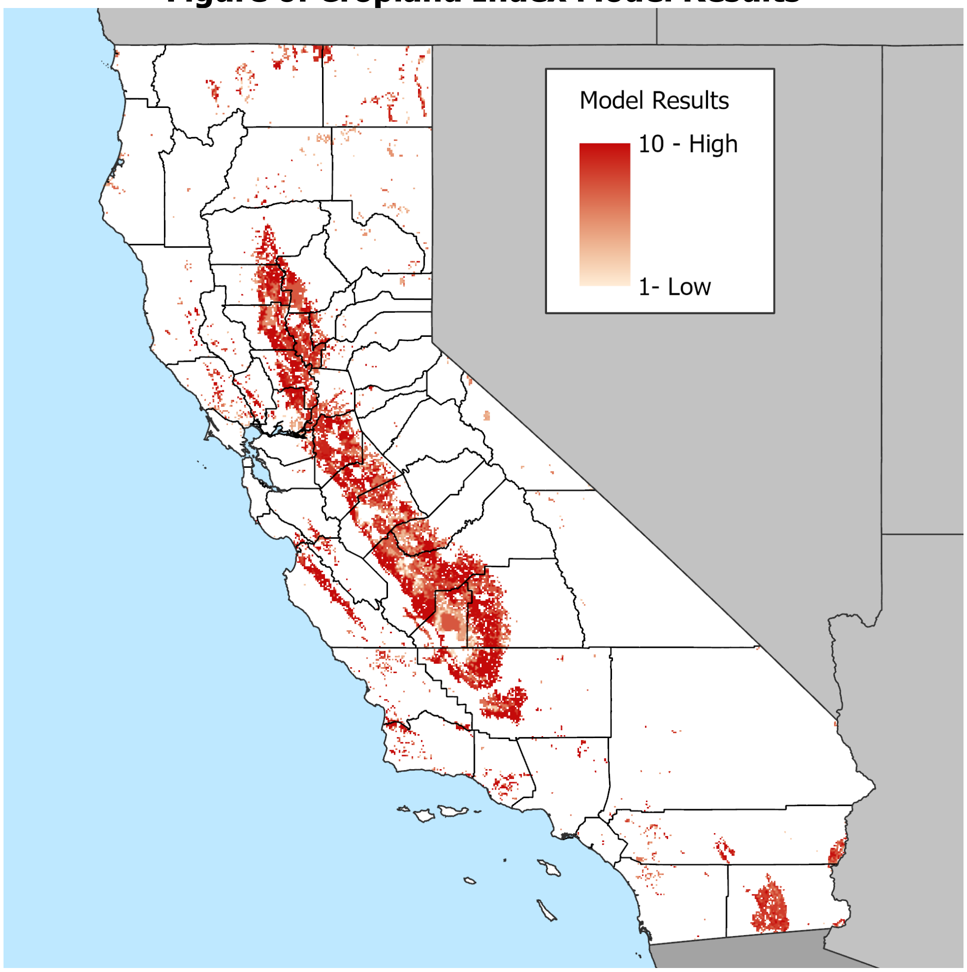
39 In this analysis, *implication* is defined as a possible significance or a likely consequence of an action, for example, planning for energy infrastructure development in areas of higher biodiversity has *implications* for biodiversity conservation opportunities.

Cropland Index model — This model represents a numerically weighted index of importance for croplands at a given location determined by valuing and combining farmland designations, crop mapping, and soils data. This Cropland model does not include statewide information for grazing lands or rangelands.

Figure 6: Cropland Index Model Results



Source: CEC staff

Cropland Index Model results. Areas with more factors that support high-value croplands appear in red. Areas with fewer factors that support high-value croplands appear in lighter hues.

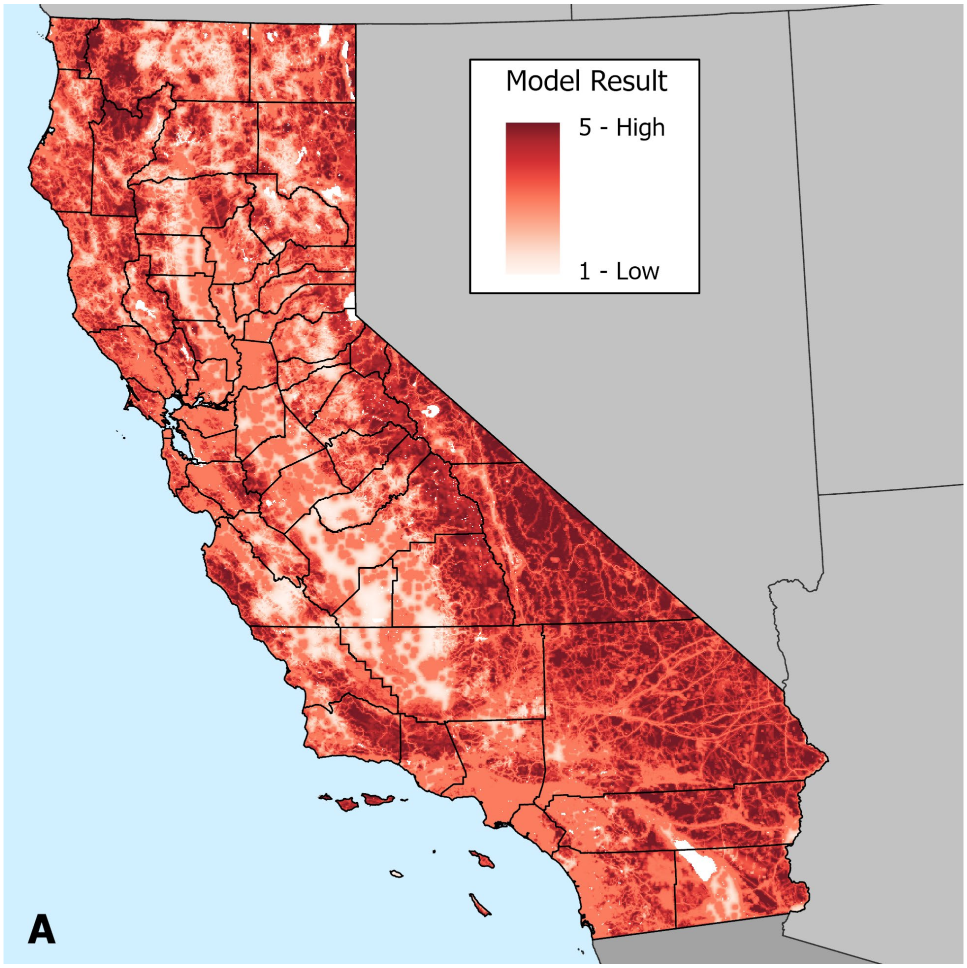
The map above shows the relative score for each location on a continuum of values. Dark reds have higher scores (in other words are locations with more factors that support high-value croplands) and lighter hues have the lower scores (in other words are locations with fewer factors that support high-value croplands). CEC staff partitioned these results into areas of higher and lower implication[40] in the land-use screens. Areas of higher implication are incorporated as an exclusion in resource potential estimates.

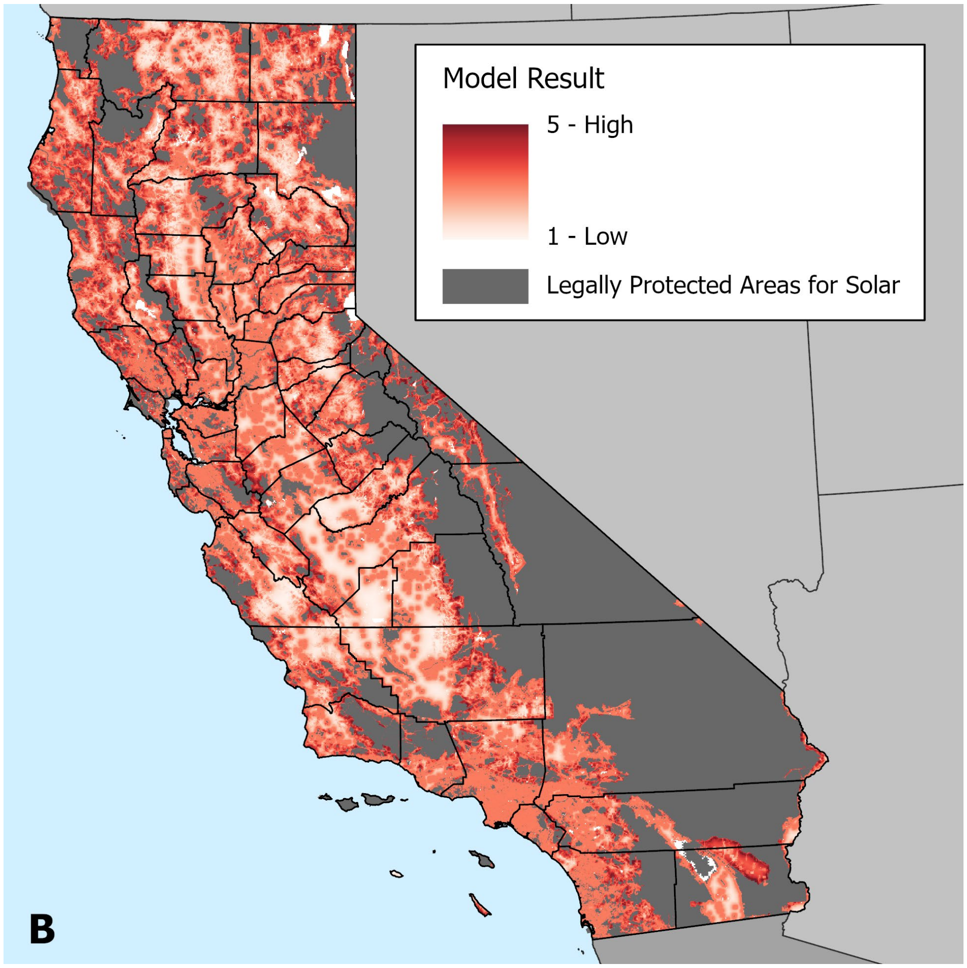
Intactness and Proximity to Protected Areas — This model represents a numerically weighted index of terrestrial landscape intactness (that is, condition) and adjacency to protected areas. *Terrestrial landscape intactness* is a measure of landscape condition based on the extent to which human impacts such as agriculture, urban development, natural resource extraction, and invasive species have disrupted the landscape across California. Terrestrial intactness values are higher in areas where these impacts are less prevalent.[41] The second input dataset for this model, the protected areas exclusion layer, is a comprehensive footprint of land areas that are in conserved status or have legal restrictions on utility-scale renewable energy generation development. The distance to the edge of any excluded feature within this layer is calculated for every 1-kilometer grid cell throughout the state.

[40] In this analysis, *implication* is defined as a possible significance or a likely consequence of an action, for example, planning for energy infrastructure development in areas with more factors that support high-value croplands has *implications* for opportunities to preserve agricultural land.

41 "Landscape Intactness (1 km.), California." Data Basin. Available at https://databasin.org/datasets/e3ee00e8d94a4de58082fdbc91248a65.

Figure 7: Intactness and Proximity to Protected Areas Results





Source: CEC staff

Intactness and distance to legally protected areas are combined to create the suitability surface shown in panel A above. Higher model scores are shown in red, indicating relative proximity to legally protected areas and land that has less human impact. Lower model scores are shown in lighter colors, indicating lands with a relatively higher level of disturbed lands and that are far from protected areas. Panel B shows the same model results with the legally protected areas for solar overlayed in grey.

The raw model results are shown in Figure 7, Panel A. The combined measure of both input factors at each location is given on a scale of 1 to 5, with higher model scores indicating that the area is both higher in intactness and close to a protected area. Low model scores indicate the area has lower intactness (that is, higher disturbance) and is far from protected areas. Panel B shows the same model results, but with the legally protected areas for solar overlayed in grey. This overlay was used to create the distance to a protected area data set, which was used as an input to this model and is also one of the three components of the base exclusions.

Areas of higher landscape intactness have lower levels of disturbance. Areas that have higher landscape intactness and are adjacent to a protected area should fall in the highest model scores and be given precedence to remain intact. Planning for energy infrastructure development in these areas may result in implications to landscape intactness and ecosystem function conservation priorities and are better suited for conservation under these modeling assumptions.

Areas of low landscape intactness have higher levels of disturbance and are therefore most suited for exploration of renewable resource potential under these modeling assumptions. In addition, if these areas are far from a protected area, they should fall in the lowest model scores and be given consideration for renewable resource technical potential under these modeling assumptions.

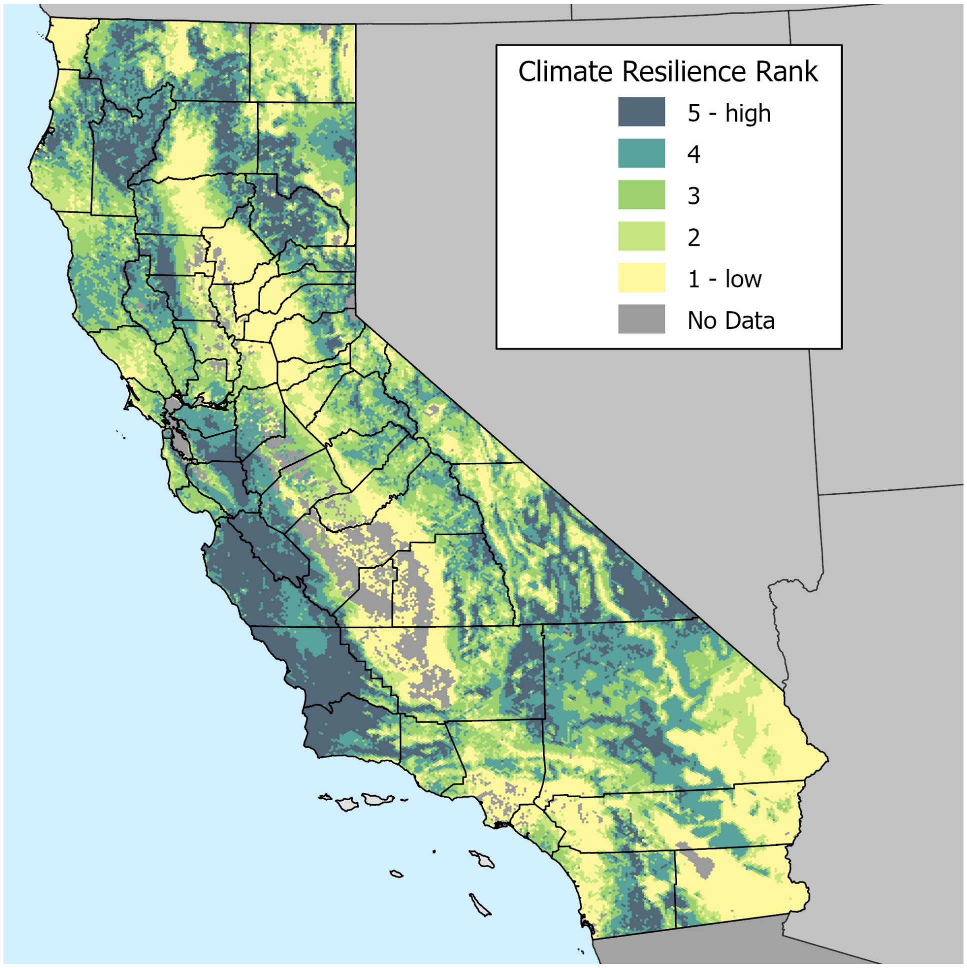
Climate Resilience

The final component of data used to inform the land-use evaluation in this report is the Terrestrial Climate Change Resilience dataset from CDFW's ACE project. It identifies areas of the state that are likely to serve as climate refugia[42] under changing climate conditions. Areas of higher ranks are predicted to be less vulnerable to the effects of climate change and indicate regions where conditions will generally remain suitable for the current array of dominant plant species that form the core of the ACE climate resilience analysis.[43] As plant communities provide much of the living matter and structure for wildlife habitat, it is assumed that greater stability in these communities will extend to the animal communities that depend upon them. Areas of lower climate resilience rank will likely experience climatic conditions that stress the dominant plant species, leading to local extinctions and new species introductions as plant ranges shift. This community reshuffling will bring changes in habitat composition and structure, elevating uncertainties regarding ecological function. Figure 8 shows the distribution of climate resilience ranks determined by the ACE project. For this analysis, CEC staff assumes that areas of lower climate resilience rank are more suitable for exploration of renewable resource technical potential, while areas of higher resilience rank are better suited for conservation planning under these modeling assumptions. A more complete explanation of this dataset, derivation, and its use in this report can be found in Appendix C.

42 Refugia are areas relatively buffered from the effects of climate change, where conditions will likely remain suitable for the current array of plants and wildlife that reside within a location, and where ecological functions are more likely to remain intact. Available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=150836&inline.

43 Ibid.

Figure 8: Terrestrial Climate Change Resilience



Source: CEC staff

This figure shows areas that are more or less vulnerable to climate change from the ACE Terrestrial Climate Change Resilience data set. Areas shown in blue (higher rank values) have more resilience to changing climate conditions for existing vegetation types.

The following chapter describes how the renewable resource potential datasets, exclusion datasets, and spatial model outputs are combined into land-use screens to estimate resource potential for onshore wind and utility-scale solar PV for use in electric system planning.

CHAPTER 3: Recommended Land-Use Screens

Based on the CEC staff's analysis of publicly available geospatial information as presented and evaluated in this report and feedback from agencies and the public, CEC staff recommends the following three revised land-use screens for electric system planning. The revised land-use screens build upon and update the land-use screens that are in use by the CEC and CPUC.

1. Land-Use Screen 1: base exclusions, biodiversity, cropland
2. Land-Use Screen 2: base exclusions, biodiversity, cropland, landscape intactness, proximity to protected areas
3. Land-Use Screen 3: base exclusions, biodiversity, cropland, terrestrial climate resilience

Land-Use Screen 1

The high-level statewide land use evaluation in Land-Use Screen 1 includes the following statewide data and information described in Chapter 2 and Appendix C: (1) base exclusion datasets; (2) excluded lands identified as higher implication in the Biodiversity Index model (threshold set at ≥ 2.75); and (3) excluded lands identified as higher implication in the Cropland Index model. This screen identifies 5.32 million acres of utility-scale solar PV resource potential (Figure 9) and 2.32 million acres of onshore wind resource potential (Figure 11).

Land-Use Screen 2

The high-level statewide land-use evaluation in Land-Use Screen 2 includes the following statewide data and information described in Chapter 2 and Appendix C: (1) base exclusion datasets, (2) excluded lands identified as higher implication in the Biodiversity Index model (threshold set at > 2.5), (3) excluded lands identified as higher implication in the Cropland Index model, and (4) excluded lands that are both high in intactness and close to a protected area identified in the Intactness and Proximity to Protected Areas model. This screen identifies 2.61 million acres of utility-scale solar PV resource potential (Figure 9) and 1.07 million acres of onshore wind resource potential (Figure 11).

Land-Use Screen 3

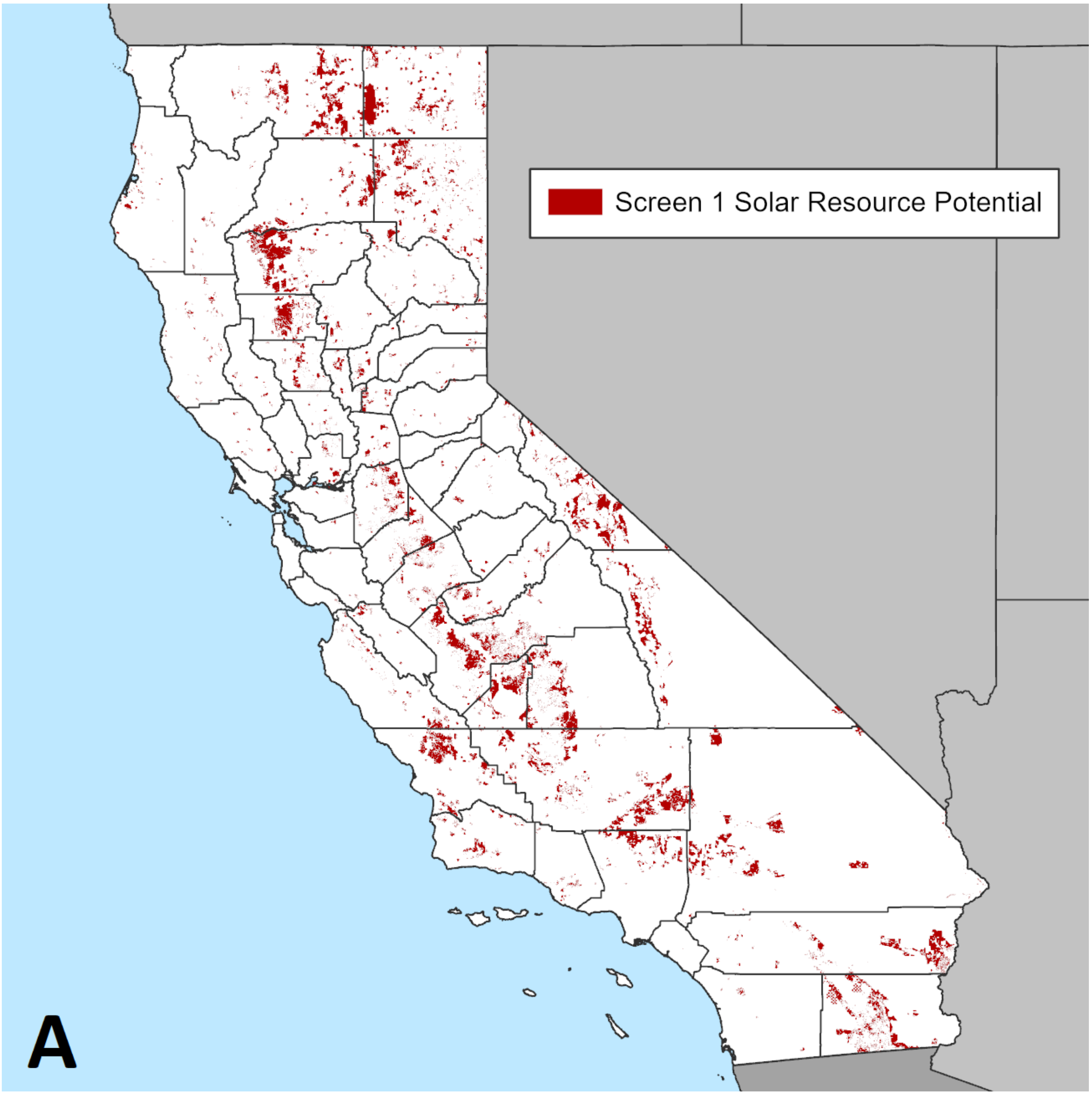
The high-level statewide land use evaluation in Land-Use Screen 3 includes the following statewide data and information described in Chapter 2 and Appendix C: (1) base exclusion datasets, (2) excluded lands identified as higher implication in the Biodiversity Index model (threshold set at > 2.5), (3) excluded lands identified as higher implication in the Cropland

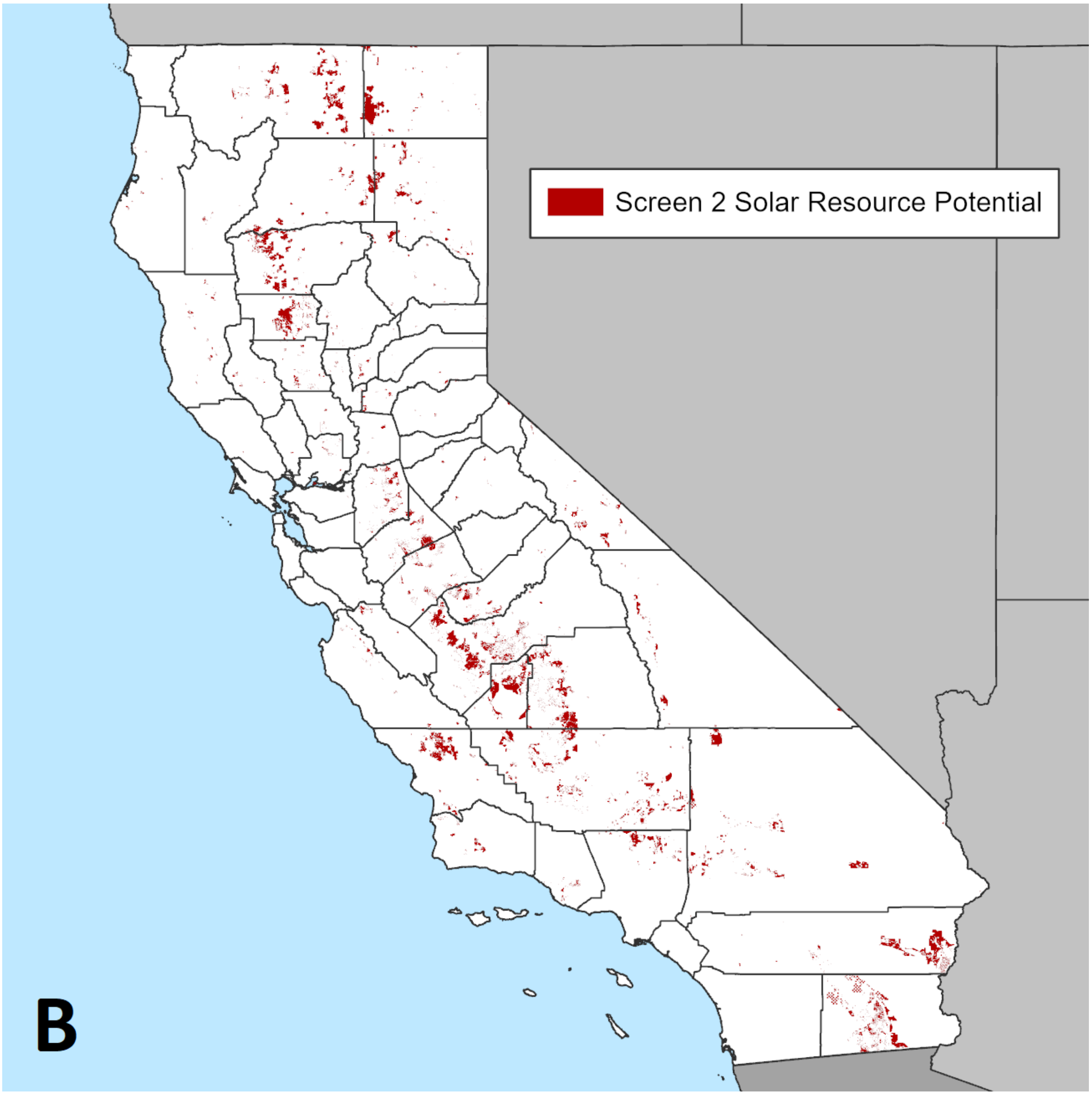
Index model, and (4) excluded lands that have higher probability of serving as refugia[44] for species adapting to climate change. This screen identifies 3.08 million acres of utility-scale solar PV resource potential (Figure 9) and 1.31 million acres of onshore wind resource potential (Figure 11).

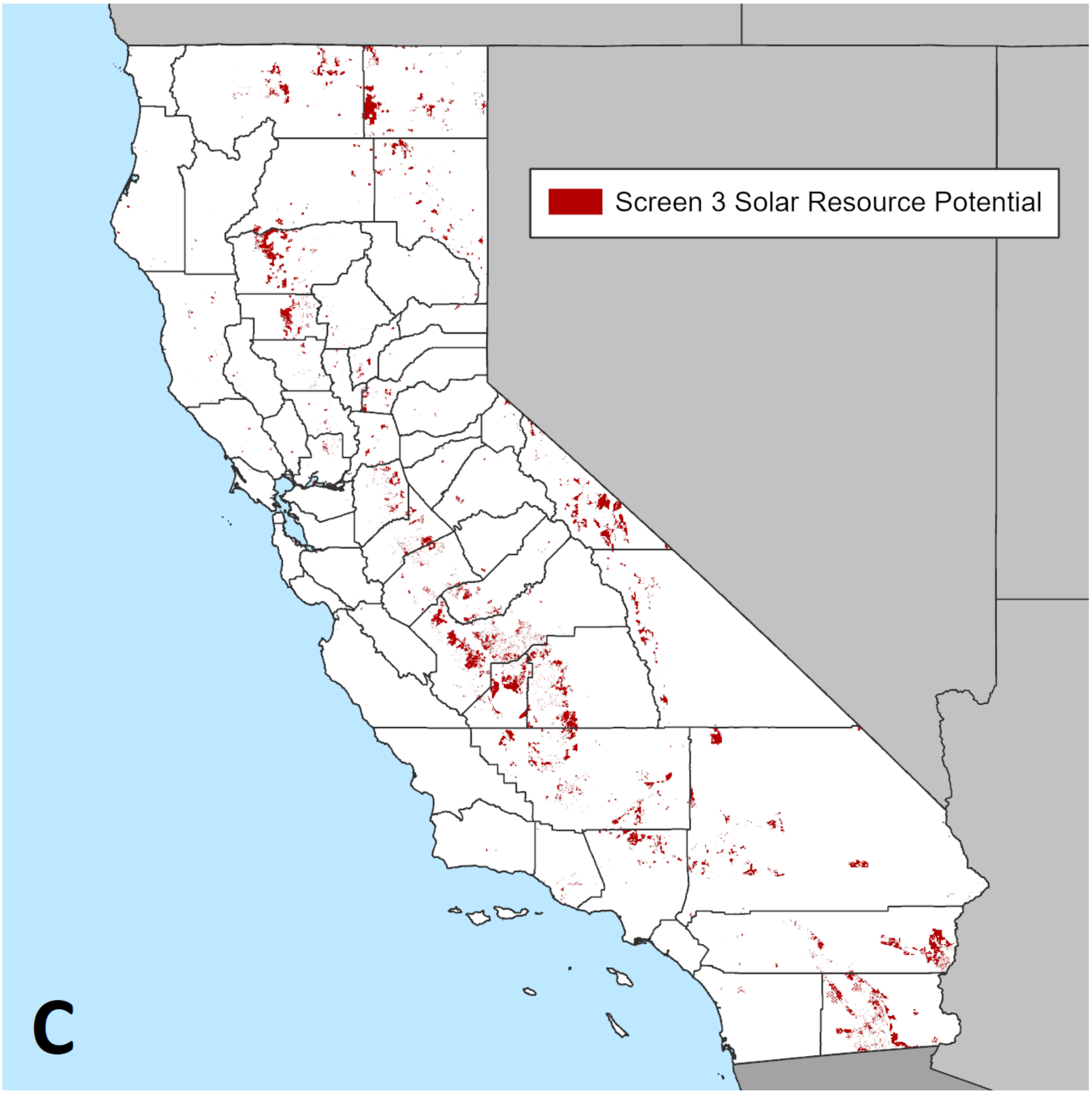
Figures 9, 10, 11, and 12 illustrate the resource potential footprints for utility-scale solar PV and onshore wind technologies for each of the three screens.

44 Refugia are areas relatively buffered from the effects of climate change, where conditions will likely remain suitable for the current array of plants and wildlife that reside within a location, and where ecological functions are more likely to remain intact. Available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=150836&inline.

Figure 9: Lands with Solar Photovoltaic Resource Potential in Each Screen




Screen 2 Solar Resource Potential
B

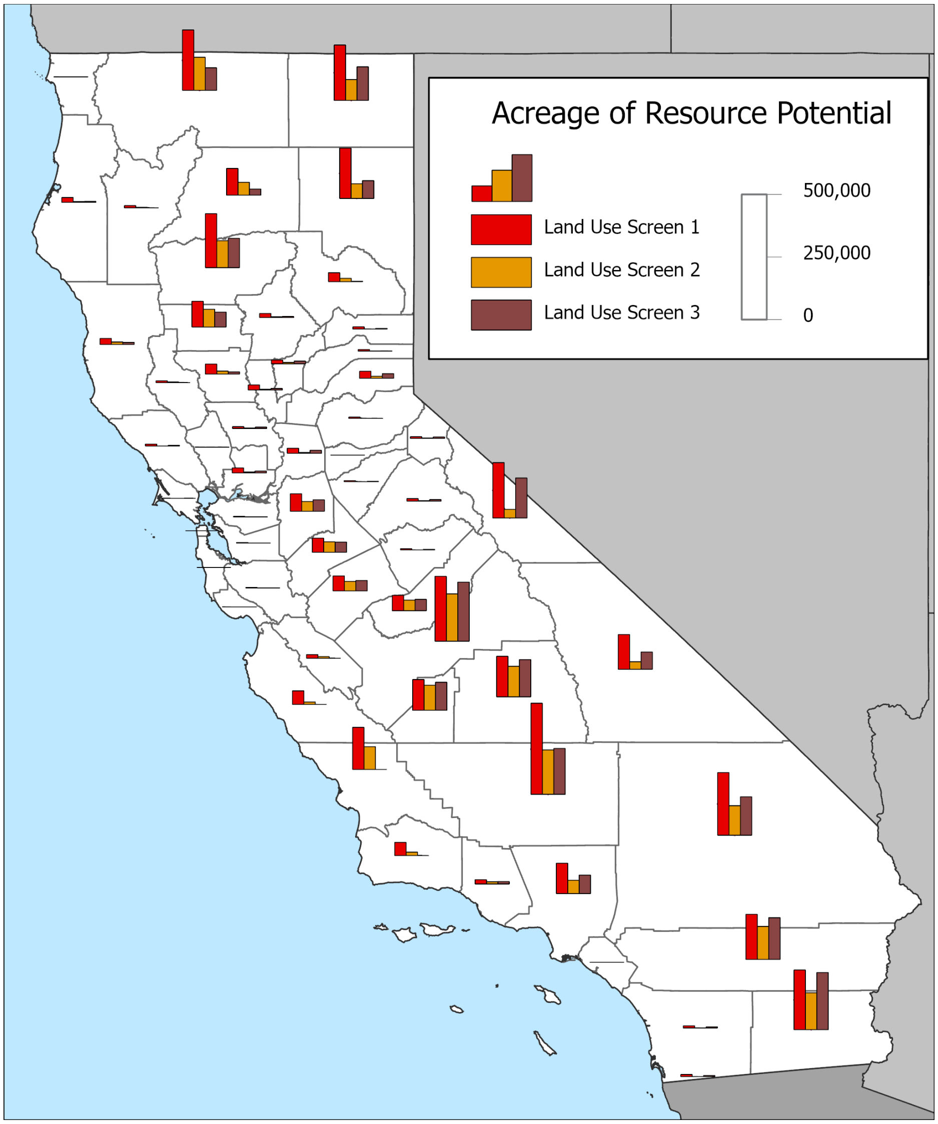


Screen	Panel	Acres (Millions)
Land-Use Screen 1	A	5.32
Land-Use Screen 2	B	2.61
Land-Use Screen 3	C	3.08

Source: CEC staff

Lands with resource potential for solar PV for each of the three screens. Panel A displays the results after applying Land-Use Screen 1, Panel B shows the results after applying Land-Use Screen 2, and Panel C shows the results after applying Land-Use Screen 3.

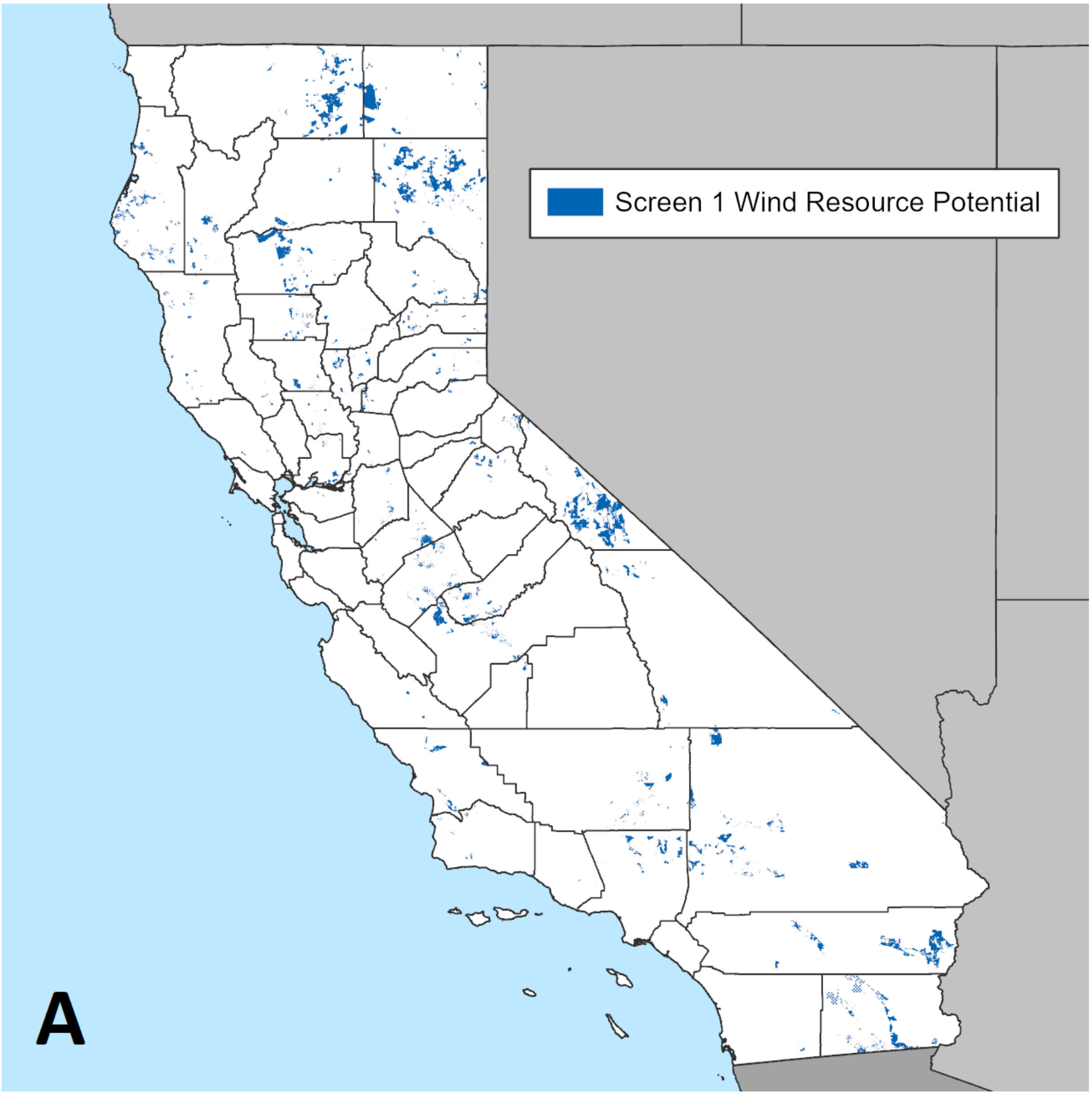
Figure 10: California Counties with Bar Charts Representing Amount of Land (Acres) with Solar PV Resource Potential After Application of Screens

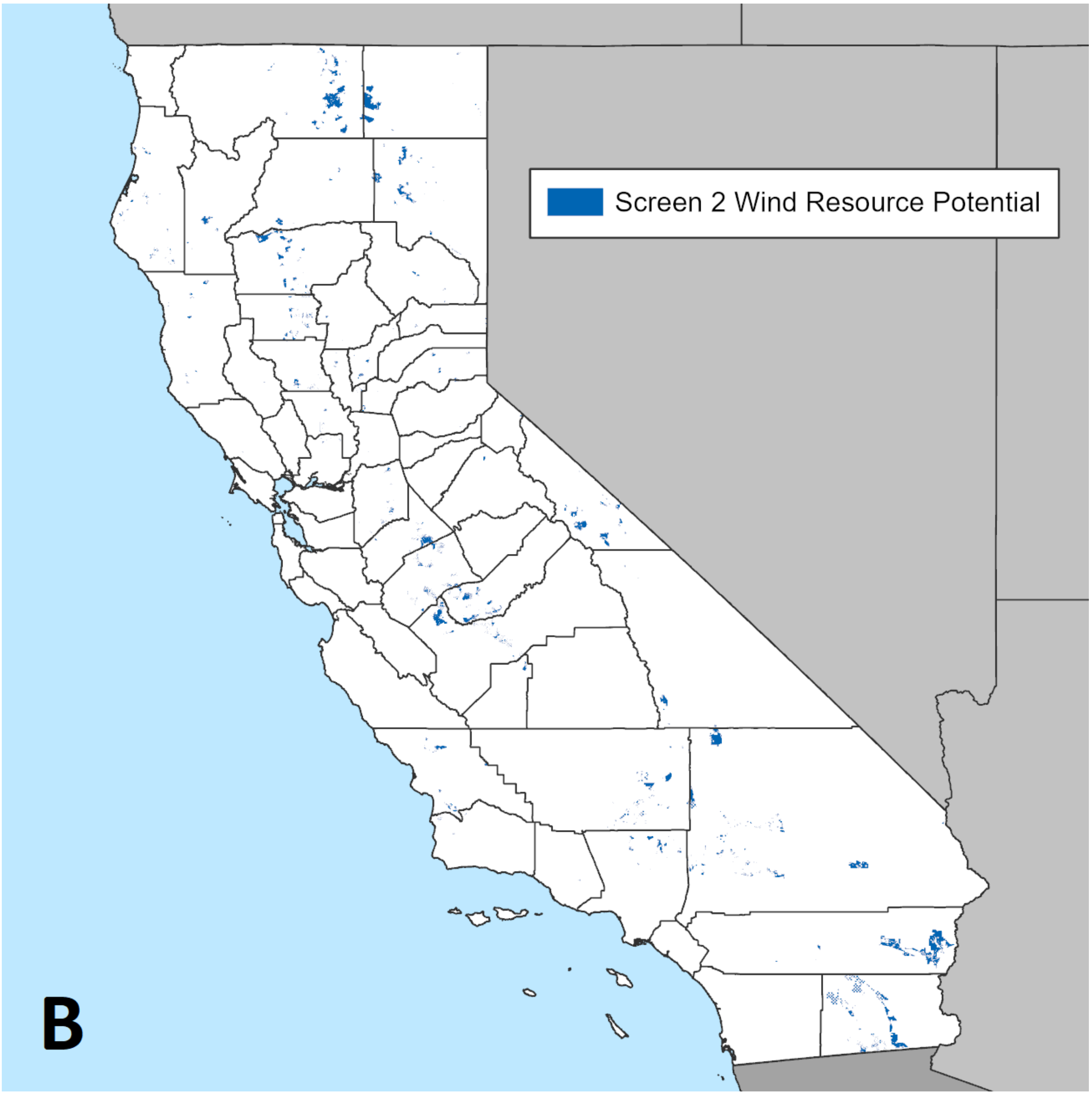


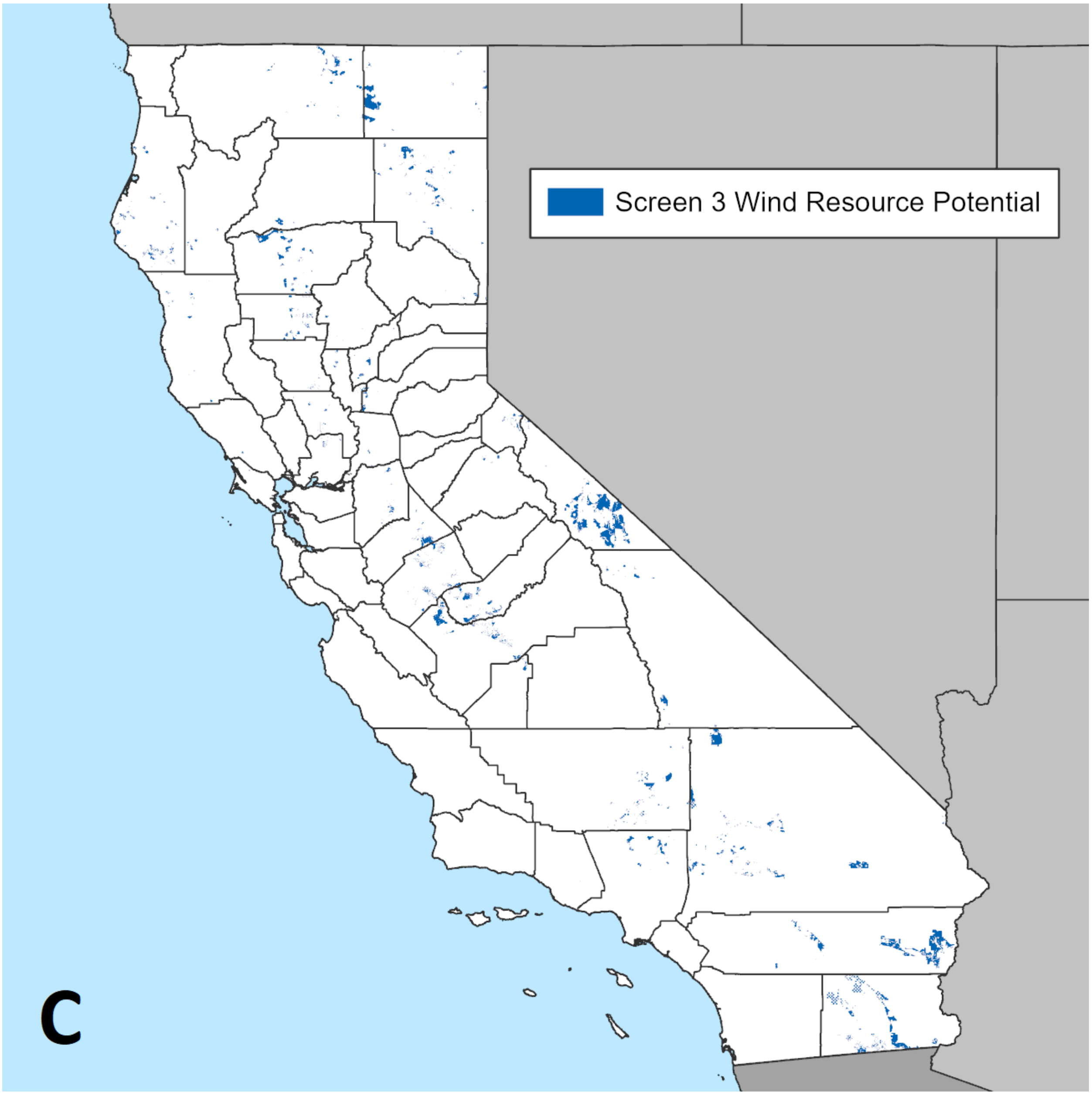
Source: CEC staff

This map depicts total acreage of land within each county with resource potential for solar photovoltaic for each of the three screens.

Figure 11: Lands with Onshore Wind Resource Potential in Each Screen




Screen 2 Wind Resource Potential
B

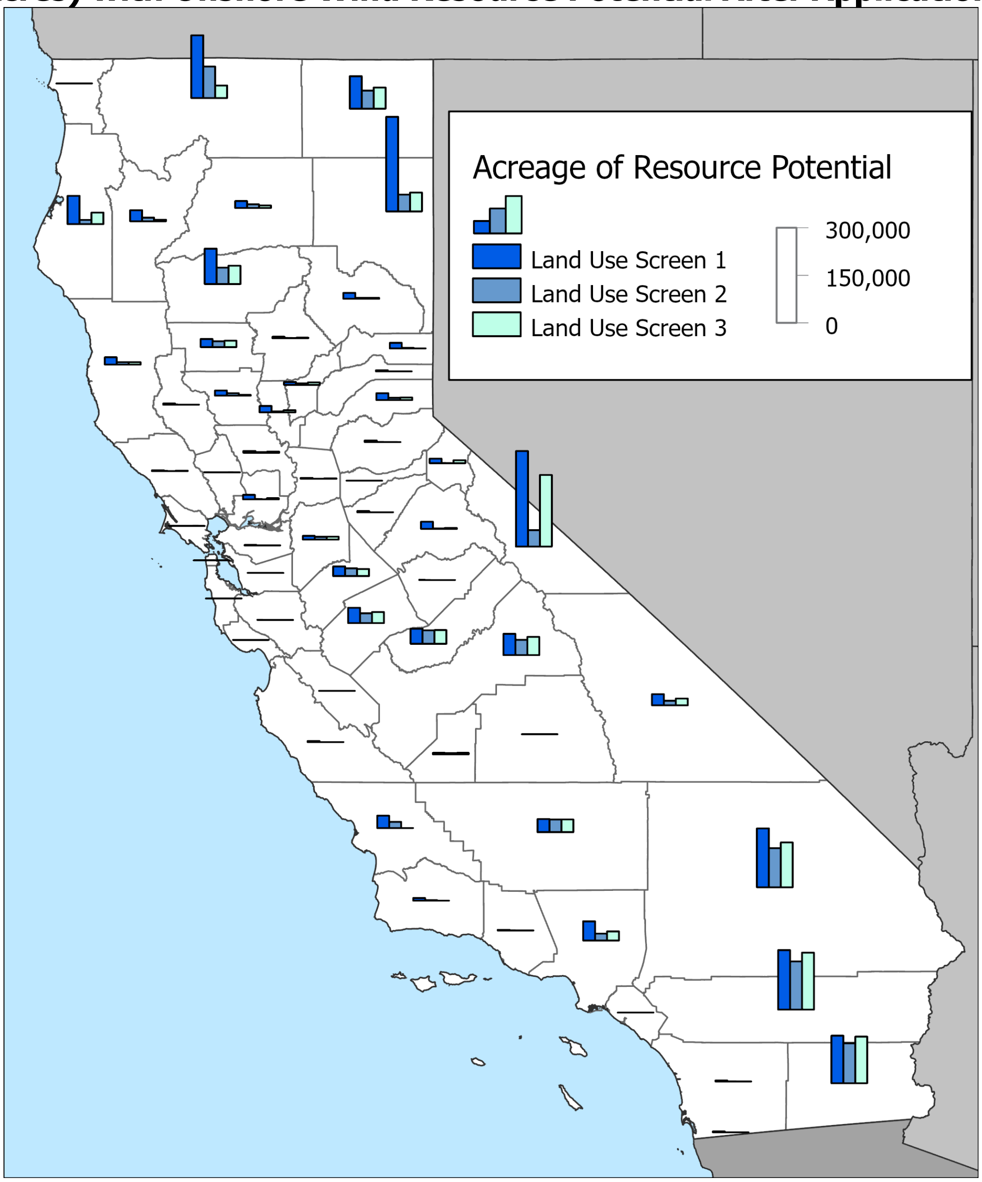


Screen	Panel	Acres (Millions)
Land-Use Screen 1	A	2.32
Land-Use Screen 2	B	1.07
Land-Use Screen 3	C	1.31

Source: CEC staff

Lands with resource potential for onshore wind for each of the three screens. Panel A displays the results after applying Land-Use Screen 1, Panel B shows the results after applying Land-Use Screen 2, and Panel C shows the results after applying Land-Use Screen 3.

Figure 12: California Counties with Bar Charts Representing Amount of Land (Acres) with Onshore Wind Resource Potential After Application of Screens

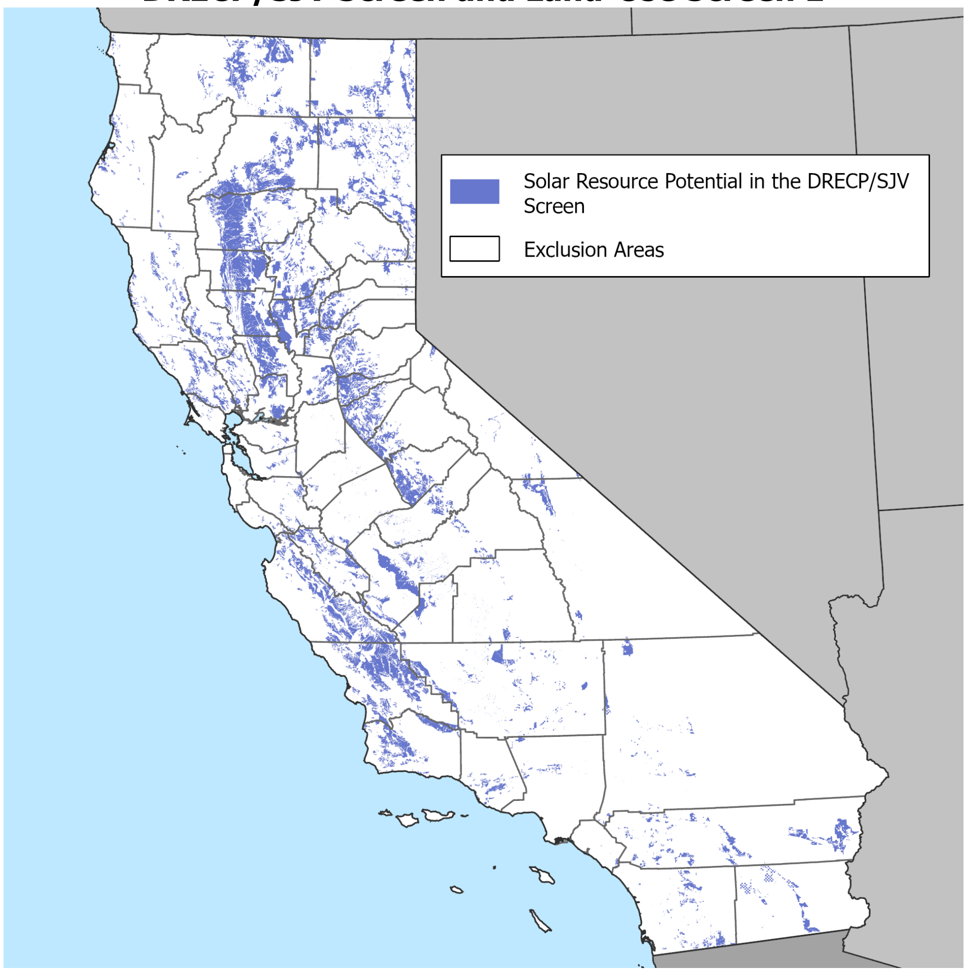


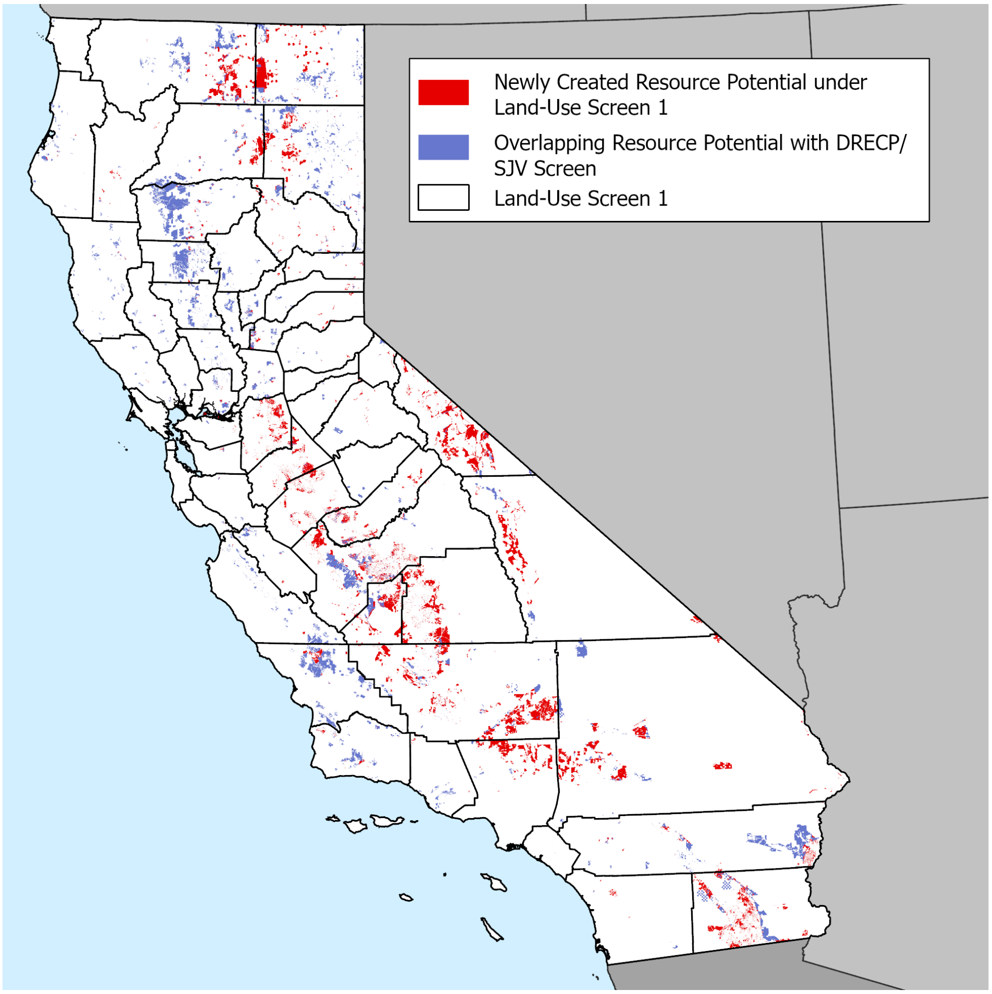
Source: CEC staff

This map depicts total acreage per county of resource potential for onshore wind for each of the three screens.

Figure 13 compares lands with solar photovoltaic resource potential in the DRECP/SJV screen to lands with solar photovoltaic resource potential in Land-Use Screen 1. As described in Chapter 1, the DRECP/SJV screen was used for IRP RESOLVE modeling for all cycles between 2018 and 2022, and for the 2021 SB 100 analysis and joint agency report. Moving forward, CEC staff recommends the use of Land-Use Screen 1 as the primary screen for estimating resource potential for onshore wind and solar PV for use in electric system planning (for example, capacity expansion modeling in SB 100 and CPUC IRP analysis).

Figure 13: Comparison of Lands with Solar Photovoltaic Resource Potential in DRECP/SJV Screen and Land-Use Screen 1



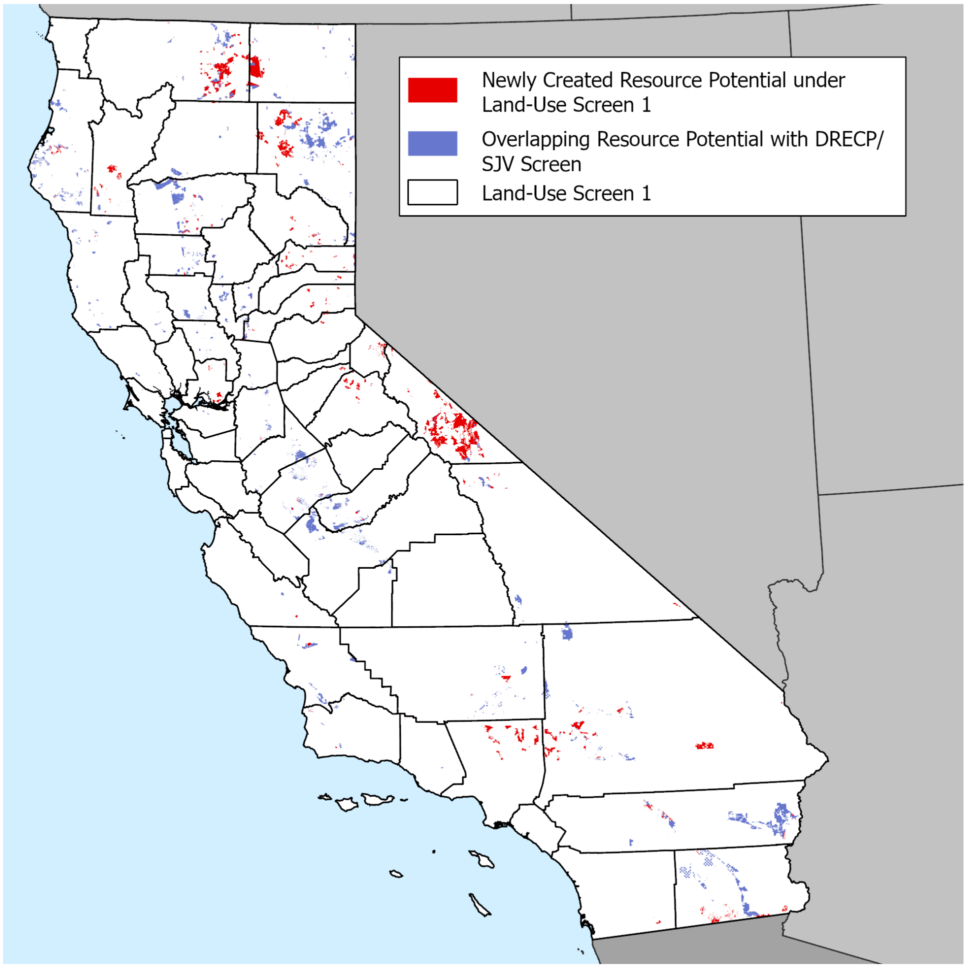


Source: CEC staff

Lands with solar photovoltaic resource potential in the DRECP/SJV screen are shown in purple (top). Lands with solar photovoltaic resource potential in Land-Use Screen 1 are shown in purple and red (bottom). The red color represents resource potential that was newly made available as a result of the change in screening.

A similar comparison can be made of the resource potential for onshore wind. The DRECP/SJV screen and the Land-Use Screen 1 resource potential footprints are shown below in Figure 14.

Figure 14: Comparison of Lands with Wind Resource Potential Under DRECP/SJV Screen and Land-Use Screen 1



Source: CEC staff

Lands with wind resource potential in the DRECP/SJV screen are shown in purple (top). Lands with wind resource potential in Land-Use Screen 1 are shown in purple and red (bottom). The red color represents resource potential that was newly made available as a result of the change in screening.

The following chapter describes how CEC staff recommends applying the land-use screens in electric system planning.

CHAPTER 4: Applications and Path Forward

Applications in Electric System Planning

CEC staff recommends applying the land-use screens in estimating renewable resource technical potential for onshore wind and utility-scale solar PV. At this time, CEC staff does not propose to apply the land-use screens to geothermal resource potential estimates, given the proposed methods of focusing on geographically defined KGRAs.

Application in SB 100: For SB 100 capacity expansion modeling, CEC staff recommends using Land-Use Screen 1 to inform the renewable resource technical potential available for selecting new build or generic renewable energy resources. CEC staff recommends using the Land-Use Screen 2 and Land-Use Screen 3 to explore trade-offs in SB 100 land-use analysis.

Application in IRP: The land-use screens established in this report were developed in coordination with CPUC staff and are available for use in RESOLVE capacity expansion modeling for integrated resource planning to inform the renewable resource technical potential available to identify new build or generic renewable energy resources.

Application in Busbar Mapping: *Busbar mapping* is the process of refining the geographically coarse portfolios produced in the CPUC's Integrated Resource Plan proceeding, into plausible network modeling locations for transmission analysis in the California ISO's annual TPP. In December 2021, the CPUC released a document describing the busbar mapping methodology.[45]

In busbar mapping, CEC staff creates a GIS layer to identify the potential environmental and land-use implications of the RESOLVE-selected renewable resources. The layer is a combination of the biodiversity and cropland index models. The datasets are normalized and summed to create a comprehensive layer with numerical scores that represent the degree of potential environmental and land-use implications if resources are used. The environmental and land-use layers are overlain with the renewable resource potential geographies to identify the environmental implications (lower and higher) of developing renewable resources, particularly solar resources and where necessary, onshore wind energy resources. Moving forward, CEC staff recommends using the land use screens established in this report for busbar mapping for the 2024–2025 TPP.

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45 See *Methodology for Resource-to-Busbar Mapping & Assumptions for the 2021–2022 TPP,* available at https://files.cpuc.ca.gov/energy/modeling/Busbar%20Mapping%20Methodology%20for%202021-2022%20TPP_V.2021-01-07.pdf.

Path Forward

The land-use screens staff report will be stored in the CEC's California Planning Library. The California Planning Library will provide a centralized location on the CEC website for the public to find analytic products and data. CEC staff proposes to review and update the land-use screens every two years as needed. There is a need for continued investment and updates to keep the analysis current and relevant to California's energy and land conservation priorities.

Appropriate Use

The models and land-use screens described in this report are for use in electric system planning, including SB 100, IRP, and busbar mapping for the TPP. The geospatial land-use screens are intended to inform high-level estimates of renewable resource technical potential for electric system planning and should not be used, on their own, to guide siting of generation projects or electrical transmission projects nor assess project-level impacts.

APPENDIX A:
List of Acronyms

ACE – Areas of Conservation Emphasis

BLM – Bureau of Land Management

CalGEM - California Geologic Energy Management Division

California ISO – California Independent System Operator

CARB – California Air Resources Board

CBI – Conservation Biology Institute

CEC – California Energy Commission

CDFA – California Department of Food and Agriculture

CDFW – California Department of Fish and Wildlife

CPUC – California Public Utilities Commission

DFA – Development Focus Area

DOC – Department of Conservation

DRECP – Desert Renewable Energy Conservation Plan

DWR - Department of Water Resources

FMMP – Farmland Mapping and Monitoring Program

GHG – Greenhouse Gas

GIS – Geographic Information System

IRP – Integrated resource plan

KGRA – Known geothermal area

LSE – Load-serving entity

MW - Megawatt

NRCS – Natural Resources Conservation Service

NGO – Nongovernmental organization

RPS – Renewables Portfolio Standard

RETI – Renewable Energy Transmission Initiative

SB – Senate Bill

SSURGO – Soil Survey Geographic Database

TPP – Transmission Planning Process

USFWS – United States Fish and Wildlife Service

USGS - United States Geological Survey

APPENDIX B: Glossary of Terms

Candidate project area — A GIS-modeled area with estimated renewable energy attributes (for example, square kilometer, megawatts, capacity factor, estimated annual generation, estimated capital cost, spatial boundary). Candidate project areas are the output of the site suitability analysis that apply spatially explicit technoeconomic criteria that were then subdivided into typical large-scale renewable energy project-sized areas.

Economywide decarbonization — A reduction of carbon emissions throughout the economy, such as in the electricity, buildings, industry, and transportation sectors.

Integrated Resource Planning — The CPUC's Integrated Resource Planning (IRP) process is an "umbrella" planning proceeding to consider all of its electric procurement policies and programs and ensure California has a safe, reliable, and cost-effective electricity supply. The proceeding is also the Commission's primary venue for implementation of the Senate Bill 350 requirements related to IRP (Public Utilities Code Sections 454.51 and 454.52). The process ensures that load serving entities meet targets that allow the electricity sector to contribute to California's economy-wide greenhouse gas emissions reductions goals.

Land-use implication — In this analysis, implication is defined as a possible significance or a likely consequence of an action, for example, planning for energy infrastructure development in areas of higher biodiversity has *implications* for other land-use planning priorities.

Land-use screens — Land-use screening brings to light the land access limitations or competing land-use priorities that can be experienced in renewable energy project development, thereby helping system planners focus on areas that have a greater potential for successful deployment of new solar photovoltaic, onshore wind, or geothermal capacity. The geospatial datasets in a land-use screen may include technical, biodiversity, and agricultural land-use priorities and considerations.

Landscape-level approaches — Landscape-level approaches, also known as landscape-scale planning, consider a wide range of potential constraints and conflicts, including environmental sensitivity, conservation and other land uses, tribal cultural resources, and more when considering future renewable energy development.

Legally protected areas — Areas where utility-scale renewable energy or transmission development is presently precluded by state or federal law, policy, or regulation.

Load serving entity — A load serving entity is defined by the California Independent System Operator as an entity that has been "granted authority by state or local law, regulation or franchise to serve [their] own load directly through wholesale energy purchases."

Nongovernmental Organization — An organization that is formed independent from government such as a non-profit.

Refugia — Refugia are areas relatively buffered from the effects of climate change, where conditions will likely remain suitable for the current array of plants and wildlife that reside within a location and where ecological functions are more likely to remain intact.

Resource potential basemaps — A mapped area with solar photovoltaic, onshore wind, and geothermal resource potential after the removal of the base exclusions defined in Appendices C and D. These mapped areas form the starting point (or base) used in further steps of the analyses, including renewable resource estimation and application of environmental and land-use datasets to explore implications.

Renewable resource technical potential —The renewable resource technical potential of a technology is its achievable energy generation given technoeconomic, topographic, environmental, and land-use constraints.

APPENDIX C: Technical GIS Methods

Appendix C provides a detailed accounting of the technical GIS methods applied by CEC staff to revise the land-use screens for electric system planning.

Input Data

Input data for updating the land-use screens used in electric system planning were acquired from many authoritative sources, including the CPUC, CDFW, DOC, CDFA, NRCS, DWR, BLM, USFWS, and NREL. See Appendix D for tables showing input data for the exclusion datasets and the models.

Energy Resource Potential Datasets

To estimate the technical resource potential from onshore wind or utility-scale solar PV for energy resource planning within California, CEC staff used estimates produced by Energy + Environmental Economics (E3) and Montara Mountain Energy, consultants to the California Public Utility Commission. Based on realistic model outputs of solar radiation and wind speed (raw resource), a series of modeling and data processing steps were used to create an average capacity factor map that is used in the CEC staff assessment. The following outline summarizes the steps taken to estimate electrical energy production by E3 and Montara Mountain Energy.

- Simulations of realistic electrical energy output are produced from the System Advisor Model (SAM)[46]
  - The renewable resource potential relies on raw resource data from the National Renewable Energy Laboratory (NREL) National Solar Radiation Database and Wind Toolkit. The Direct Normal Irradiance and Global Horizontal Irradiance datasets and wind speed at 80 meters height are extracted at 2-kilometer spatial resolution and hourly temporal resolution for one year. These data are described and listed in Table D-5 in A
  - ppendix D.
  - Technology specifications for wind turbines and photovoltaic panels are specified.
- This output is averaged to produce a capacity factor map for each technology. The resulting dataset is a raster format with 250-meter resolution.

46 Blair, Nate, Nicholas DiOrio, Janine Freeman, Paul Gilman, Steven Janzou, Ty Neises, and Michael Wagner. 2018. System Advisor Model (SAM) General Description (Version 2017.9.5). Golden, CO: National Renewable Energy Laboratory. NREL/ TP-6A20-70414. https://www.nrel.gov/docs/fy18osti/70414.pdf.

- Technoeconomic exclusions are applied, including the application of a minimum capacity factor threshold to ensure that utility-scale energy production is economically feasible in the remaining areas.
- The MapRE toolset[47] was used to convert the resource potential map into a grid of realistic project size polygons for each technology. These are called candidate project areas (CPAs), and the minimum size is chosen for each technology (2 by 2 kilometers for solar and 6 by 6 kilometers for wind). CPAs could be larger than this to maximize regions of resource potential. Discontinuous polygons that were smaller than the chosen unit of analysis were removed.
- Technical potential estimates of energy production were calculated[48] using the area of each CPA and a constant power density value[49] for each resource type (30 MW/kilometer^2 for solar and 2.7 MW/kilometer^2 for wind).

This methodology has been used in previous energy planning by the CEC and CPUC. For more information on this please see *Inputs & Assumptions: 2019–2020 Integrated Resource Planning*.[50]

An estimate of the resource potential can be obtained by multiplying the land area available for energy production by the power density for each technology. The resource potential basemap and the land remaining after each screen were applied are converted to capacity by 30 and 2.7 MW/kilometer^2 for solar and onshore wind, respectively. The figures below show the energy resource potential available within each screen and by technology.

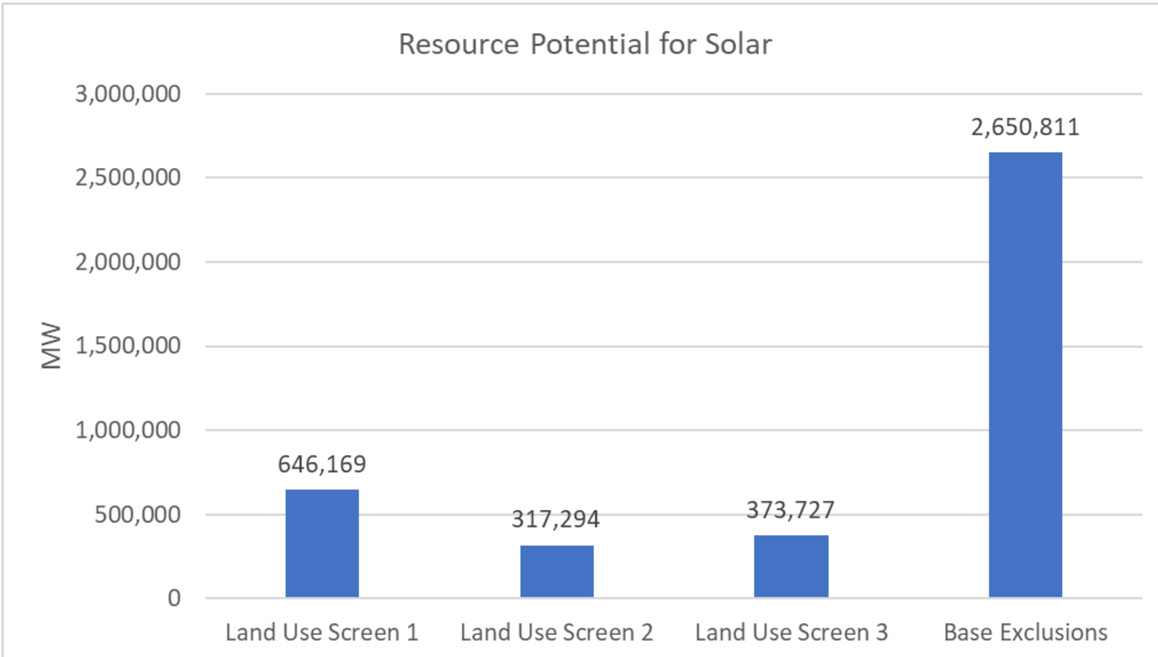
47 "Geographic Information Systems (GIS) Script Tools for Renewable Energy (RE) Zoning." University of California at Santa Barbara. Available at https://mapre.es.ucsb.edu/gis-tools/.

48 Lopez, A., B. Roberts, D. Heimiller, N. Blair, and G. Porro. "U.S Renewable Energy Technical Potentials: a GIS-Based Analysis." National Renewable Energy Lab, July 2012. https://www.nrel.gov/docs/fy12osti/51946.pdf.

49 Ong, S., C. Campbell, P. Denholm, R. Margolis, and G. Heath. "Land-Use Requirements for Solar Power Plants in the United States." National Renewable Energy Laboratory, June 2013. https://www.nrel.gov/docs/fy13osti/56290.pdf. Denholm, P., M. Hand, M. Jackson, and S. Ong. "Land-Use Requirements of Modern Wind Power Plants in the United States." National Renewable Energy Laboratory, August 2009. https://www.nrel.gov/docs/fy09osti/45834.pdf.

50 See *Inputs & Assumptions: 2019-2020 Integrated Resource Planning*, available at https://files.cpuc.ca.gov/energy/modeling/Inputs%20%20Assumptions%202019-2020%20CPUC%20IRP%202020-02-27.pdf.

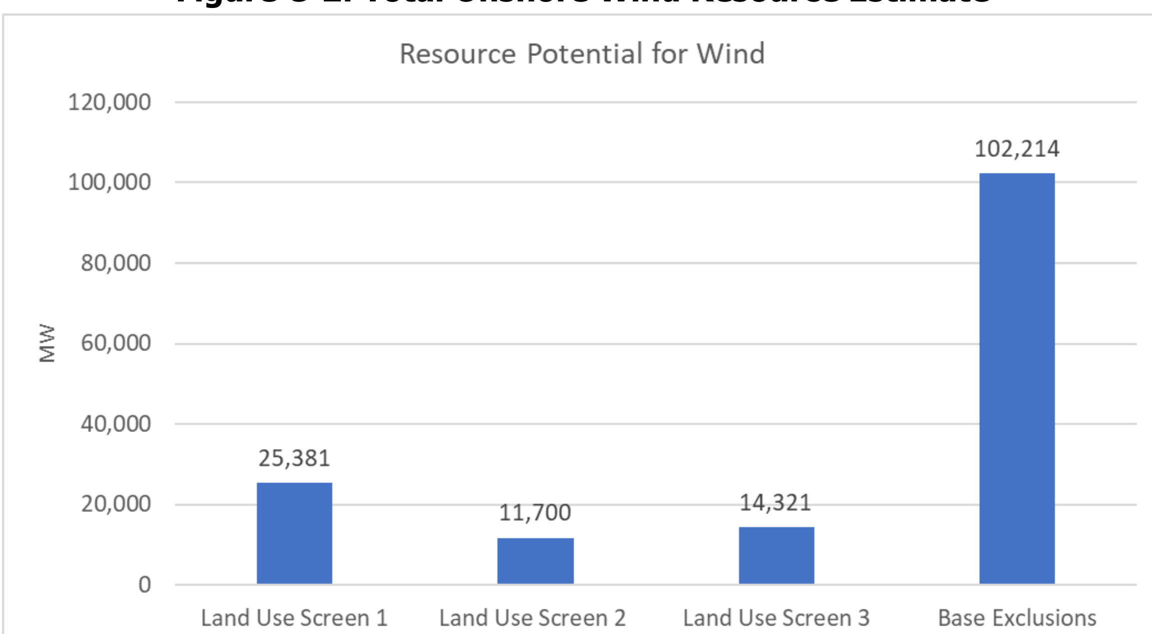
Figure C-1: Total Solar Resource Estimate



Source: CEC staff

The total solar resource potential in MW throughout the state after the base exclusions have been applied and after each screen was applied. A 30 MW/kilometer² power density was used to estimate the resource potential.

Figure C-2: Total Onshore Wind Resource Estimate



Source: CEC staff

The total onshore wind resource potential in MW throughout the state after the application of the base exclusions and each of the three screens. A 2.7 MW/kilometer² power density was used to estimate the resource potential.

The area estimates have not been converted into CPAs. There are small fragments of polygons remaining as available in the resource potential footprint which are not large enough to support a utility-scale renewable energy project. CEC staff expect to revise the map to exclude these discontiguous slivers, which will slightly decrease the MW values shown here.

For geothermal resources, a USGS statewide electrical power generation from identified or undiscovered resources estimate spans a range from 5,400 to 11,340 MW, respectively, with mean certainty.[51] A NREL report has estimated that 170,000 MW could be produced statewide from enhanced geothermal systems from reservoirs as deep as 10 kilometers, and temperatures greater than or equal to 150°C within the state.[52] All of these calculations are generally based on the volume method.[53]

Few studies have estimated the technical resource potential coming from regions of known geothermal fields. The latest assessment known to CEC staff is a 2004 study by Lovekin et al.[54] In that study, the authors incorporate the uncertainties of reservoir temperature and volume, (among other uncertain parameters) by performing a Monte Carlo simulation to estimate the thermal energy of the reservoir. This results in a probability distribution of the generation capacity of each geothermal field. The most likely values from the range of possible values are reproduced below in Figure C-3. The estimate of the generating capacity at Truckhaven is 50 MW from the environmental impact statement of the geothermal leasing areas that the BLM manages.[55] In addition, the Niland and Sulphur Bank generation capacities are added to the estimate of the KGRA that they are located in (the Salton Sea and Geysers, respectively).

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51 Williams, Colin F., Reed, Marshall J., Mariner, Robert H., DeAngelo, Jacob, Galanis, S. Peter, Jr., 2008, Assessment of moderate- and high-temperature geothermal resources of the United States: U.S. Geological Survey Fact Sheet 2008-3082, 4 p.

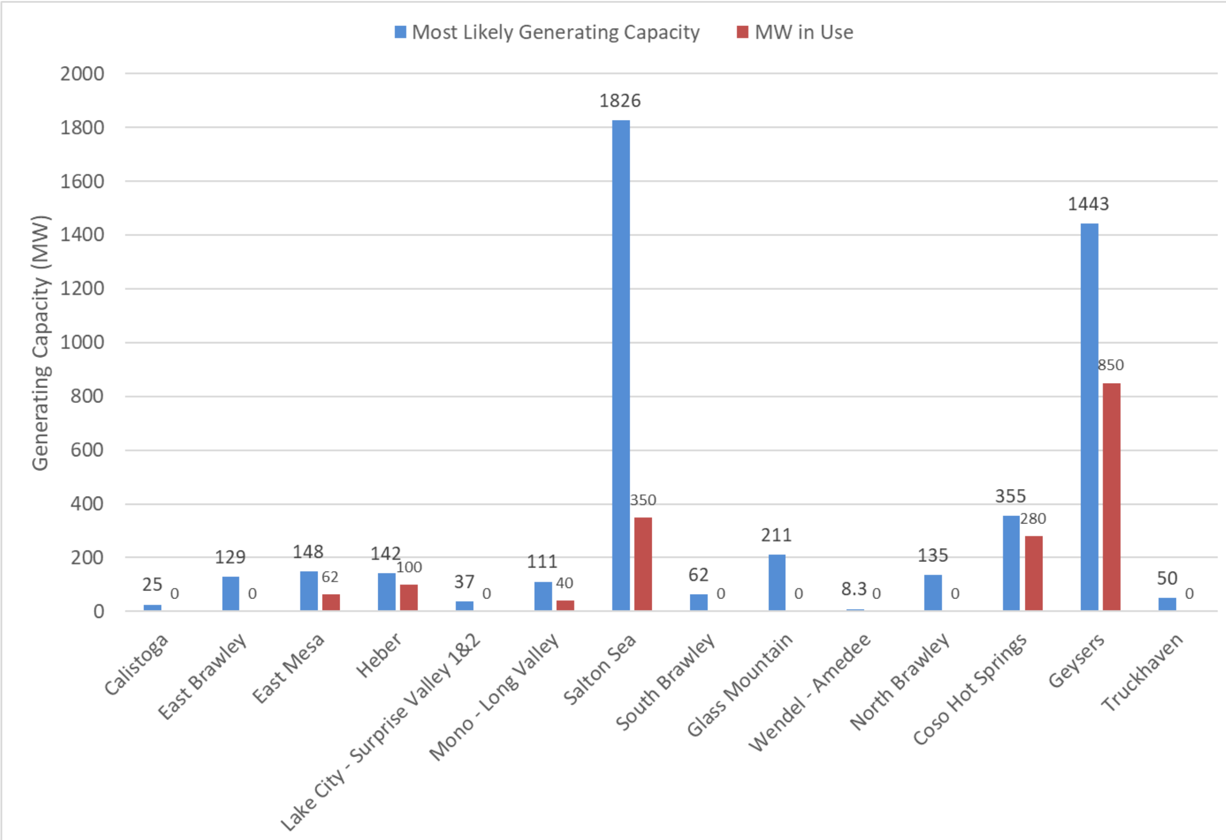
52 Lopez, A., B. Roberts, D. Heimiller, N. Blair, and G. Porro. "U.S Renewable Energy Technical Potentials: a GIS-Based Analysis." National Renewable Energy Lab, July 2012. https://www.nrel.gov/docs/fy12osti/51946.pdf.

53 Three references: (1) Muffler, L.P.J., 1979, Assessment of geothermal resources of the United States-1978: U.S. Geological Survey Circular 790, p. 163. (2) Brook, C.A., Mariner, R.H., Mabey, D.R., Swanson, J.R., Fuggganti, M., and Muffler, L.J.P, 1978, Hydrothermal convection systems with reservoir temperatures ≥ 90°C, in, Muffler, L.J.P., (ed), Assessment of the Geothermal Resources of the United States – 1978: U.S. Geological Survey Circular 790, 163 p. and 3 sheets. (3) Williams, C.F., Reed, M.J., and Mariner, R.H., 2008, A review of methods applied by the U.S. Geological Survey in the assessment of identified geothermal resources: U.S. Geological Survey Open-File Report 2008-1296, p. 27. http://pubs.usgs.gov/of/2008/1296/.

54 Lovekin, James W., Subir K. Sanyal, Christopher W. Klein. 2004. "New Geothermal Site Identification and Qualification." Richmond, California: California Energy Commission: Public Interest Energy Research Program. Accessed September 14, 2022.

55 El Centro Field Office, Bureau of Land Management (2007). Final Environmental Impact Statement for the Truckhaven Geothermal Leasing Area (Publication Index Number: BLM/CA/ES-2007-017+3200). United States Department of the Interior Bureau of Land Management.

Figure C-3: Generation Capacities from Resource Potential Basemap



Source: CEC staff

The undeveloped electrical power generation estimated for the geothermal resource potential basemap. Differencing the most likely generating capacity and the MW already in production (MW in use) yields the net capacity of undeveloped resource for each geothermal field.

It is estimated that a total of 4,682 MW of gross electrical energy can be produced from the geothermal fields that remain in the resource potential basemap. Subtracting the total MW that are already in use yields a net total of 3,000 MW of undeveloped electrical power generation that can be produced within these reserves. Given that the gross electrical energy estimates were calculated for the reserves, not the total geothermal resource that conceptually includes the total heat in place of the geothermal formation, they are likely a conservative estimate. The reserves are limited to the portion of the subsurface reservoir that is "reasonably likely" to contain sufficient temperatures and permeability to be economically and technologically extractable[56] at the time of publication almost 20 years ago.

Although this is a smaller generation capacity than the USGS estimates and does not include nonconventional technologies such as enhanced geothermal systems, this is a spatially constrained estimate. It is necessary to know which specific regions of the state can produce

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56 Lovekin, James W., Subir K. Sanyal, Christopher W. Klein. 2004. "New Geothermal Site Identification and Qualification." Richmond, California: California Energy Commission: Public Interest Energy Research Program. Accessed September 14, 2022.

geothermal energy of an estimated quantity to support a diverse portfolio of renewable energy for future planning. An important consideration for geothermal resource development in California is the availability of an adequate water supply. Current technologies for geothermal energy power production are water-intensive, and where there is a constrained water supply, the potential for development could be limited. In addition, knowledge of areas with high resource potential that are far from infrastructure is important to consider for growth of the electric system to support the large buildout of energy resources for SB 100.

Exclusion Datasets

CEC staff started by examining the exclusion datasets previously used in electric system planning between 2010 and 2022, including the CPUC's RPS Calculator, RESOLVE modeling for the Integrated Resource Plan, and RESOLVE modeling for the 2021 SB 100 Joint Agency Report. The exclusion datasets were informed by conventions established in prior work, including RETI 1.0. Prior land-use screening methods established three categories of exclusion data: technoeconomic criteria,[57] legally protected areas criteria,[58] and California Native American tribes' tribal lands. Where applicable, the exclusion datasets were updated to reflect the availability of newer information from state and federal agencies. See **Appendix D, Tables D-1 to D-3,** for tables showing input data for the exclusion datasets.

The technoeconomic exclusions for solar and onshore wind technology types came from the candidate project areas (CPAs) developed for the CPUC.[59] Although the CPAs had already been geo-processed to polygon features of minimum project size, CEC staff used the inverse of these results, the areas not included in the CPAs, as the technoeconomic exclusions footprint for onshore wind and solar.

The protected areas were heavily based on RETI 1.0 blackout areas[60] and pertain to natural and wilderness areas where development of utility-scale renewable energy is prohibited. The PAD-US (CBI Edition)[61] was the main source used to identify these lands. A manual approach

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57 Spatial datasets that capture technical (for example, competitive wind resource locations), physical (for example, slope, water bodies), and socio-economic or hazardous (for example, densely populated areas, railways, airports, mines, flood zones) criteria. This category also includes military lands. The data sets that were used in this exclusion category were provided by CPUC staff.

58 These criteria are applied to identify areas with existing legal restrictions against utility-scale energy development, for example National Parks, land conservation designations within the DRECP.

59 See *Inputs & Assumptions: 2019-2020 Integrated Resource Planning*, available at https://files.cpuc.ca.gov/energy/modeling/Inputs%20%20Assumptions%202019-2020%20CPUC%20IRP%202020-02-27.pdf.

60 Final RETI Phase 2A report, available at https://ww2.energy.ca.gov/2009publications/RETI-1000-2009-001/RETI-1000-2009-001-F-REV2.PDF.

61 "PAD-US (CBI Edition) Version 2.1b, California." Conservation Biology Institute. 2016. https://databasin.org/datasets/64538491f43e42ba83e26b849f2cad28.

was used to identify which fields and values in the database were appropriate in extracting the areas that should be excluded from renewable resource estimates. GAP statuses of 1 or 2 were used as a main category of lands that restrict utility-scale renewable energy development due to biological and ecological conservation purposes. The primary designation type (p_des_tp) field and subsidiaries (secondary and tertiary designation types) were found to be most useful in defining much of the other protected areas. Based on categorization judgements like these, a series of selection queries were created to extract the appropriate designations known to prohibit utility-scale energy development. For example, to select all state parks or state recreation areas, the following selection query was placed on the PAD-US (CBI Edition) database: *p_des_tp IN ('State Park','State Recreation Area')*. Sometimes the designation type field was insufficient in capturing all of the land of a certain type, and the primary local designation (p_loc_ds) field was used instead. A compilation of the specific selection queries used for each protected category is given in Table D-2 of Appendix D.

The CA Nature 30x30 Conserved Areas, Terrestrial dataset[62] is used to ensure that the manual process described above (using mainly designation terms) did not omit any protected areas from a biodiversity perspective. Extensive care was taken to properly define GAP status in this dataset. Polygons with reGAP values of 1 and 2 were extracted from this dataset, as these follow the GAP definitions of lands that follow management protocols that emphasize protection and sustaining or improving biodiversity. Most of these records were already accounted for from the PAD-US data source, but many city and county lands that hold a preservation status and had been missed from the manual approach described above were provided by this additional data source. In total, the new additions of conservation areas expanded the exclusions footprint of this project by 1 percent.

The final major component of natural lands and wilderness areas that are protected under a conservation designation comes from the BLM's National Conservation Lands (part of the National Landscape Conservation System).[63] Inventoried Roadless Areas,[64] Greater Sage-

62 "30x30 Conserved Areas, Terrestrial." CA Nature working group. August 3, 2022. Available at https://www.californianature.ca.gov/datasets/CAnature::30x30-conserved-areas-terrestrial/about.

63 "BLM CA NLCS Released Wilderness Study Areas Polygons." Bureau of Land Management. Available at https://data.cnra.ca.gov/dataset/blm-ca-nlcs-released-wilderness-study-areas-polygons.

64 "Inventoried Roadless Areas by State." United States Forest Service. Available at https://www.fs.usda.gov/detail/roadless/2001roadlessrule/maps/statemaps/?cid=stelprdb5400185.

Grouse Habitat Management Areas,[65] and the California Conservation Easements Database[66] were brought in independently as some of these datasets fell under management decisions that were made after the last update of the PAD-US. The Greater Sage-Grouse Resource Management Plan Amendment provides an allocation decision that defines which habitat management area (prime, general or other) prohibits onshore wind and solar resource development. Geothermal resource development is not excluded in any of these management areas. The compilation of all the aforementioned datasets, including PAD-US and 30x30 Conserved Areas, is shown below in Figure C-4. It uses the Greater Sage-Grouse Habitat Management Area exclusion regions for solar. A similar map can be created for onshore wind, with only minor differences in the northeast portion of the state where the Greater Sage-Grouse Habitat Management Areas that are excluded for wind lie.

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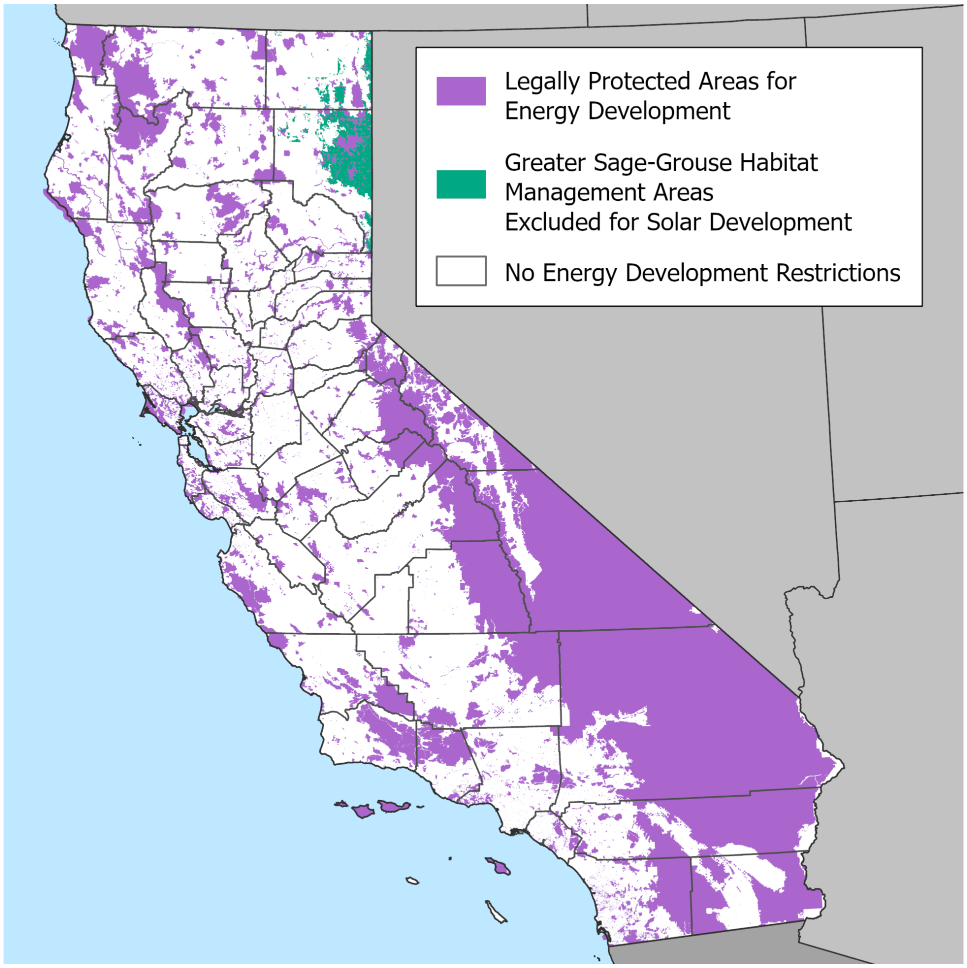
65 *Nevada and Northeastern California Greater Sage-Grouse Approved Resource Management Plan Amendment*. See Table 2-1 for the summary of allocation decisions for various resources, including solar, wind and geothermal energy in the Nevada and Northeastern California Greater Sage-Grouse Approved Resource Management Plan Amendment. Available at https://eplanning.blm.gov/public_projects/lup/103343/143707/176908/NVCA_Approved_RMP_Amendment.pdf.

66 "California Conservation Easement Database." Protected Areas Data Portal. Available at https://www.calands.org/cced/.

Figure C-4: Merged Footprint of Legally Protected Areas for Solar



Source: CEC staff

The major components of the legally protected areas are shown above (protected areas from PAD-US [CBI Edition], 30x30 Terrestrial Conserved Areas, NCLS, Inventoried Roadless Areas, Greater Sage-Grouse Habitat Management Areas, and California Conservation Easements).

California Native American tribes' tribal lands spatial extents are obtained from the Department of Interior's Bureau of Indian Affairs American Indian and Alaska Native Land Area Representation (AIAN-LAR) dataset.[67] These areas depict the extent of federally recognized Indian reservations and associated land held in "trust" by the United States, "restricted fee" or "mixed ownership" status for federally recognized tribes and individual Indians. This dataset includes other land area types such as public domain allotments, dependent Indian

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67 "American Indian and Alaska Native Land Area Representation (AIAN-LAR) Geographic Information System (GIS) dataset." United States Department of the Interior, Bureau of Indian Affairs. Available at https://biamaps.doi.gov/bogs/datadownload.html.

communities, and homesteads. The Bureau of Indian Affairs notes this dataset is prepared strictly for illustrative and reference purposes. CEC staff found these data to be the best geospatial data available that represent California Native American tribes' tribal lands; however, the information is incomplete in that it does not include state-recognized tribes or unrecognized tribes.

Once all exclusion data were acquired, they were merged into a single exclusion layer for utility-scale solar PV and onshore wind resource types. For geothermal resources, CEC staff applied only the legally protected areas and California Native American tribes' tribal lands. The Union Tool[68] was implemented with the "Gaps Allowed" parameter left unchecked, meaning that gaps were not allowed. Any holes left by multiple exclusions encircling an area, or if the land management designation was not contiguous, would be filled during this merging step.

Consistent with past approaches, the land-use screens include renewable resource potential from the BLM DRECP Land Use Plan Amendment (LUPA) Development Focus Areas (DFAs). In this update, CEC staff proposes to include renewable resource potential from Variance Process Lands (VPLs). These results, the compilation of all three categories of exclusions, are shown below in Figure C-5. These base exclusions are used in all subsequent analysis for energy potential estimates and modeling screens.

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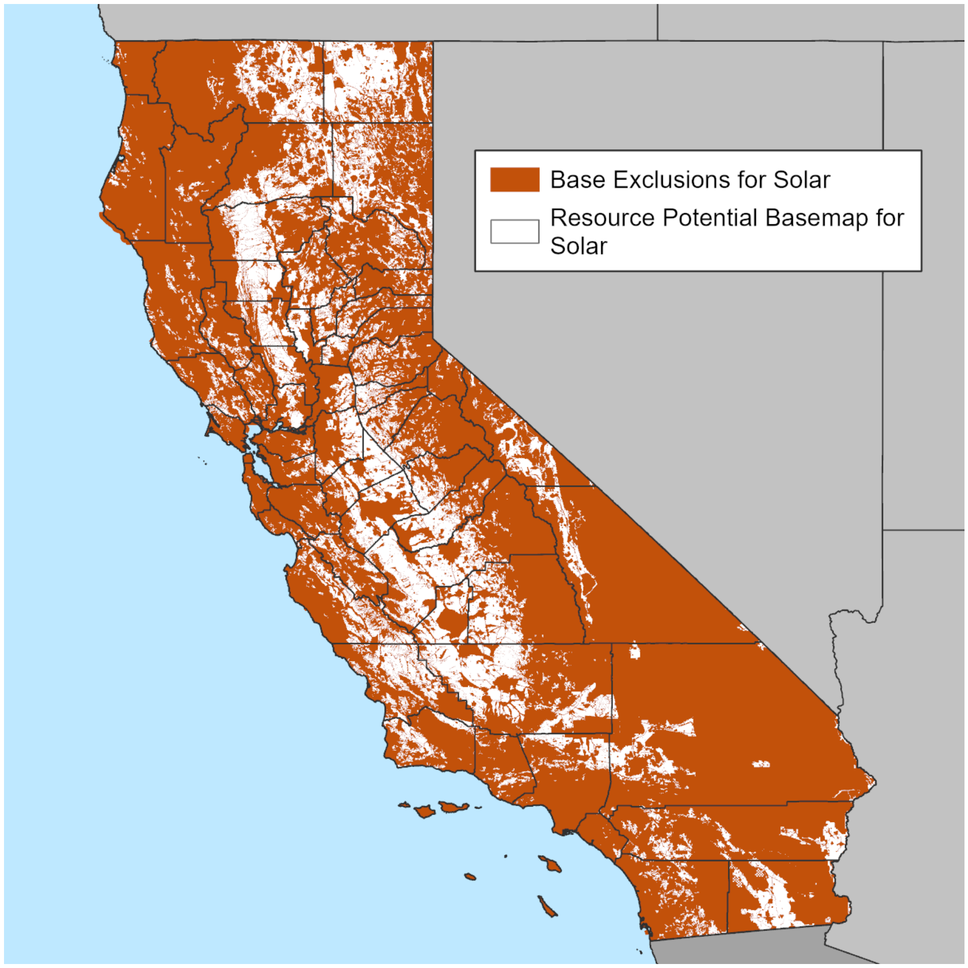
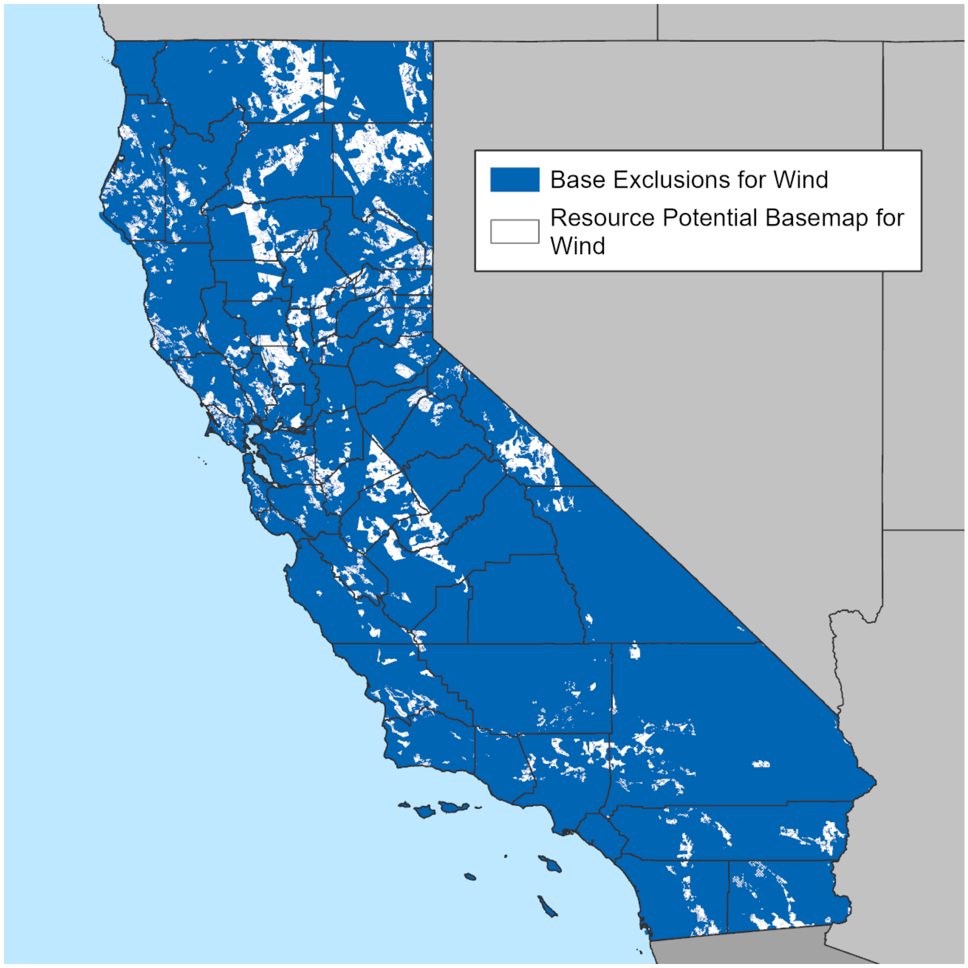
68 "Union (Analysis)." ArcGIS Pro. Full documentation available at https://pro.arcgis.com/en/pro-app/2.8/tool-reference/analysis/union.htm.

Figure C-5 Base Exclusions and Resource Potential Basemaps for Solar and Onshore Wind





Source: CEC staff

Base exclusion maps for each technology. Solar is on top, and onshore wind on the bottom. The inverse of the base exclusions, the area remaining within California that is not within the base exclusion footprint, is the resource potential basemap.

Comparison of Resource Potential Basemaps to Previous Studies

The area of California remaining after removing the base exclusions is the resource potential basemap and is the basis of much of the CEC staff analysis in subsequent steps. Past studies have used similar approaches as described above to construct resource potential basemaps. A comparison of the total areas (Table C-1) demonstrates that the updated methodology presented in this report produced a total footprint area for solar within the range of the other efforts. The updated basemap recommended in this staff report most closely agrees with the RETI/CPUC 2016 basemap. This is an expected result given that the categories used to construct the exclusions, especially those of the protected areas, closely followed those of the RETI 1.0 blackout areas.

Table C-1: Comparison of Resource Potential Basemaps for Solar Across Agency and External Analyses

	New Base Exclusions in current Land-Use Screens Report (2022)	RETI Categories 1 and 2 Exclusions	The Nature Conservancy (TNC) Siting Level 1 (Unconstrained)	TNC Siting Level 2 (Unconstrained)	WECC Risk Categories 3 and 4
Area Remaining in CA (Million Acres)	21.83	21.70	17.26	13.69	32.85

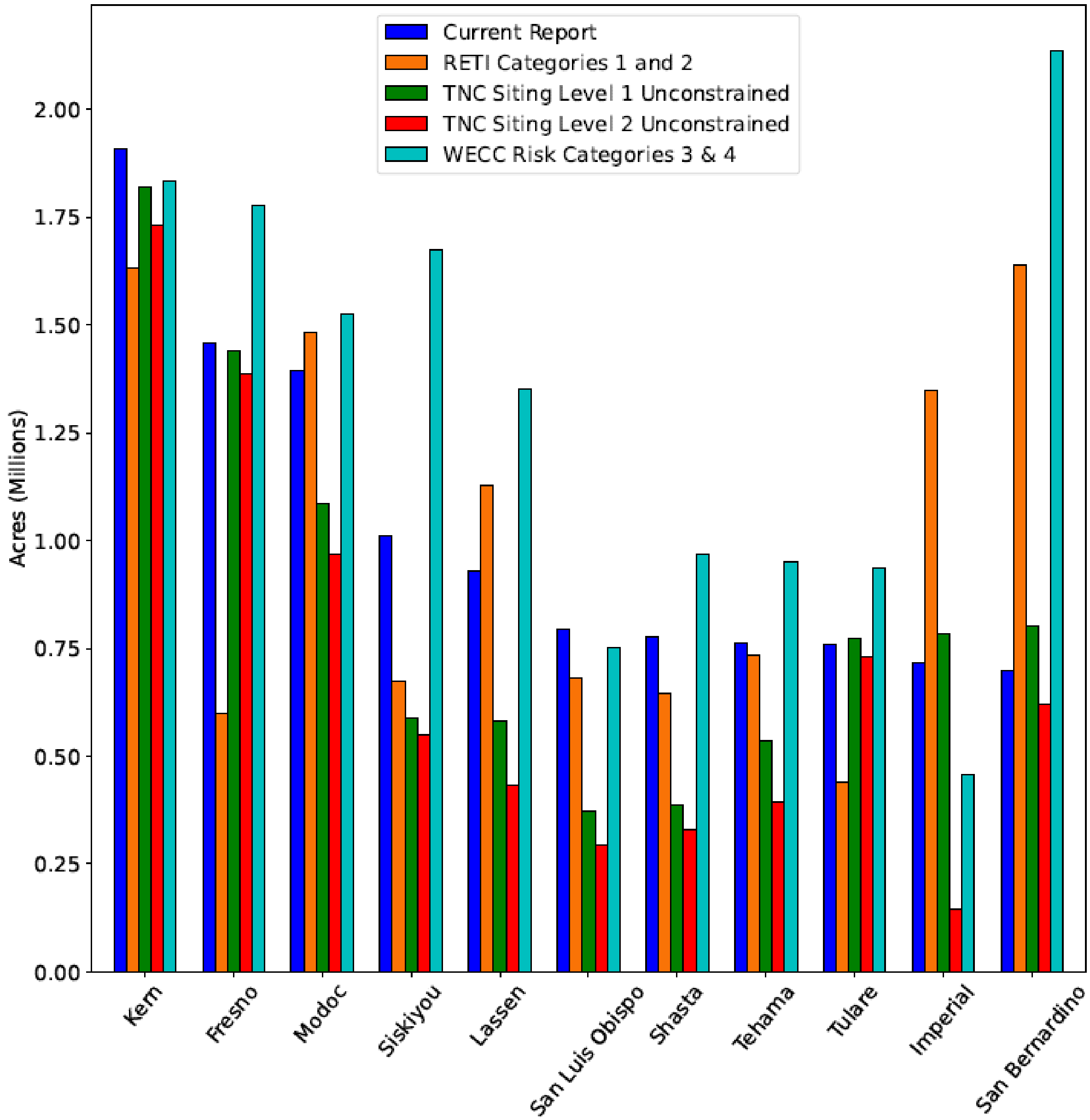
Source: CEC staff

The statewide area remaining for renewable resource potential is shown in millions of acres.

CEC staff finds that the newly constructed resource potential basemap broadly agrees with the other studies for various counties (Figure C-6). This finding is important because electric system planning needs to consider the spatial footprint of these results. Distance to a transmission line and proximity to a substation are important factors when considering cost and feasibility of future resources. Aggregating the resource potential basemap by county helps elucidate any differences that exist between CEC staff construction of the resource potential basemaps and past efforts in a more impactful way. The updated resource potential basemap created here typically matches the less restrictive scenarios such as the RETI exclusions and Siting Level 1 (unconstrained) case from The Nature Conservancy (TNC).[69] Given that the resource potential basemap developed here for electric system planning is a set of base exclusions that are used in every modeling scenario and planning purpose, the spatial footprint should be more in line with the general cases rather than the ones with elevated conservation conditions (for example, TNC Siting Level 2).

69 Wu, Grace, et al. 2020. "Low-impact land use pathways to deep decarbonization of electricity." *Environmental Research Letters.* 15 074044. Available at https://iopscience.iop.org/article/10.1088/1748-9326/ab87d1.

Figure C-6: Solar Resource Potential Basemap Acreage Under Agency and External Studies' Exclusions for Select Counties



Source: CEC staff

Comparison of Resource Potential Basemap areas per select counties

The following sections discuss the input data variables, modeling, and construction of screens used to further evaluate land-use in terms of opportunities and constraints for electric system planning.

Input Data for Suitability Models and Screens

To explore planning considerations related to biodiversity, lands used to produce crops, and terrestrial landscape intactness, CEC staff developed three models using the ArcGIS Pro Suitability Modeler. The suitability modeling tool is a multi-criteria evaluation method common in geospatial analyses when multiple inputs affect an overall value decision for an area. It uses a weighted raster overlay (WRO) to combine input data layers to produce a map showing the resulting summation value of all the input data sets.

CEC staff consulted source data owners, associated subject matter experts, and partnering agencies to develop a list of source authoritative datasets, determine best practices working with those datasets, develop a modeling methodology, and determine value ranges from each dataset that represent the impact to each model. Redundant source datasets were removed, best practices were noted, source data was acquired, and transformed to be used in the model methodology. Source datasets for each model are described below. Please see **Tables D 4 –7 of Appendix D** for a list of each data set used in the models and screens.

Biodiversity Index

The biodiversity index uses and relies heavily on CDFW's Areas of Conservation Emphasis (ACE) project. The ACE 3.0 dataset uses observed and modeled data on wildlife, vegetation and habitats to create high level maps for conservation planning purposes.

- Terrestrial Biodiversity: This dataset provides a metric on relative biodiversity levels for birds, amphibians, plants, mammals and reptiles across each USDA ecoregion. Biodiversity measures the native species richness (diversity of all species in the state), rare species richness (diversity of rare species), and irreplaceability (highlights unique endemic species). The Ecoregion Weights attribute the landscape in 2.5 square mile units with overall biodiversity values ranging from zero to one.
- Terrestrial Connectivity: This dataset evaluates how an area contributes to habitat connectivity. It includes information on corridors that allow for species migration, especially between areas that are large, contiguous and natural, which is another metric used in this dataset. Intactness, the final metric for connectivity, is higher when human disturbance is low. The ACE Ranks are used to indicate level of connectivity, with essential corridors and linkages emphasized with scores of 4 or 5, while large, intact regions with very fewer important linkages are given a lower rank of 2. Areas that show no opportunity for connectivity are given the lowest rank of 1.

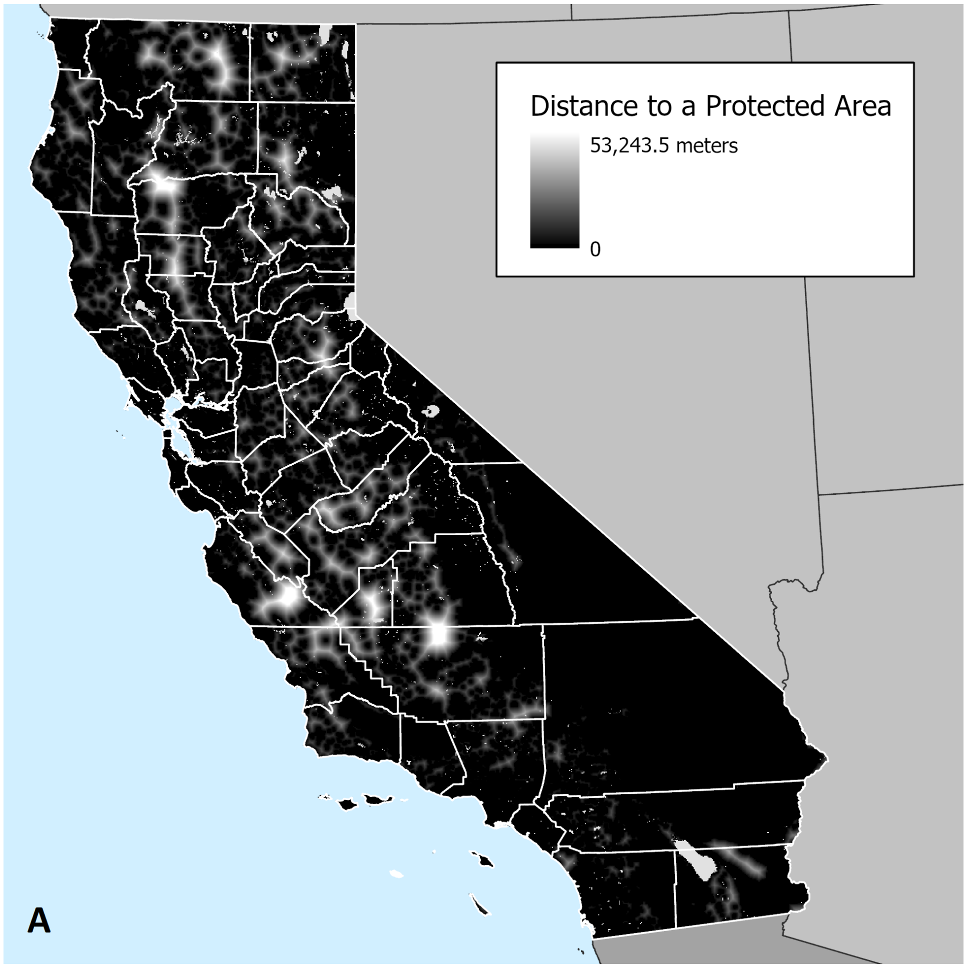
Landscape Intactness

This dataset provides an estimate of terrestrial landscape intactness, (that is, condition), based on the extent to which human impacts such as agriculture, urban development, natural resource extraction, and invasive species have disrupted the landscape across the State of California. Terrestrial intactness values are higher in areas where these impacts are lower. This is used as one of the two data sets in Land-Use Screen 2.

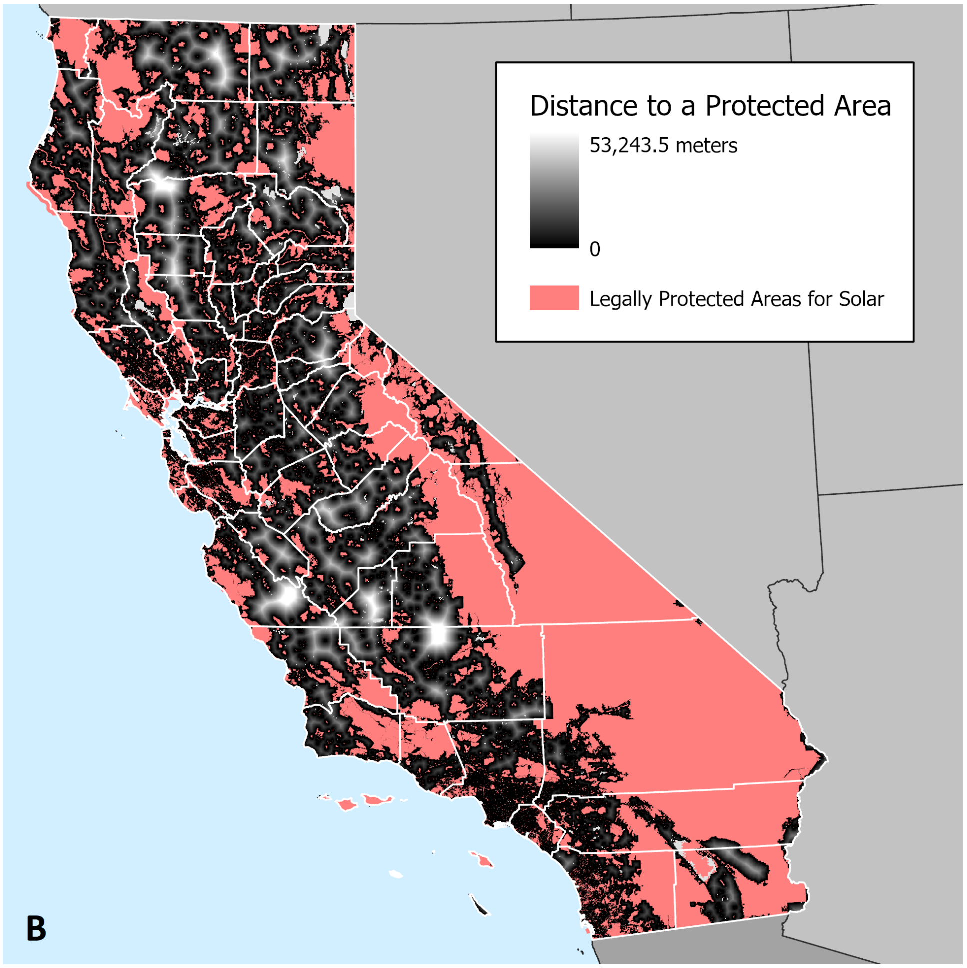
Proximity to Protected Areas

This data set is constructed from the Legally Protected category of exclusions. The shortest geodesic distance, the shortest path between two points, given the topology of the land, from every grid cell in the Landscape Intactness data set is calculated to the edge of the nearest conserved feature in the protected areas layer by the ArcGIS Pro Near Tool.[70] This results in a 1-kilometer resolution raster of California where every grid cell is given a value of 0 to approximately 54,000 meters. If a grid cell is within a protected area, its value in the Distance to Legally Protected Areas data set is 0. The results are shown below in Figure C-7. As the distance to a legally protected area increases, the map appears brighter.

Figure C-7: Distance to Legally Protected Areas



70 "ArcGIS Pro Near Tool." Full documentation of Esri Tool is available at https://pro.arcgis.com/en/pro-app/latest/tool-reference/analysis/near.htm.



Source: CEC staff

Panel A of this figure depicts the raw results of calculating the closest distance in meters to a protected area from every grid cell in the Landscape Intactness data set. There are large areas with a value of 0 indicating that the grid cell center point is within a protected area. Those areas are shown in pink in figure panel B. The grey to white shading indicates increasing distance to a legally protected area.

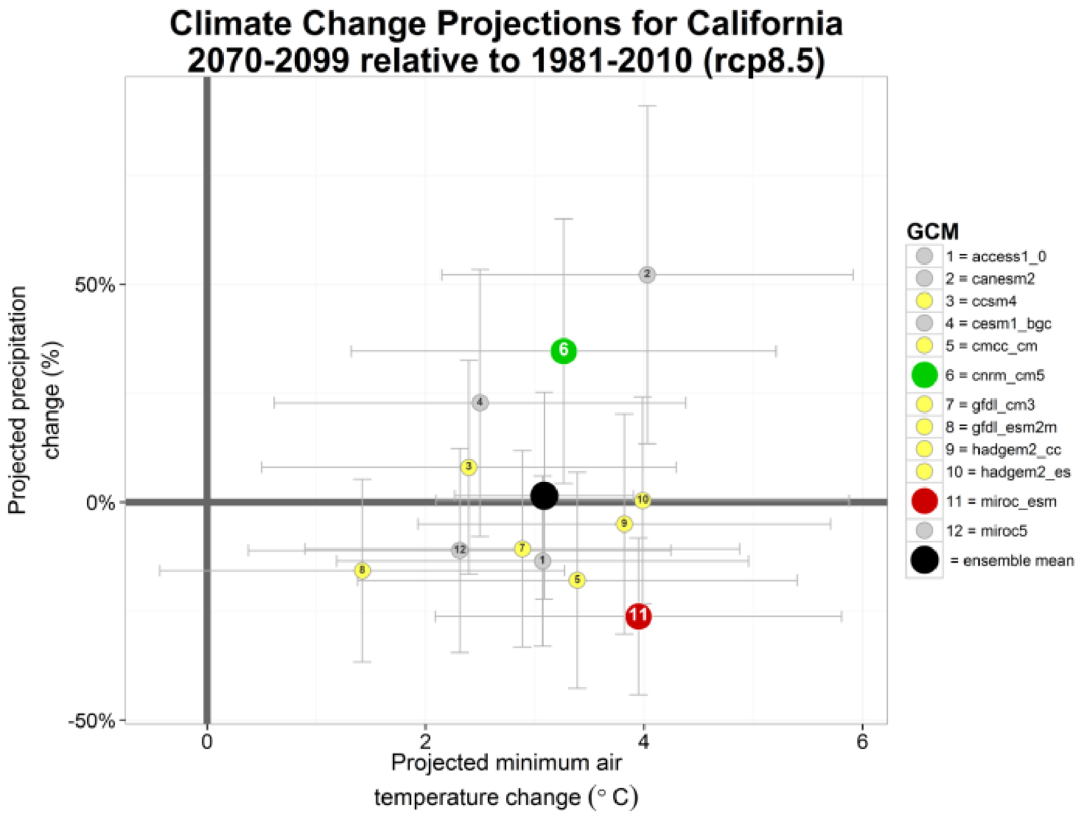
Terrestrial Climate Resilience

The ACE Terrestrial Climate Resilience data set is based upon the work by Thorne et al.[71] to understand the sensitivity, adaptive capacity, magnitude of exposure, and potential spatial disruption of coarse vegetation community types under various climate change scenarios. Thorne et al. used a statewide grid of 270-meter resolution, representing vegetation (Macrogroups) across California, to develop a baseline model of current climate conditions as well future conditions under eight climate model projections.

71 Thorne, J.H., R.M. Boynton, A.J. Holguin, J.A.E. Stewart, & J. Bjorkman. 2016. *A Climate Change Vulnerability Assessment of California's Terrestrial Vegetation*. Prepared for: California Department of Fish and Wildlife (CDFW), Sacramento, CA. Available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=116208&inline.

The MIROC ESM and the CNRM CM5 global climate models were chosen under two time horizons (mid-century and end-of-century), and under two different representation concentration pathways (RCP) of future greenhouse gas emissions (the RCP 8.5 and RCP 4.5 scenarios).[72] Those particular models were chosen because they represent a broad range of possible future climate trajectories in California. As shown in Figure C-8 below (reproduced from Figure 6 in the original Thorne et al. 2016 report),[73] the MIROC ESM model result produces a hotter and drier result compared to all other GCM results shown here from the Coupled Model Intercomparison Project – Phase 5 (CMIP-5). The CNRM CM5 model simulates one of the warmer and wetter projections compared to other models and the ensemble mean.

Figure C-8: Range of Global Climate Model Projections



Source: Thorne et al. 2016

This figure shows how the CNRM CM5 and MIROC ESM models compare to other global climate models in their end-of-century projections of precipitation and minimum temperature changes for California under the RCP 8.5. The large green dot represents the mean CNRM results, and the large red dot represents the mean MIROC results. The large black dot represents the ensemble mean.

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72 The RCP 8.5 represents the business as usual, no reduction in emissions case. The RCP 4.5 represents a future emissions forcing of the climate models where a drastic reduction occurs after 2040.

73 Thorne, J.H., R.M. Boynton, A.J. Holguin, J.A.E. Stewart, & J. Bjorkman. 2016. *A Climate Change Vulnerability Assessment of California's Terrestrial Vegetation*. Prepared for: California Department of Fish and Wildlife (CDFW), Sacramento, CA. Available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=116208&inline.

The MIROC ESM and CNRM CM5 model scenarios described above at the two RCP scenarios were used to establish a temporal baseline set of historical climatic conditions (1981-2010). These data were statistically downscaled to 270 meters and run through a hydroclimatic model to derive nine landscape hydrology variables which are expected to more directly affect vegetation health. These variables are annual mean minimum temperature, annual mean maximum temperature, annual precipitation, actual evapotranspiration, potential evapotranspiration, climatic water deficit, snowpack depth on April 1st, runoff, and recharge. These variables were then reduced to a two-dimensional climate space through principal component analysis, representing approximately 79 percent of the variability in the data. Applying a kernel density estimator[74] to sampled points for each vegetation type within this climate space produced continuous point density surfaces, establishing the baseline conditions in which each vegetation macrogroup is found. The density surfaces were then partitioned with contour lines, fitted so that each contour encompasses 5 percent of pixels of the vegetation type. These contours can additionally be grouped into classes, so that all pixels within 80 percent of the core baseline climate distribution can be considered to lie within climatically suitable areas. Areas beyond that can be considered to experience increasingly stressed, and then marginal environmental conditions.

Corresponding envelopes were then constructed based on the mid-century and end-of-century climate models. If the predicted climate exposure caused a deviation in conditions that was outside of the 95 percent contour of the historical distribution, the grid cell was considered stressed under climate change. If the prediction did not shift the climatic indicators beyond the 80 percent range, the area was considered a refugia since the vegetation would remain within a suitable climatic envelope.

The CDFW then generalized these model results to the 2.5 mile^2 hexagon units of the ACE project. The binary results, indicating whether a 270-meter vegetation cell would remain in suitable conditions under each of the eight climate projections, were summed and then divided by eight to get a score of 0 to 1. A cell where all models indicated refugia climatic conditions would get a score of 1 (8/8) while a cell where no models indicated refugia would receive a score of 0 (0/8). Those scores were then summarized onto the ACE hexagonal grid, weighting each grid cell score by the percent area of the hexagon that it covered. If any part of the hexagon covered non-natural areas, that area was excluded from the calculation. A score of 1 would indicate a hexagon whose entire natural area was comprised of 270-meter grid cells in which all eight model outputs indicated these areas would remain intact ecologically under changing climate conditions. Finally, the ACE ranks (1 through 5) were determined by binning those climate refugia scores into equal interval categories. Ranks of 4 and 5 correspond to a climate refugia score greater than 0.6. In this report, regions that are classified into the highest ranks (ranks 5 or 4) are identified as an exclusion under Land-Use Screen 3.

[74] "Kernel Density Estimation." Full documentation available at https://stat.ethz.ch/R-manual/R-devel/library/MASS/html/kde2d.html.

Cropland Index

The Cropland Index evaluates lands used to produce crops based on the following input datasets: Revised Storie Index, California Important Farmland data, Electrical Conductivity (EC), and Sodium Adsorption Ratio (SAR).

CEC staff used the following input datasets:

- California Important Farmland data – statistical data used for analyzing impacts on California's agricultural resources from the Farmland Mapping and Monitoring Program. Agricultural land is rated according to soil quality and irrigation status. The maps are updated every two years (on even numbered years) with the use of a computer mapping system, aerial imagery, public review, and field reconnaissance.
  - Extent was used to determine the Cropland Index Mask.
  - Prime Farmland – farmland with the best combination of physical and chemical features able to sustain long term agricultural production. This land has the soil quality, growing season, and moisture supply needed to produce sustained high yields. Land must have been used for irrigated agricultural production at some time during the four years prior to the mapping date.
  - Farmland of Statewide Importance – farmland similar to Prime Farmland but with minor shortcomings, such as greater slopes or less ability to store soil moisture. Land must have been used for irrigated agricultural production at some time during the four years prior to the mapping date.
  - Unique Farmland – farmland of lesser quality soils used for the production of the state's leading agricultural crops. This land is usually irrigated but may include Non irrigated orchards or vineyards as found in some climatic zones in California. Land must have been cropped at some time during the four years prior to the mapping date.
- Gridded Soil Survey Geographic Database (gSSURGO) – a database containing information about soil as collected by the National Cooperative Soil Survey over the course of a century. The information can be displayed in tables or as maps and is available for most areas in the United States and the Territories, Commonwealths, and Island Nations served by the USDA-NRCS. The information was gathered by walking over the land and observing the soil. Many soil samples were analyzed in laboratories.
  - California Revised Storie Index is a soil rating based on soil properties that govern a soil's potential for cultivated agriculture in California. The Revised Storie Index assesses the productivity of a soil from the following four characteristics: Factor A, degree of soil profile development; factor B, texture of the surface layer; factor C, slope; and factor X, manageable features, including drainage, microrelief, fertility, acidity, erosion, and salt content. A score ranging from 0 to 100 percent is determined for each factor, and the scores are then multiplied together to derive an index rating.

  - Electrical Conductivity is the electrolytic conductivity of an extract from saturated soil paste, expressed as Deci siemens per meter at 25 degrees C. Electrical conductivity is a measure of the concentration of water-soluble salts in soils. It is used to indicate saline soils. High concentrations of neutral salts, such as sodium chloride and sodium sulfate, may interfere with the adsorption of water by plants because the osmotic pressure in the soil solution is nearly as high as or higher than that in the plant cells.
  - Sodium adsorption ratio is a measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration. Soils that have SAR values of 13 or more may be characterized by an increased dispersion of organic matter and clay particles, reduced saturated hydraulic conductivity (Ksat) and aeration, and a general degradation of soil structure.
- California Statewide Crop Mapping – A comprehensive and accurate spatial land-use database for Water Year 2018, covering over 9.4 million acres of irrigable agriculture on a field scale.
  - Extent was used to define the Cropland Index Mask.
- Cropland Index Mask – This is a constructed data set used to define the model domain. Its footprint is defined by combining the extent of the California Important Farmland data (2018) classifications listed above and the area defined by California Statewide Crop Mapping for the state of California. This layer was used to mask all other Cropland Index inputs and is shown below in Figure C-9.

Figure C-9: Cropland Index Mask

Source: CEC staff

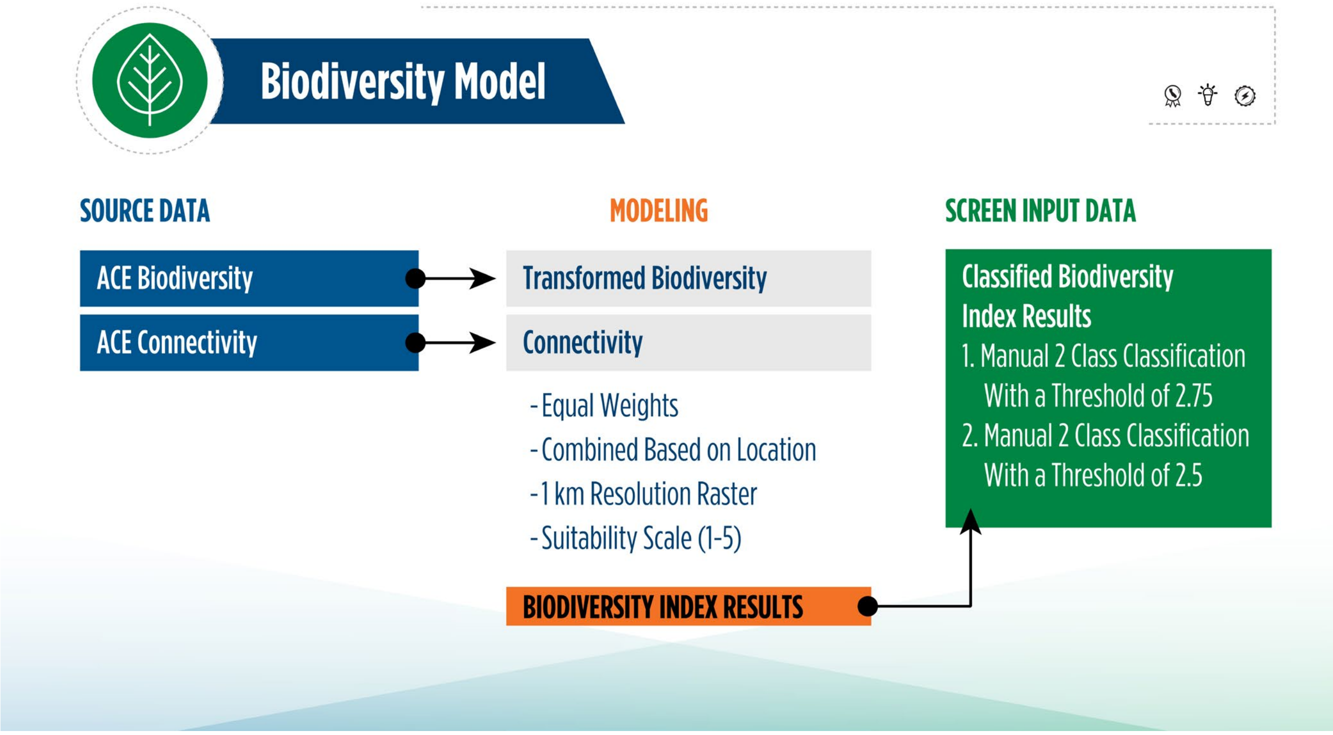
Map of the cropland index modeling extent is the combined footprints of the 2019 California Statewide Crop Mapping and three California Important Farmland codes used in this analysis (Prime, Statewide Importance and Unique Farmland). Areas where gSSURGO Revised Storie Index are null value are removed, resulting in the cropland mask shown here.

The next section describes how the input data was incorporated into the three suitability models. The model results are described, including their categorization into higher and lower classes in preparation for construction of the land-use screens.

Model Evaluation

The Biodiversity Index Model

Figure C-10: Steps in Biodiversity Modeling



Source: CEC staff

The diagram above depicts the data processing steps taken to develop the Biodiversity Index Model for use in the land-use screens.

The next section describes how the input data was incorporated into the three suitability models. The model results are described, including their categorization into higher and lower classes in preparation for construction of the land-use screens.

The Biodiversity Index consists of two input variables – Terrestrial Biodiversity and Terrestrial Connectivity. A simple approach to modeling the combination of both biodiversity and connectivity factors into a single measure of biodiversity index is to use the vector intersection method. In this method, both input data sets are kept in their native 2.5 square mile hexagonal grid and their ranks are added to produce an overall model score. Higher model scores indicate that biodiversity and connectivity are both relatively high, and vice versa. In this way, the measures of both variables are combined to show how both criteria fare in an area.

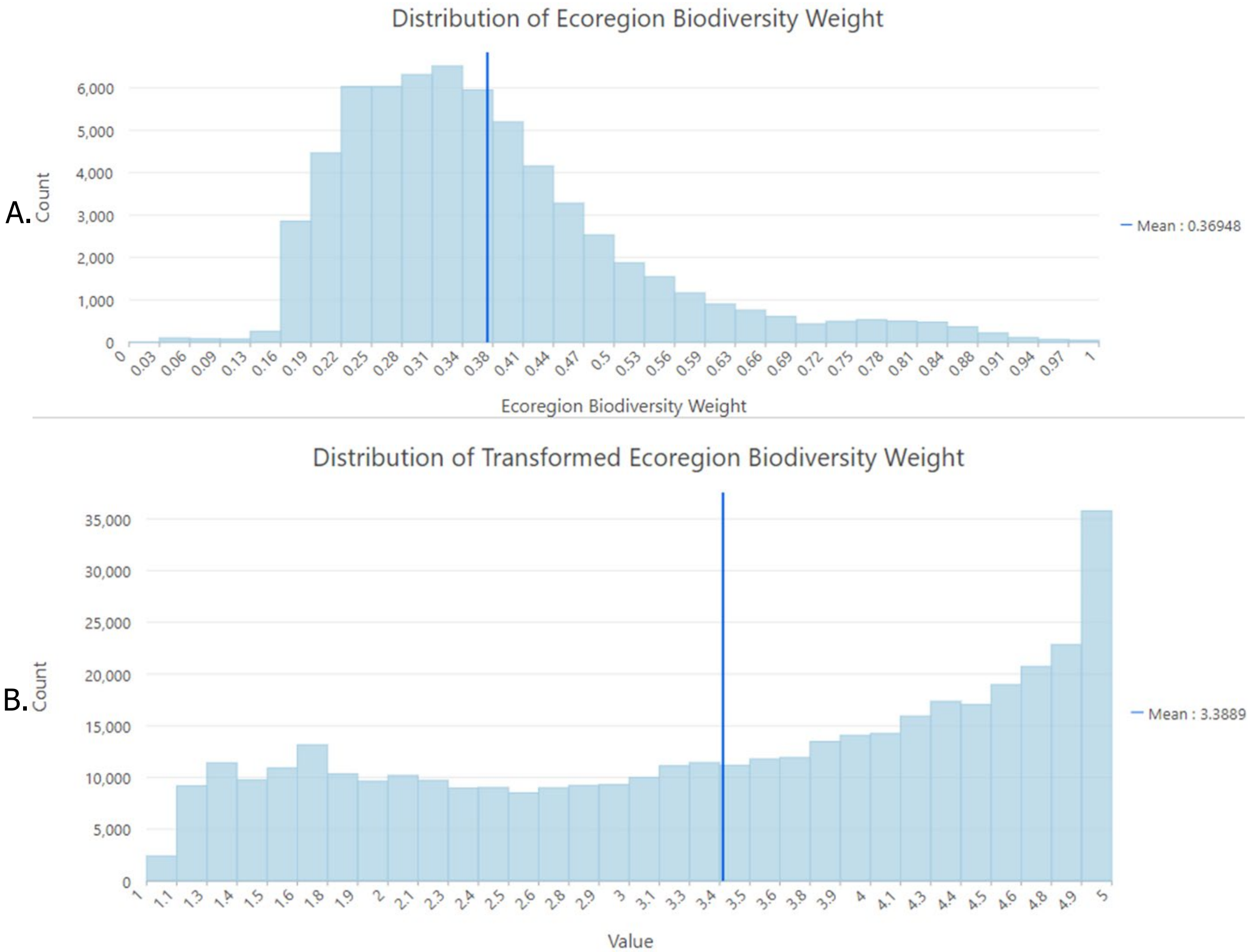
When using the suitability modeling tool, this same fundamental process occurs, but the input data must be in raster format instead of vector. Biodiversity and connectivity were rasterized from the native 2.5 square-mile hexagonal grid (with an average spacing of 3.7 kilometers from center point to center point) onto a 1-kilometer resolution regular grid using the Polygon to Raster Conversion tool.[75] 1-kilometer was chosen as an optimum resolution because it provides a gradual change between the values of the grid cells, making it more representative of the native data. Downsampling data when rasterizing is ideal, and how much downsampling occurs depends on the purpose of the project and computational power available. In the examination of results of test models at 1-kilometer resolution verses a vector intersection method, model results followed a very similar distribution, indicating that the 1-kilometer raster representation of biodiversity and intactness was sufficiently accurate when compared to the vector intersection method.

As each of these input data sets were brought into the Suitability Modeling Tool in their raster format, they needed to be brought onto the same scale. Since connectivity's ranks of 1-5 have very specific definitions, this was kept in its categorical fashion of 5 categories with 5 having the highest value in terms of connectivity. Raw biodiversity values, given between 0 and 1 by the Ecoregion Biodiversity Weight (or BioSumEco) attribute, are the combination of three metrics describing native species richness, irreplaceability, and rare species richness. This biodiversity score was transformed onto the 1-5 scale using a 'Large' function with a midpoint value of 0.3 to best capture the raw data distribution. Default values from ArcGIS Pro's Suitability Modeling Tool were used in the remaining parameters, as shown in Table C-2 below.

A comparison of the distributions of the raw data and the transformed data indicate that the 'Large' function was appropriate. The distribution of the original data shows an abrupt rise from very few counts of low values to the highest values of the histogram. The distribution of the data then falls more gradually and has a long tail for values at the high end of the histogram. The 'Large' function captures this by rolling over into the highest suitability value (5) for most of the values of the long right hand side tail. In between, the data scales almost linearly, and this matches the almost constant distribution of values throughout most of the data points.

75 The optional "cell assignment type" was set to "maximum combined area" because of the irregular divisions of values between the hexagonal grid compared to the regular raster grid. "Polygon to Raster (Conversion)." ArcGIS Pro. See full documentation at https://pro.arcgis.com/en/pro-app/2.9/tool-reference/conversion/polygon-to-raster.htm.

Figure C-11: Plots: Distribution of data prior and after transformation



Source: CEC staff

Panel A shows the distribution of the raw biodiversity scores. Panel B shows the distribution of the transformed biodiversity data set.

Table C-2: Input Parameters used to Transform the ACE Biodiversity dataset

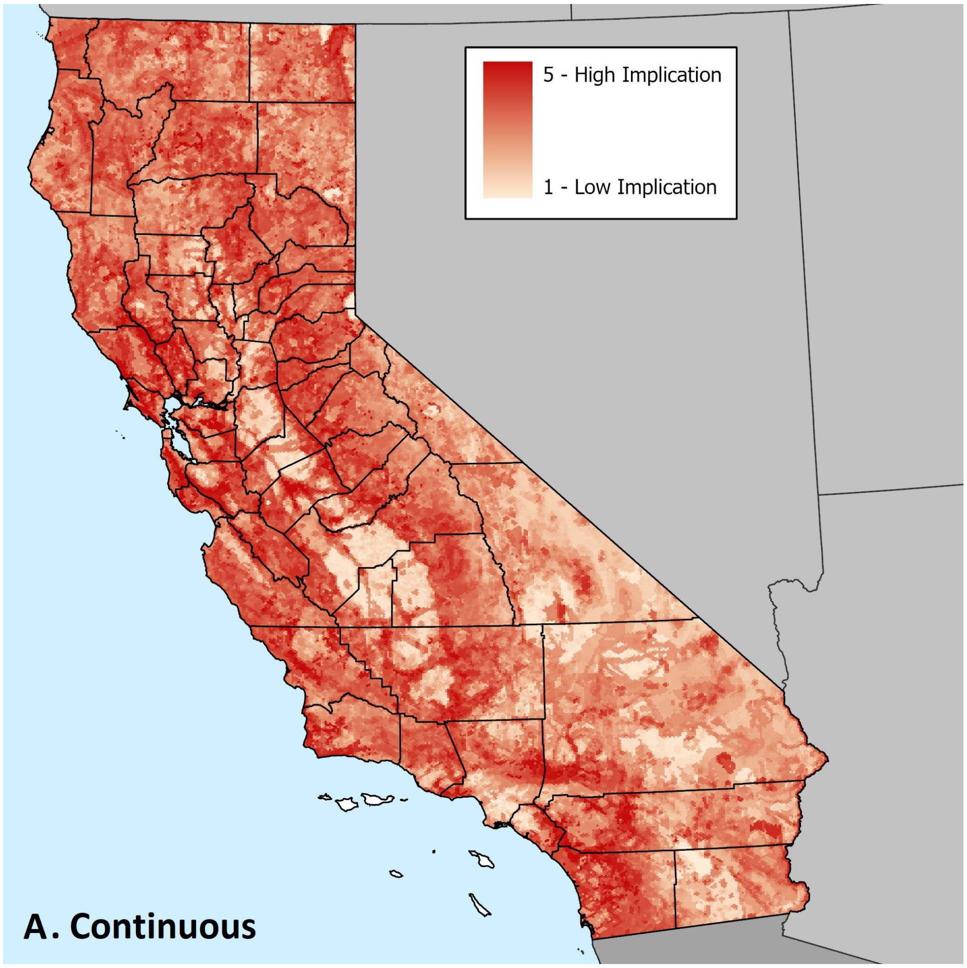
Transformation Parameters using a Large Function	Midpoint	0.3
	Point Spread	5
	Lower threshold	0.011725
	Value below threshold	0
	Upper threshold	1
	Value above threshold	0

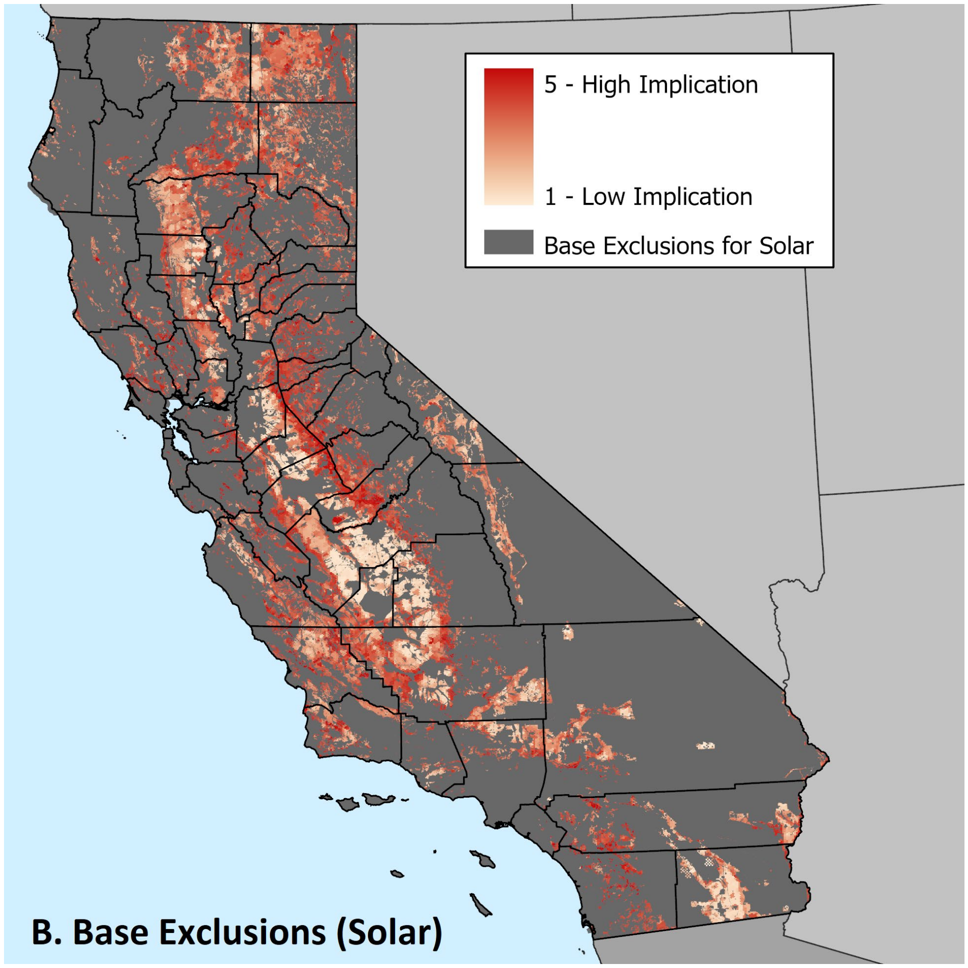
Source: CEC Staff

Connectivity and biodiversity were weighted equally in this model run. The results are shown below in Figure C-12 A where biodiversity index results span the range 1 through 5. Higher scores are shown in red, and lower scores lighten to white. There are large regions of low value in the Central Valley and desert regions. There are strong red or higher model score results in the foothills of the Sierra Nevada mountains, surrounding the Bay Area, and mountainous regions surrounding the Los Angeles Basin. Some striations of the connectivity data set are visible in the Mojave Desert region and in Central California, where higher connectivity values have uniformly raised the output values of the model.

When the base exclusions for solar are overlaid on the model results, many of the areas with highest biodiversity index scores are removed from the resource potential. Those remaining are shown in Figure C-12 B.

Figure C-12: Biodiversity Model Results



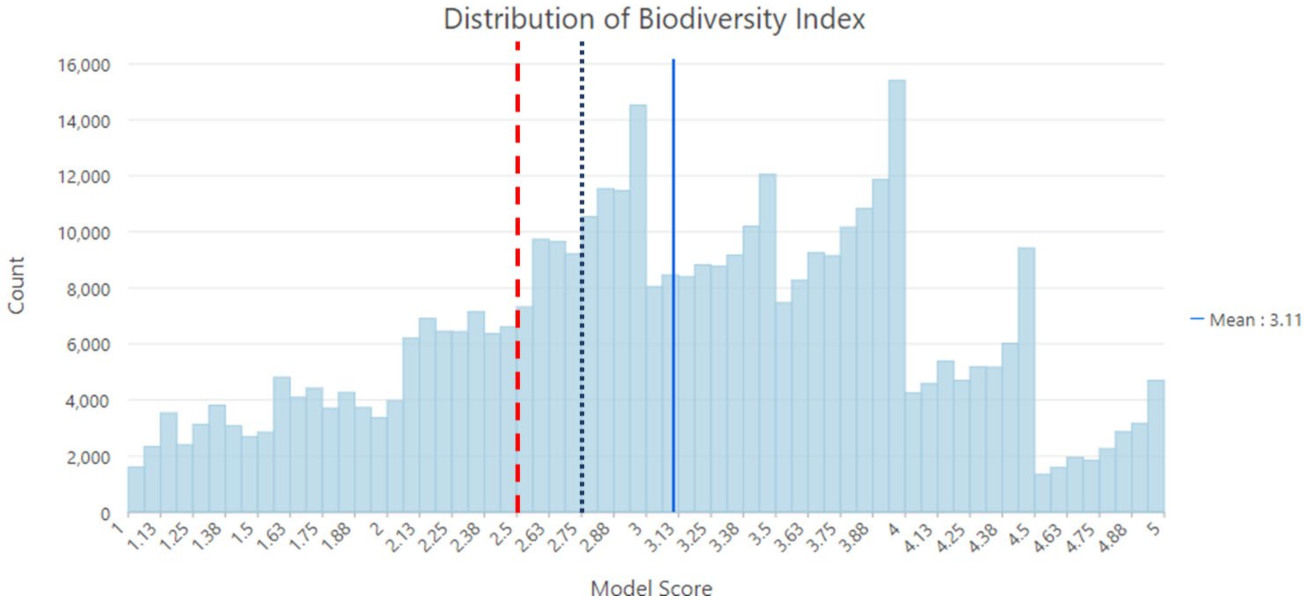


Source: CEC staff

(A) The Biodiversity Index Model results after running biodiversity and connectivity through the suitability modeling tool. Areas of higher biodiversity appear in red, while areas of lower biodiversity lighten to white. (B) The Biodiversity Index Model results with the base exclusions for solar overlayed.

The distribution of model results is shown in figure C-13. The mean is slightly higher than the midpoint of the range, suggesting the data is slightly skewed to the right.

Figure C-13: Distribution of Biodiversity Index



Source: CEC staff

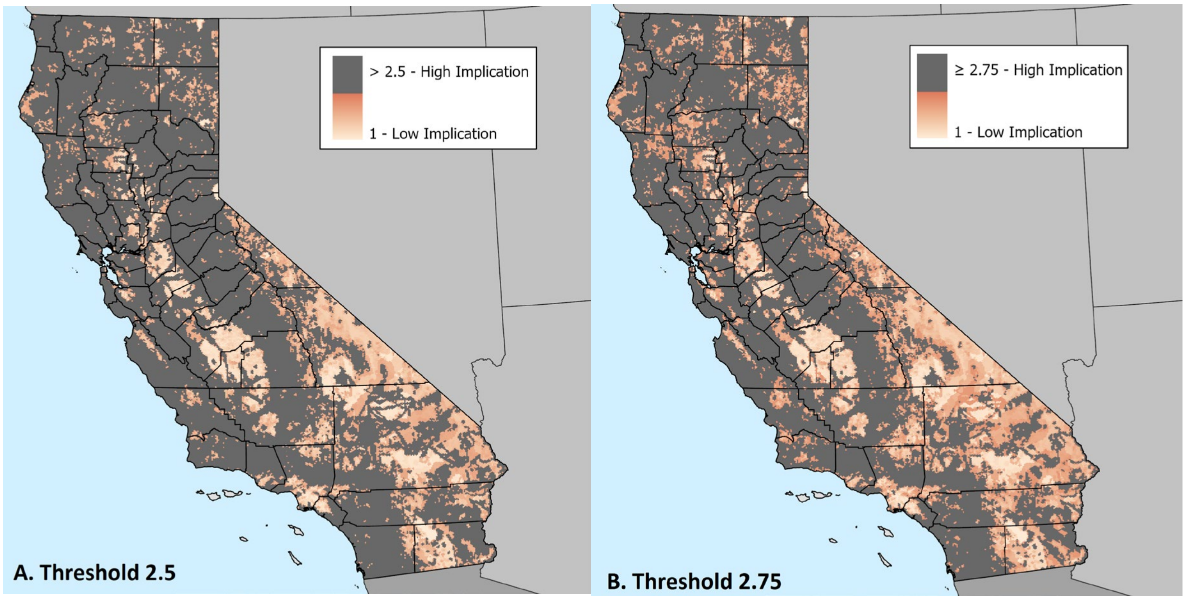
The distribution of the biodiversity index model results is shown here. Model scores ≥ 2.75 are binned into the higher category for Land-Use Screen 1, and model scores ≥ 2.5 are considered in the higher category for Land-Use Screen 2 and 3. These boundaries are shown by the red dashed line (for the Land-Use Screen 1 threshold) and the blue dotted line (for the Land-Use Screens 2 and 3 threshold). The solid blue line indicates the model mean value.

CEC staff chose two thresholds for partitioning the Biodiversity model result into higher and lower categories. The first threshold, model scores ≥2.75, was chosen for Land-Use Screen 1. The second threshold, a slightly more restrictive value of model scores ≥2.5, was chosen for Land-Use Screens 2 and 3. A relatively lower value (a value below the mean) was chosen in both of these cases to minimize areas where connectivity is higher. A rank of 2 or higher in the connectivity data set still characterizes good conditions for habitat and natural landscape. This is unlike a typical scale where a linear scaling between the categories is implied, as in the Biodiversity layer. In the Connectivity layer, lower scores could still be valuable and thus lower thresholds were chosen.

Because Land-Use Screens 2 and 3 incorporate additional environmental and land-use data, CEC staff chose to lower the threshold from 2.75 to 2.5 for these screens. The boundary of 2.5 excludes all areas with a Connectivity score of 4 and 5. This ensures that the very critical habitat linkage corridors are partitioned into the higher implication category and excluded from the renewable resource technical potential.

Figure C-14 below shows the biodiversity model result overlaid with the higher biodiversity categories for each of the thresholds. These regions are shown in blue. Only the lowest model scores – those less than or equal to 2.5 or less than 2.75 – remain. These are the areas partitioned into the lower implication category and included in renewable resource technical potential estimates.

Figure C-14: Biodiversity Model Results and Threshold Comparison



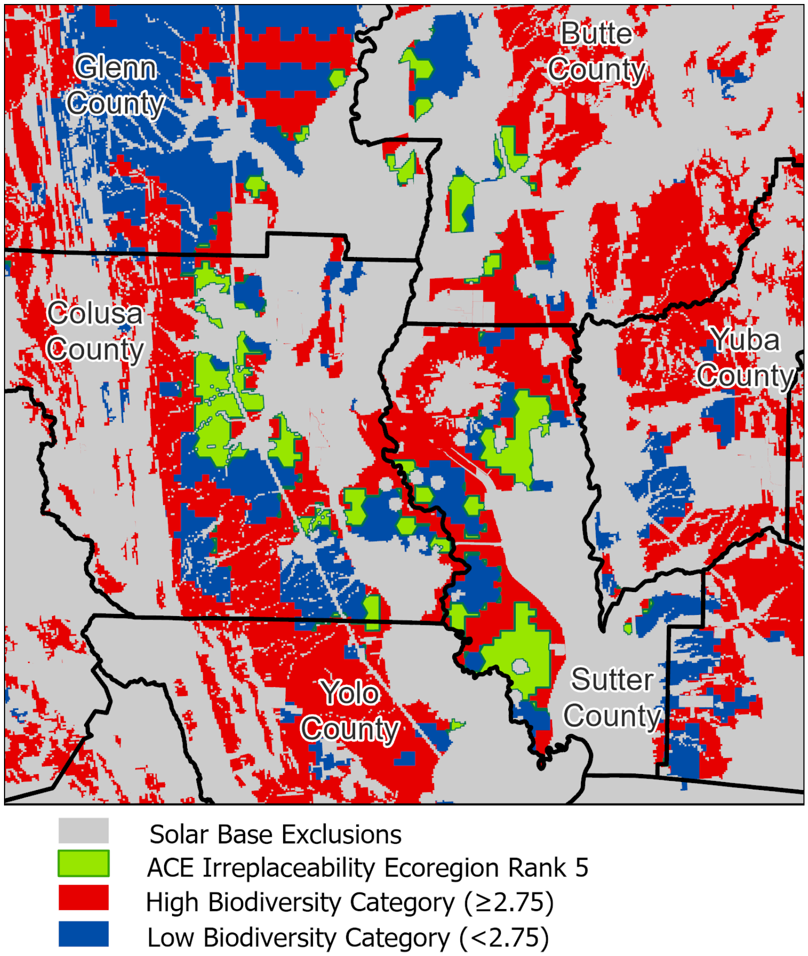
Source: CEC staff

Biodiversity model results are overlaid by the higher implication areas using two different thresholds. The areas that have a biodiversity model score > 2.5 are displayed on the left in panel A and the areas with a biodiversity model score ≥ 2.75 are displayed on the right in panel B.

To investigate the effectiveness of partitioning the model results into higher and lower biodiversity implication categories, CEC staff analyzed the footprint of irreplaceability[76] within the lower implication region. First, staff combined the base exclusions for solar with the higher biodiversity category (using the greater than or equal to 2.75 threshold) and erased the BLM DFA and VPL designations. The areas remaining in California contain low biodiversity scores and amount to approximately 7.8 million acres., with ~278,000 acres of those in the highest 20 percent of irreplaceability scores or having an Irreplaceability Ecoregion rank of 5. This amounts to about 3.5 percent of the low biodiversity implication category. This was calculated by taking the intersection of the irreplaceability layer with the low biodiversity index areas that remain after applying the base exclusions for solar. The region where the largest contiguous area with the highest irreplaceability ranking exists is in northern California, north of the delta and Sacramento County. These areas are shown in green in Figure C-15. Most of those areas have a biodiversity index score of 2 or greater (but still within the category of scores less than or equal to 2.75), so they are in the higher end of the lower implication category.

76 Terrestrial irreplaceability measures the relative importance of a habitat's uniqueness in the landscape for rare endemic species. *Terrestrial Irreplaceability*. California Department of Fish and Wildlife. Available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=150816&inline.

Figure C-15: Regions of High Irreplaceability in the Lower Biodiversity Implication Category



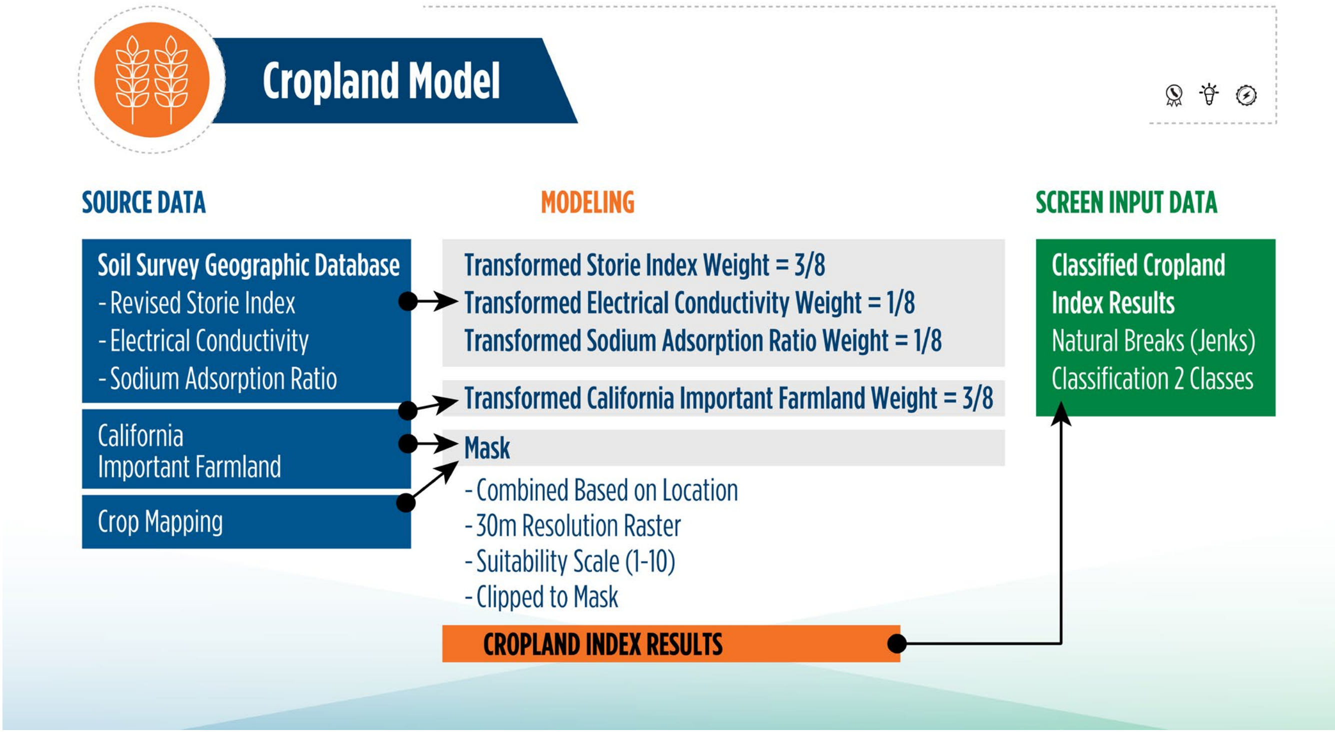
Source: CEC staff

The biodiversity index model results centered on Colusa and Sutter counties. Areas of higher biodiversity implication (red) are excluded from further analysis. Of the remaining lower biodiversity regions (blue), areas of higher irreplaceability are highlighted in green. This is the largest contiguous area of higher irreplaceability.

A similar analysis was performed using the 2.5 threshold on the biodiversity index model results. Under this threshold, out of nearly 6.2 million acres, approximately 114,000 acres, or 1.8 percent intersect with areas of the highest irreplaceability rank 5. In both thresholds, the majority of the irreplaceability ranks of 5 falls within the higher biodiversity category and will be excluded from renewable resource technical potential estimates.

The Cropland Index Model

Figure C-16: Steps in Cropland Modeling



Source: CEC staff

The diagram above depicts the data processing steps to develop the Cropland Index Model for use in the land-use screens.

The Cropland Index Model was created by using each of the input data sets (Revised Storie Index, California Important Farmland data, Electrical Conductivity, and Sodium Adsorption Ratio) in the suitability modeling tool. Each input was converted to a raster format with a resolution of 30 meters and snapped to the same grid. This resolution was chosen as it represents the source data with a high resolution and still maintained manageable file size. Data was transformed using appropriate thresholds across each data sets' range to categorize the data according to level suitability for agriculture. A common scale of 1-10 was chosen for all of the input data sets, where 1 represents the lowest levels of suitability for agriculture of that particular data set and 10 represents characteristics of the input data that have highest suitability for agriculture. Each input raster layer was given a weight to represent its magnitude of significance relative to the other input layers. The weights were informed by subject matter experts' recommendations. Below is a chart describing the weights assigned to each input dataset.

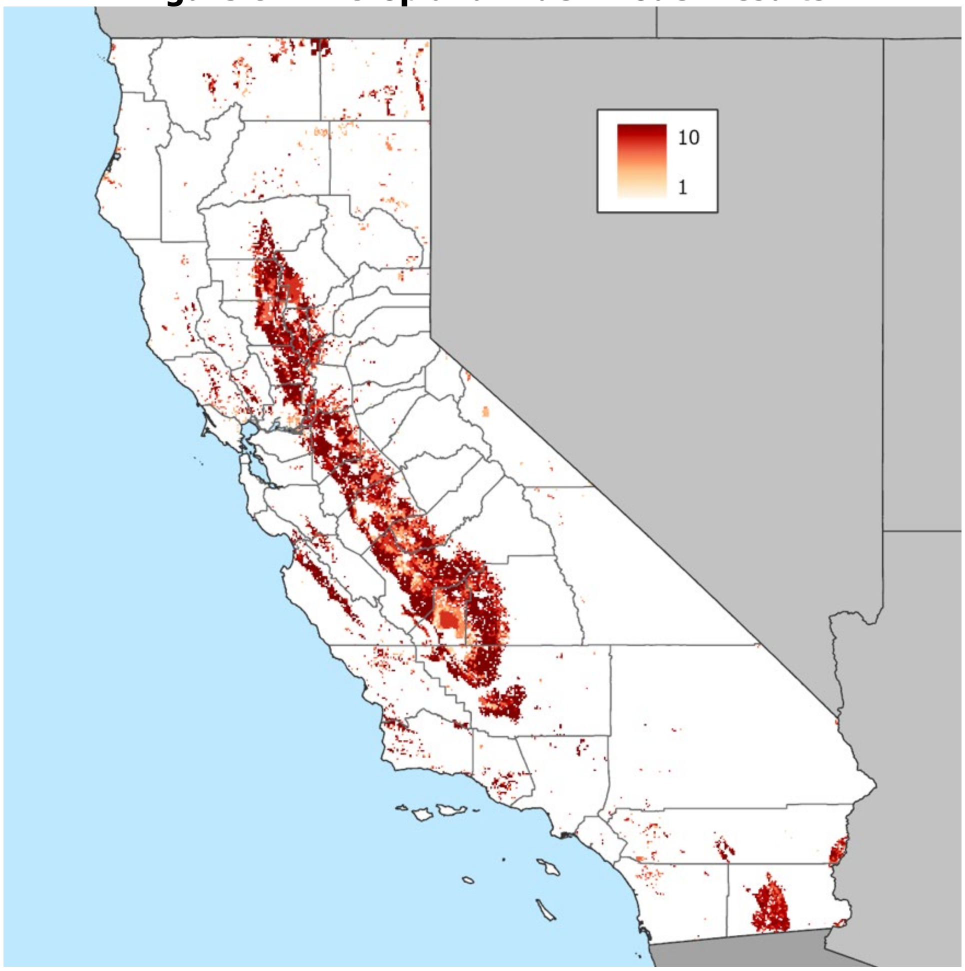
Table C-3: Weights and Categories Assigned to Cropland Model Input Datasets

Variable	Weight%	Class Type	Number of Classes	Categories and Transformation	
				Raw Value Thresholds	Transformed Value on Suitability Scale
Revised Storie Index	37.5	Range of Classes	6	0 – 10	1
				11 – 20	2
				21 – 40	4
				40 – 60	6
				61 – 80	8
				81 – 100	10
Electrical Conductivity	12.5	Range of Classes	5	0.0 – 2.0	10
				2.1 – 4.0	8
				4.1 – 8.0	4
				8.1 – 16.0	2
				>16.1	1
Sodium Adsorption Ratio	12.5	Range of Classes	5	0.0 – 13.0	10
				13.1 – 30.0	6
				30.1 – 100.0	4
				>100.1	1
California Important Farmland data	37.5	Unique Categories	4	0 (No Data)	1
				1 (Unique)	6
				2 (Statewide Importance)	8
				3 (Prime)	10

Source: CEC staff

The input data sets, transformed and weighted according to the chart above, were used in the Suitability Modeling Tool where overlapping numerical values were summed to give an overall Cropland Index value. These results are shown below in Figure C-17.

Figure C-17: Cropland Index Model Results

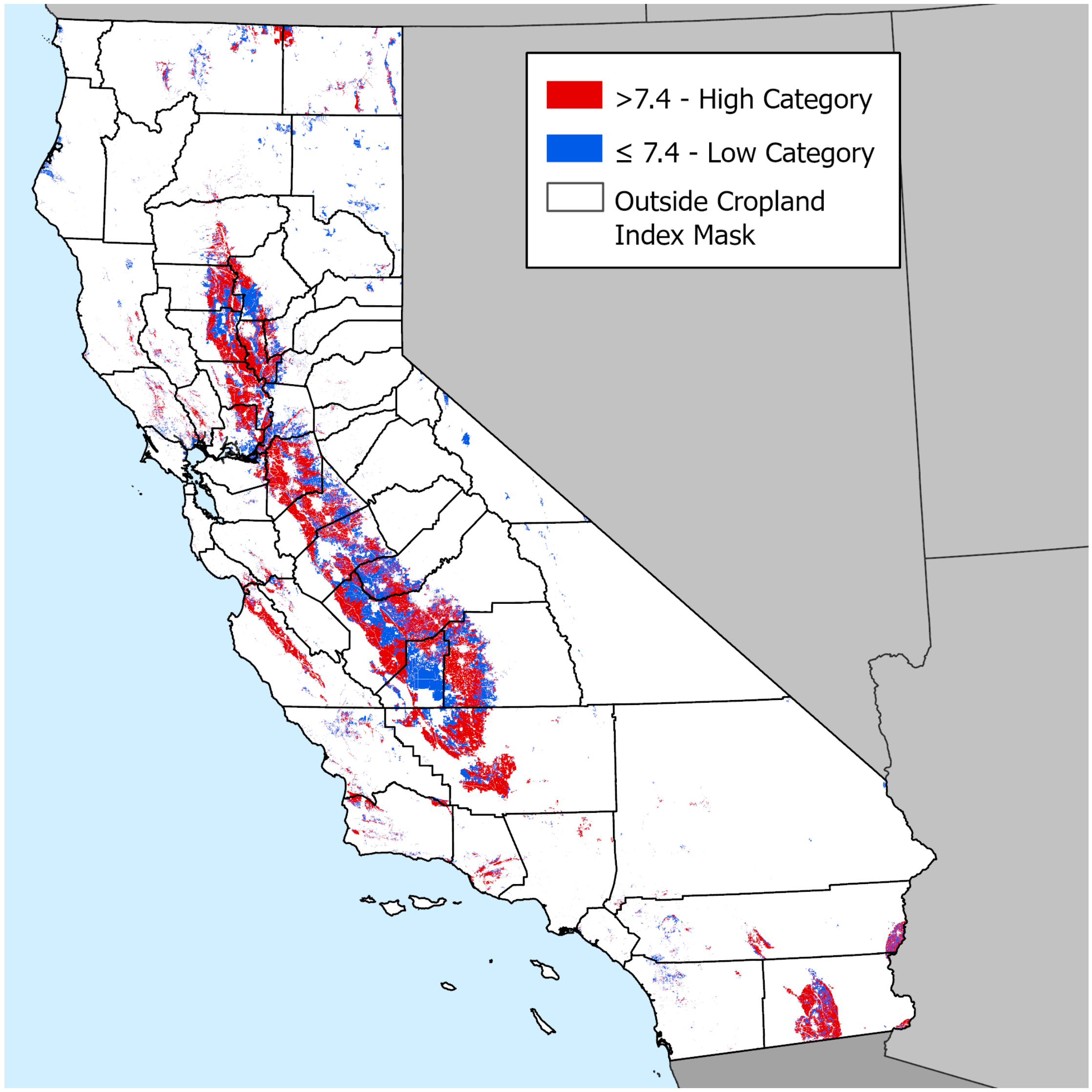


Source: CEC staff

The result of the Cropland Index Model is shown above. Dark reds have the higher scores (in other words are locations with more factors that support high-value croplands) and lighter hues have the lower scores (in other words are locations with fewer factors that support high-value croplands)

The Cropland Index Model produced a raster of the state of California, masked by croplands, consisting of a range of integer values between 1-10, where 1 is considered to have fewer factors that support high-value croplands (in other words, suited for exploration of renewable resource potential) and 10 is considered to have more factors that support high-value croplands (in other words, least suited for exploration of renewable resource potential). These results were binned into two categories of higher implication to croplands and lower implication to croplands based on a Natural breaks (Jenks) classification scheme. Natural breaks (Jenks) classification was chosen to separate cropland suitability into two categories with the most similar groupings of values, and it is determined statistically in a reproducible manner. This method yielded good agreement with the CBI model. The threshold value determined by the Jenks classification is 7.4, where cropland index values greater than that value are deemed higher implication for cropland. The model scores that are less than or equal to 7.4 are deemed lower implication.

Figure C-18: Cropland Index with Natural breaks (Jenks) Classification



Source: CEC staff

The result of the Cropland Index binned into two categories according to the Natural breaks (Jenks) classification method.

There are 4.3 million acres (42 percent area) identified in the lower implication category, or areas that are suited for exploration of renewable resource technical potential. The remaining 6.0 million acres (58 percent area) are in the higher implication category, where cropland value is high. This makes sense since the domain of the cropland index model, the study area, is defined by areas of existing cropland.

Comparison of Cropland Index Model to CBI Agricultural Value Model

Assessing the accuracy of the cropland index is complicated by the nature of the analysis. Unlike most raster-based classifications, suitability analysis does not seek to identify a readily verifiable phenomenon on the ground, but rather develops models grounded in data and expert opinion, to generate maps that can guide our understanding of areas that may have more factors that support high-value croplands and areas that may have fewer factors that support high-value croplands. For practical reasons, CEC staff may impose discrete thresholds on continuous data, which adds an element of subjectivity. As a result of the multivariate and subjective elements of this type of model, the validation of the results center around comparison to the CBI model.

Design of the CEC Cropland Index Model was heavily influenced by the CBI Agricultural Value model.[77] All variables present in the CEC Cropland Index are present in the CBI model, and agreement with the CBI model therefore represents a reasonable quality check. The cropland model is a simplified version of the CBI model with improved spatial resolution, updated data sources, and fewer variables. The overlapping footprints between the two models are compared, in terms of percent area.

Table C-4: Cropland Index and CBI Model Comparison

		CBI Model		Total
		% Optimal	**% Not Optimal**	
Cropland Index Model	**% Optimal**	33.57	6.10	39.7
	% Not Optimal	6.22	54.11	60.33
	total	39.8	60.21	100%
Areas of model agreement in grey				

Source: CEC staff

Table C-4 shows the results of the two-model comparison. Overall agreement with CBI is 87.7 percent (sum of percent area where both models are in agreement of being optimal or not optimal). Overall disagreement with CBI is 12.3 percent. In traditional remote sensing, error analyses where this approach is used to compare against observation, an overall agreement of 80 percent is considered acceptable.[78]

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77 "California Agricultural Value." 2018. Data Basin. Available at https://databasin.org/datasets/f55ea5085c024a96b5f17c7ddddd1147.

78 Landis, J R, and G G Koch. "The measurement of observer agreement for categorical data." *Biometrics* vol. 33,1 (1977): 159-74. Available at https://www.jstor.org/stable/2529310.

Evaluation of Correlations of Input Variables

To explore the relationships amongst the cropland datasets selected for the Cropland Index Model, CEC staff used the Band Statistics Tool[79] to identify correlation coefficients[80] across each of the input data sets, as is seen in Table C-5 below. A positive correlation indicates a direct relationship between two layers, such as when the cell values of one layer increase, the cell values of another layer are also likely to increase. A negative correlation means that one variable changed inversely to the other. A correlation of zero suggests that two layers are independent of one another. Some of the values indicate a moderate degree of correlation, such as between Electrical Conductivity and Sodium Adsorption Ration, and California Important Farmland and Revised Storie Index.

The correlation coefficient measures the strength of the linear relationship between two variables; however, variables with correlation coefficients near zero may have a non-linear relationship (where the dependence is not constant but depends on the values of each variable). For this analysis, the correlation coefficient will provide adequate information to determine the association between variables.

Table C-5: Cropland Index Correlation Matrix

Input Variable	Electrical Conductivity	California Important Farmland	Sodium Adsorption Ratio	Revised Storie Index
Electrical Conductivity	1.00	-0.20	0.55	-0.33
California Important Farmland	-0.20	1.00	-0.15	0.47
Sodium Adsorption Ratio	0.55	-0.15	1.00	-0.22
Revised Storie Index	-0.33	0.47	-0.22	1.00

Source: CEC staff

The output of the correlation matrix from the band statistics tool. This shows the strength of correlation between the input data of the cropland index model.

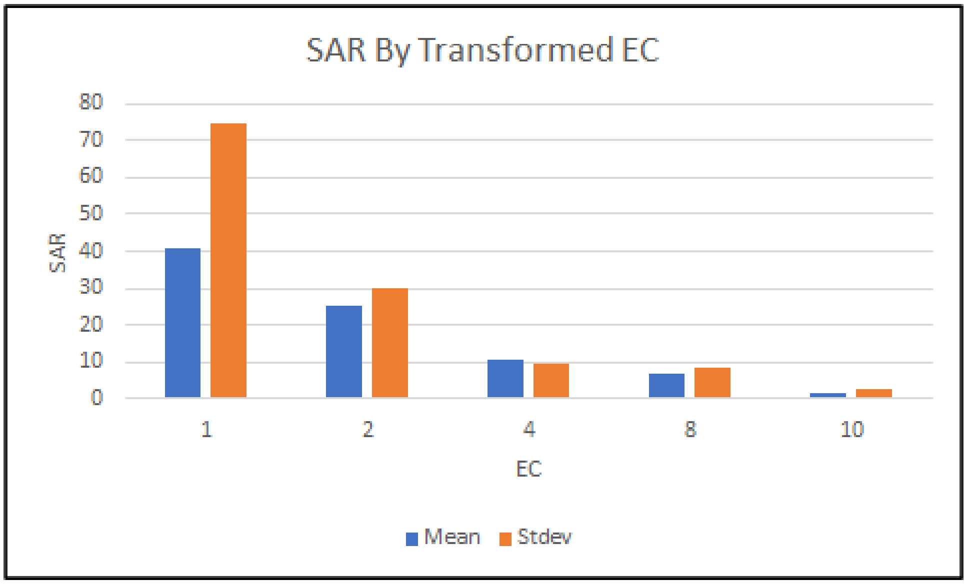
CEC investigated the relationships between cropland input datasets further by creating column charts to see how pairs of variables moved together. The objective of this evaluation was to explore whether the variables' physical and constructed relationships reduce the validity of the

79 "Band Statistics Tool." ArcGIS Pro. Complete documentation available at https://pro.arcgis.com/en/pro-app/2.8/tool-reference/spatial-analyst/band-collection-statistics.htm.

80 The correlation coefficient measures the amount of linear dependence between two variables (the strength of the relationship of the relative movement of the two variables). It ranges from –1 to 1, where –1 means the two variables are perfectly negatively related while a value of positive 1 means a perfect positive relationship.

Cropland Index Model. From this evaluation, CEC staff found that some association or relationship exists amongst cropland data variables in the suitability model; however, the data shows a lot of variability (that is, noisiness), so the relationships may not be that strong. This evaluation suggests that retaining all the cropland data variables in the model is appropriate, and that no two variables have a strong positive or negative relationship. Of the cropland input datasets, SAR and EC have the strongest correlation (0.55, see table C-5) (Figure C-19), which could be explored further in future analyses.

Figure C-19: Mean EC value by Transformed SAR

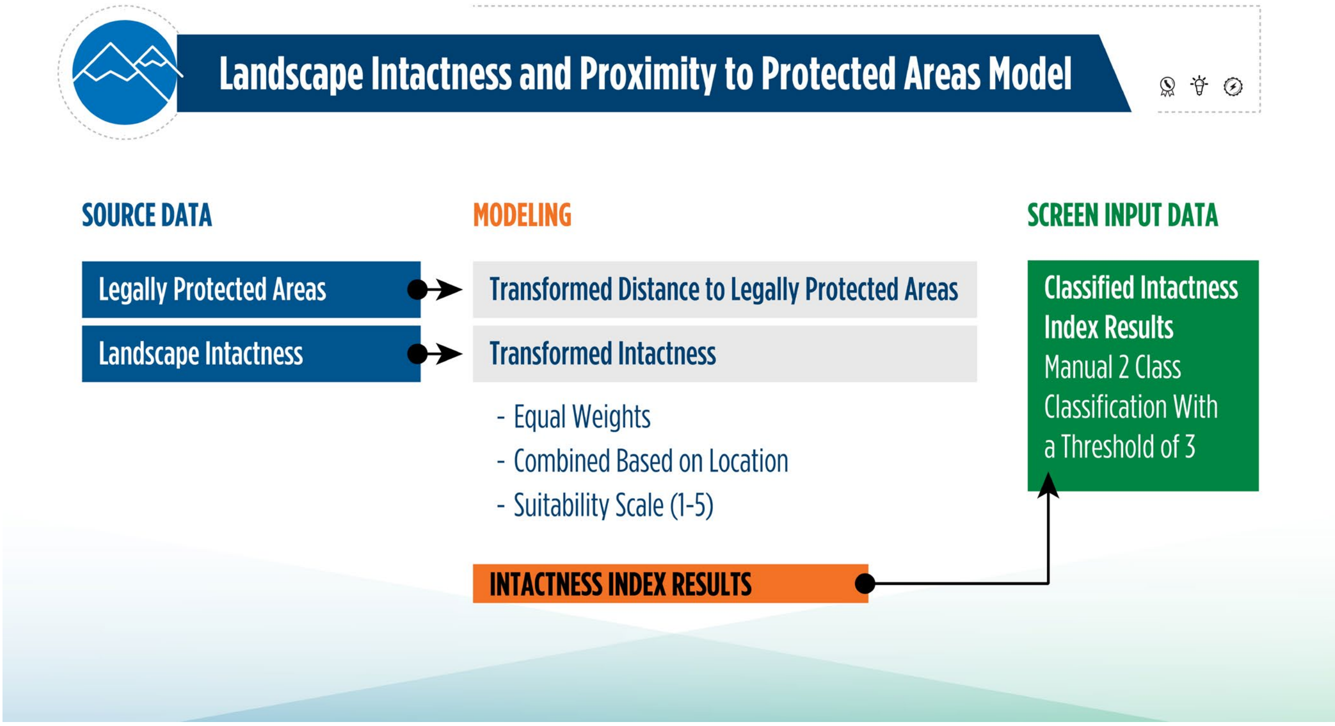


Source: CEC staff

This is a bar chart that compares average values of SAR against transformed values of EC. The blue bars are the average values of SAR while the orange bars are the standard deviation of SAR. The chart shows average SAR values tend to decrease with increasing values of transformed EC.

Landscape Intactness and Proximity to Protected Areas Model

Figure C-20: Steps in Landscape Intactness and Proximity to Protected Areas Modeling



Source: CEC staff

The diagram above depicts the data processing steps taken to develop the Landscape Intactness and Proximity to Protected Areas Model for use in the land-use screens.

The Landscape Intactness and the Distance to Legally Protected Areas were loaded into the suitability modeling tool. Both data sets were transformed by a continuous function onto a 1 through 5 scale, with lower values representing areas that have higher levels of disturbance and farther from protected areas, and higher values representing areas that have lower levels of disturbance and are closer to protected areas. Landscape Intactness was best modeled as a power function, with a large exponent. The proximity data set (Distance to Protected Areas) was transformed via a MSSmall function, with all default parameters. The specific input parameters are shown in Table C-6 below for each data set. The data sets are weighted equally in the model construction.

Table C-6: Input Parameters for the Intactness Transformation Function

Power Function (Intactness)	Input Shift	-1.966667
	Exponent	8
	Lower Threshold	-0.966667
	Value Below Threshold	0
	Upper Threshold	0.988239
	Value above threshold	0.8

Source: CEC staff

This table shows the input parameters of a Power function used in the ArcGIS suitability modeling tool to transform the Landscape Intactness onto the common 1 through 5 scale used in the Intactness Model.

Table C-7: Input Parameters for the Distance to Protected Areas Transformation Function

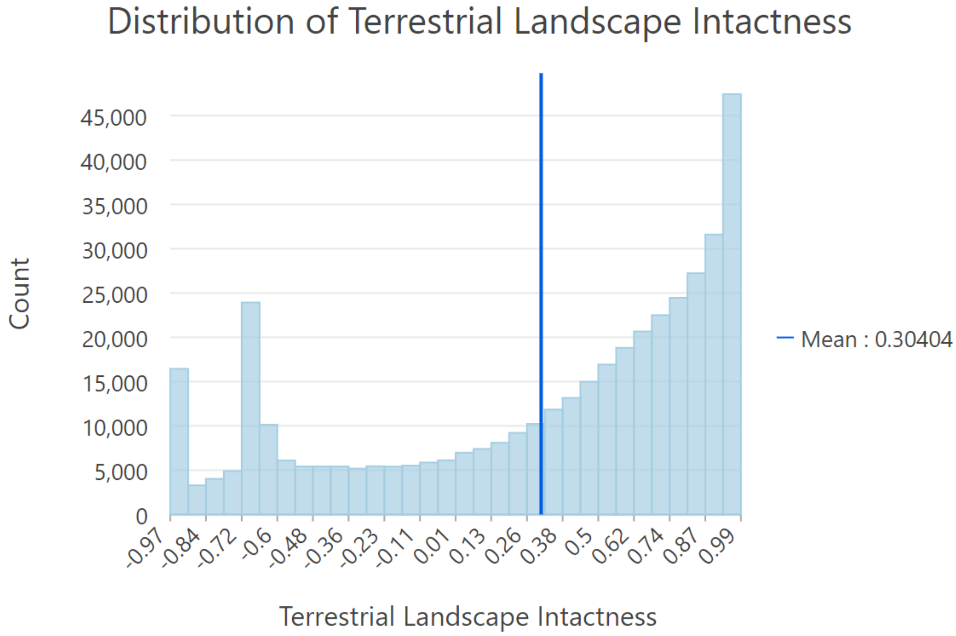
MSSmall Function (Distance to LLP)	Mean multiplier	1
	Stdv multiplier	1
	Lower threshold	0
	Value below threshold	0
	Upper threshold	53243.5
	Value above threshold	0

Source: CEC staff

This table shows the input parameters of a MSSmall function used in the ArcGIS suitability modeling tool to transform the Distance to Protected Areas data onto the common 1 through 5 scale used in the Intactness Model.

The landscape intactness data set has a distribution shown in Figure C-21, below. The power function captures the rapidly increasing spike of highly intact areas in the native space of the landscape intactness data. Although the power function doesn't capture the curvature on the low end of the scale, these are all highly disturbed lands that should receive the lowest score in the 1-5 scale.

Figure C-21: Distribution of Landscape Intactness Input Dataset



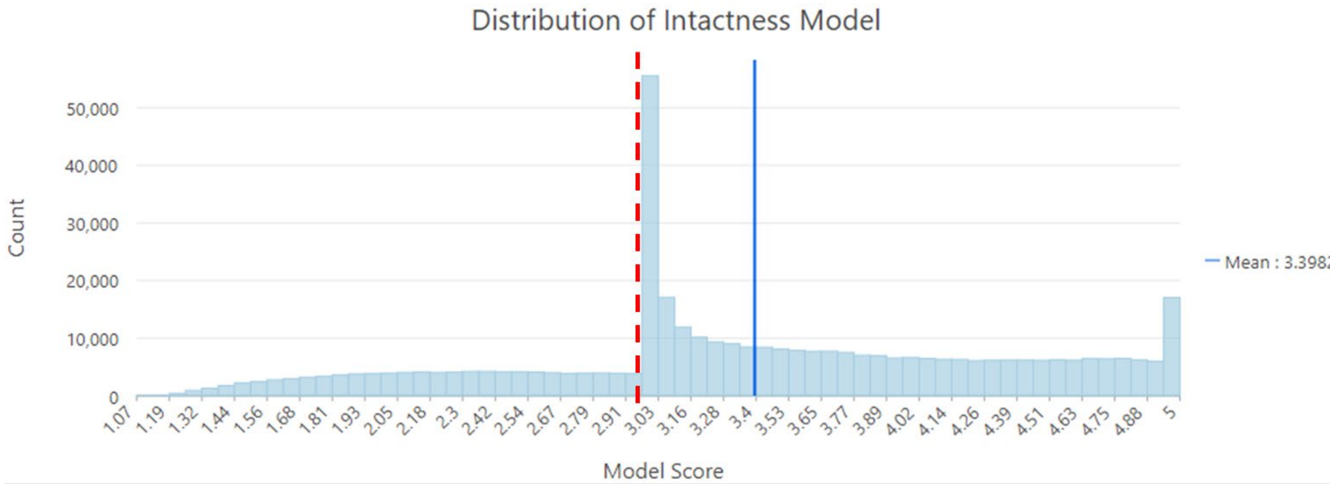
Source: CEC staff

The distribution of terrestrial landscape intactness. Higher values depict lands that have lower levels of human disturbance.

The distance to a protected area data set requires that small values (in the data set's native units) be given high values in the transformed scale because areas that are adjacent to protected areas are considered to have a higher implication than those that are far from a protected area. The MSSmall function captures the relationship where small values in the raw data, in other words, those that are close to a protected area, are transformed to high values on the 1-5 scale and vice versa.

The results of this model indicate areas that are most and least suitable by both criteria. The highest scores are highly intact areas that are closest to existing protected areas and the lowest scores are areas that have higher levels of disturbance and that are far from a protected area. The distribution of model results is shown below in Figure C-22. There is a large spike at ~3 and elevated frequencies are seen above that value. This is due to the large portion of the state that is conserved, and so those areas' distance to a protected area is 0. Those values, and other low distance values, receive the highest transformed values (5 or close to 5). Because of this property of the input data skewing the distribution, using the middle of the range value for the threshold to bin the data into two categories seemed most appropriate to CEC staff. Model scores with a value less than 3 had lower intactness and could still be included in the resource potential footprint. Model scores greater than or equal to 3 are indicative of highly intact land near an already protected area, and these areas were excluded from consideration in renewable resource technical potential estimates.

Figure C-22: Distribution of the Intactness and Proximity to Protected Areas Model Results

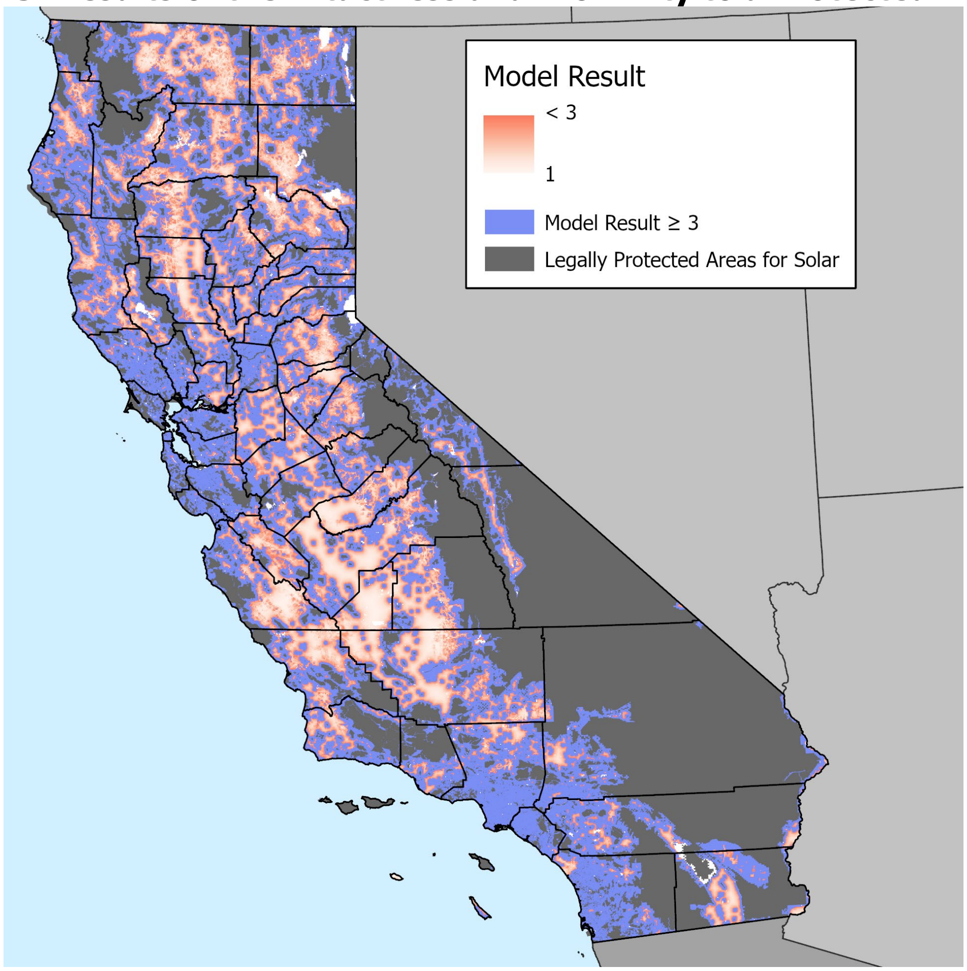


Source: CEC staff

Distribution of model results for the intactness model. Threshold value of 3 was used to divide the model into higher and lower intactness value. The mean value of the model results is indicated by the solid blue line.

The results of the intactness model are shown in Figure C-23, with the indigo areas depicting the higher model results that are greater than or equal to 3, the chosen threshold. The red to yellow gradation of colors where the model scores are below 3 are considered the lower implication regions for intactness and proximity to a protected area. These are areas where intactness levels are low and distance to protected area is high. Because agriculture is a human-induced change to the natural landscape, the Central Valley contains large swaths of low indices in the intactness model results. These areas are shown clearly in the model results shown in Figure C-23.

Figure C-23: Results of the Intactness and Proximity to a Protected Area Model



Source: CEC staff

The results of the Intactness and Distance to Protected Areas model is shown here. The grey areas are the protected areas map for solar, which was used to calculate the distance to a protected area raster, an input into this model. The indigo color masks all the model results with a value greater than or equal to 3. The yellow-orange color range depicts the remaining areas that have low landscape intactness and are far from protected areas.

The next section describes how the base exclusion layers and outputs of the suitability models were used to construct land-use screens for high-level statewide land-use evaluation for electric system planning.

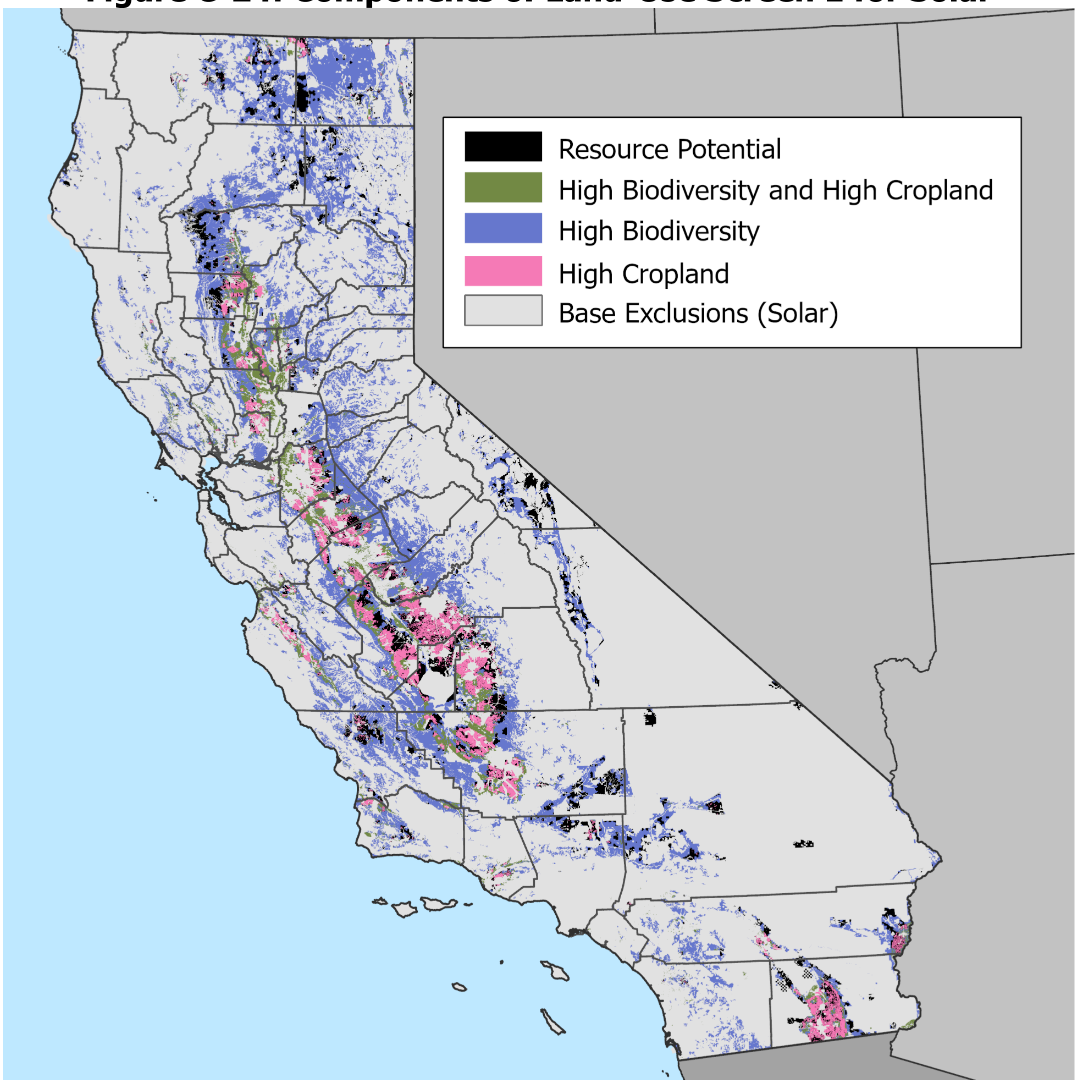
Construction of the Land-Use Screens

The output of the models, along with the selected thresholds, divide California into areas that have lower or higher implication of a specific land-use category. CEC staff combine these lower implication areas into three screens to test how these ensembles of land-use scenarios influence energy resource planning.

Land-Use Screen 1

This screen applies the base exclusions, the higher category of model output for the cropland index, and the higher biodiversity model output that uses a threshold of 2.75. The areas within the output that fall above the thresholds defined for each model are used as a further exclusion in addition to the base exclusions. The areas remaining in the resource potential map have lower implication to croplands and biodiversity. These areas, shown below, are used to estimate renewable resource technical potential for onshore wind and solar PV.

Figure C-24: Components of Land-Use Screen 1 for Solar



Source: CEC staff

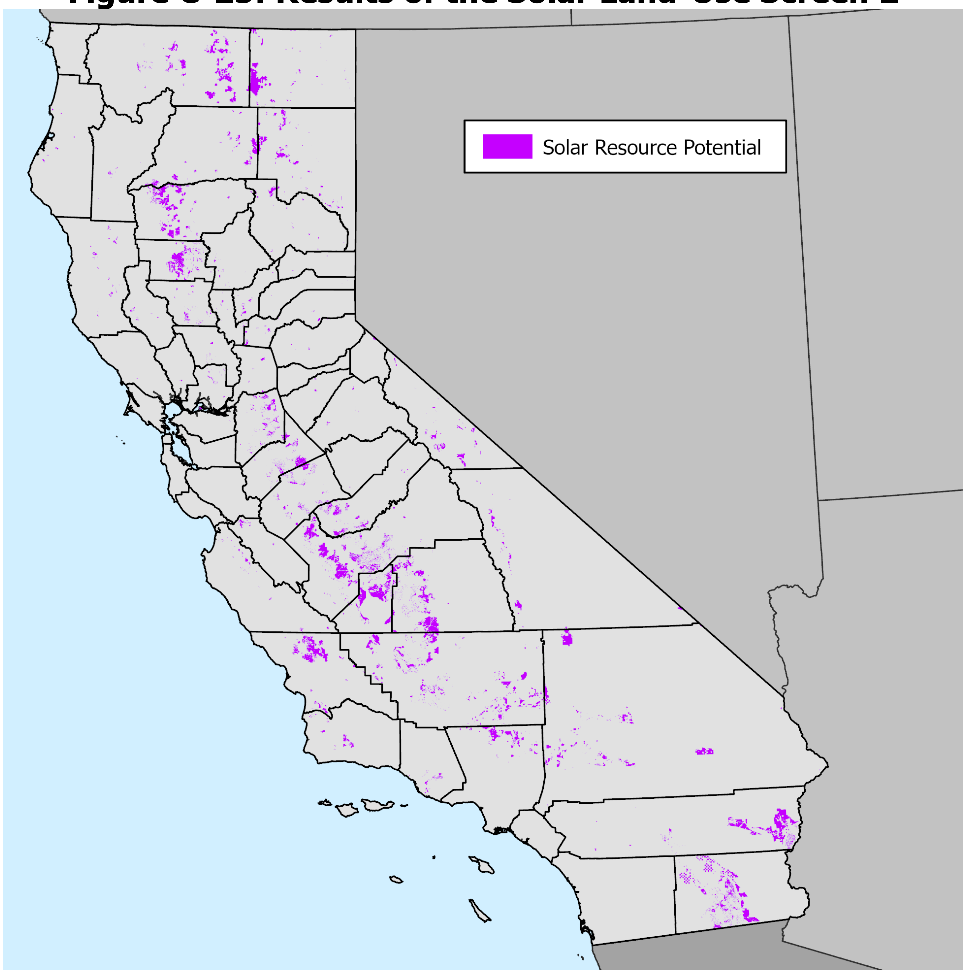
This figure shows all the exclusions used in Land-Use Screen 1. Grey depicts the base exclusions, blue is the higher biodiversity output, pink is the higher cropland model output, and black depicts the areas that are high for both the biodiversity and cropland models. Areas remaining in green are the resource potential map.

By applying these screens, the solar resource potential basemap is reduced by approximately 76 percent to create the resource potential map under Land-Use Screen 1. The Cropland Index output (high) alone removes 12 percent and the Biodiversity Index output (high) alone removes another 59 percent. The remaining 5 percent is removed because these are areas that are both high for cropland and biodiversity.

Land-Use Screen 2

This screen applies the base exclusions, the higher category of model output for the cropland index, and the higher biodiversity model output that uses a threshold of 2.5 instead of 2.75. Further, this screen excluded the higher category of the Intactness and Proximity to a Protected Area model output. The combination of all three of these screens, along with the base exclusions, creates Land-Use Screen 2. The results of this screen and the remaining land available for solar resource potential are shown below in Figure C-25.

Figure C-25: Results of the Solar Land-Use Screen 2



Source: CEC staff

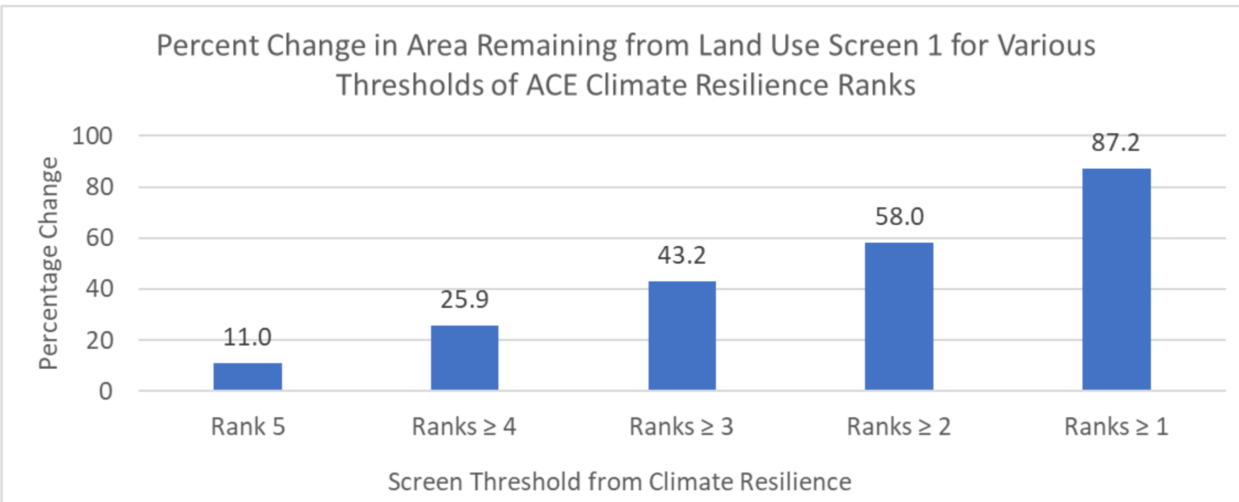
The results of land-use screen 2 for solar resource. This screen uses a more restrictive threshold for the lower biodiversity category.

Land-Use Screen 3

This screen applies the base exclusions, the higher category of model output for the cropland index, and the higher biodiversity model output that uses a threshold of 2.5 instead of 2.75.

Further, this screen excluded areas of the state that are likely to serve as climate refugia[81] under changing climate conditions. To define Land-Use Screen 3, CEC staff chose an appropriate threshold on the ACE Terrestrial Climate Change Resilience dataset as a boundary between areas that would be omitted from energy resource potential consideration or not. These areas would be added Land-Use Screen 1 to further reduce the land area with renewable resource potential. The climate resilience ranks with higher values indicate a greater concentration of modeled climate refugia at that location. In fact, a rank of 4 and 5 indicate the hexagonal grid cell contains refugia determined by more than 60 percent and 80 percent, respectively, of the models. CEC staff explored using every rank as the Land-Use Screen 3 threshold and calculated how much land would be removed from Land-Use Screen 1 resource potential with each screen definition. The percentage reduction in lands with renewable resource technical potential for each screen definition is shown in Figure C-26 below.

Figure C-26: Sensitivity of Thresholds of ACE Climate Resilience Ranks in Resource Potential for Land-Use Screen 3



Source: CEC staff

This figure shows the percentage reduction in lands with renewable resource technical potential under various definitions of Land-Use Screen 3. Thresholds greater than or equal to 1 through 5 are shown in this plot with the most restrictive case, using a threshold of 1, reduces the land area available for energy by 87 percent, whereas using a threshold of 5 reduces the land area available for energy by 11 percent.

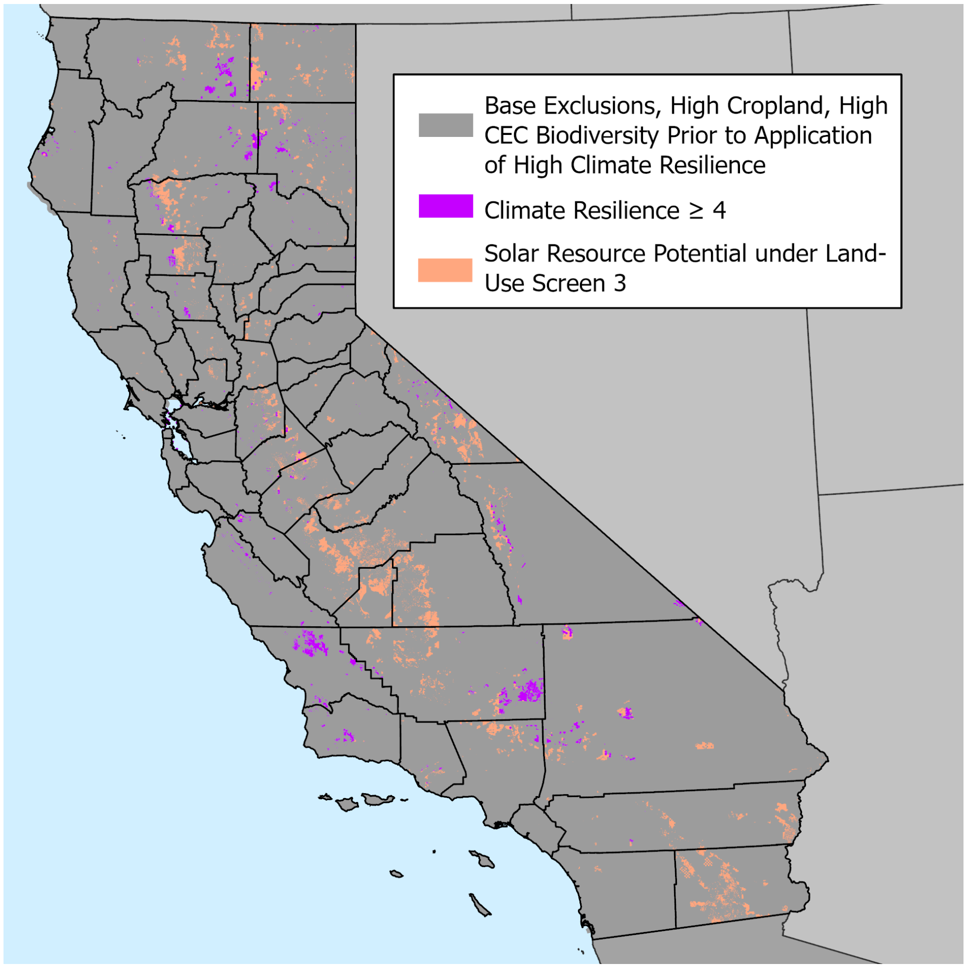
Using a rank of 5 as the definition for the screen removes approximately ten percent of the land area remaining with energy resource potential under Land-Use Screen 1, while using a rank of 2 as the threshold removes more than half of the land area. CEC staff chose a rank of 4 as the threshold for Land-Use Screen 3 because it removes areas where the majority of the

81 Refugia are areas relatively buffered from the effects of climate change, where conditions will likely remain suitable for the current array of plants and wildlife that reside within a location, and where ecological functions are more likely to remain intact. Available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=150836&inline.

models indicate the likely presence of climate refugia. No data areas, areas of the ACE data that were entirely encompassed by water, agriculture, urban or other non-natural cover, are not considered part of the screen.

The footprint of the Land-Use Screen 3 using a threshold of 4 is shown in Figure C-27 below.

Figure C-27: Areas Removed by High Climate Resilience in Land-Use Screen 3

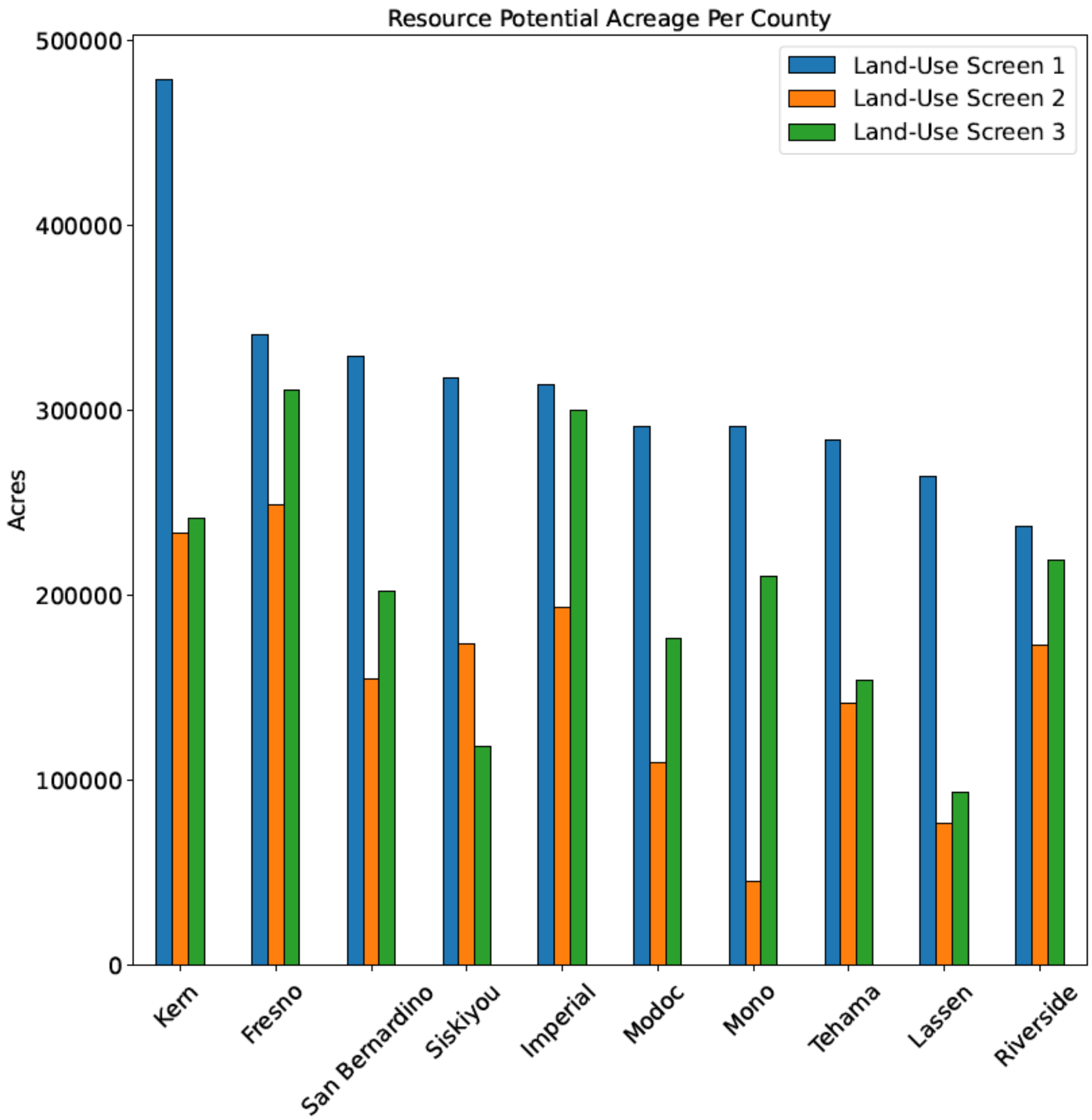


Source: CEC staff

This figure highlights the areas that are removed due to having a higher climate resilience rank from the input ACE layer. Grey areas represent areas screened out by base exclusions or the higher cropland and higher biodiversity categories, and the peach color depicts the remaining resource potential areas for solar.

Comparing the resource potential remaining within each county after applying each of the land-use screens shows the variation of where each of these screens has the most influence. Land-Use Screen 1 has the largest resource potential footprint as it only includes two factors as restrictions on the resource potential basemap (Biodiversity Index and Cropland Index results). Moreover, the Biodiversity Index model threshold for this screen is less restrictive than the other two. Land-Use Screen 2 has the largest impact across all counties, and on average reduces the resource potential per county by 67 percent for both solar and wind. Land-Use Screen 3 is sometimes as restrictive as Land-Use Screen 2, but in the counties that have the largest resource potential, Land-Use Screen 3 leaves open much more area for resource potential consideration than Land-Use Screen 2. The following two figures show a comparison of the acreage available for resource consideration under the three screens for the top ten counties that had the largest areas under Land-Use Screen 1. Figure C-28 shows this intercomparison for solar technology, and Figure C-29 shows the same for onshore wind.

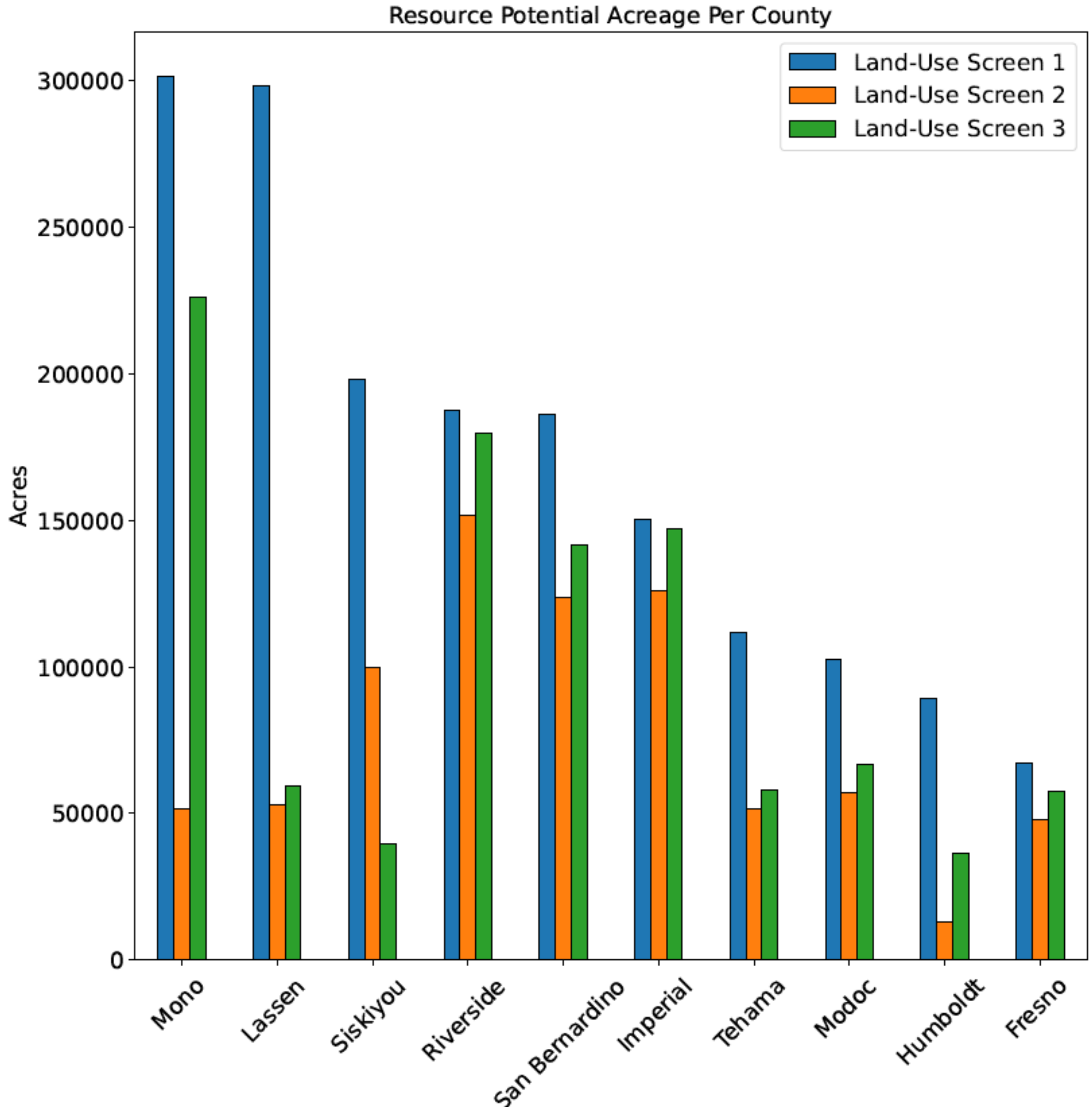
Figure C-28: Solar Resource Potential Acreage in Top Ten Counties Under Screens



Source: CEC staff

This plot depicts the total acreage available for solar resource potential under the three proposed screens. This plot only shows values for the ten counties with the highest acreage under Land-Use Screen 1.

Figure C-29: Onshore Wind Resource Potential Acreage in Top Ten Counties Under Screens



Source: CEC staff

This plot depicts the total acreage available for onshore wind resource potential under the three proposed screens. This plot only shows values for the ten counties with the highest acreage under Land-Use Screen 1.

APPENDIX D:
Model Input Data and Thresholds

Exclusion Data

Table D-1: Datasets used in the creation of the technoeconomic exclusions layer

Category	Definition for Exclusion	Source
Population Buffers	500 meter buffer for solar; 1000 meter buffer for wind	TIGER/Line Shapefile, 2017, 2010 Nation, U.S., 2010 Census Urban Area National." U.S. Census. Accessed April 17, 2020. https://catalog.data.gov/dataset/tiger-line-shapefile-2017-2010-nation-u-s-2010-census-urban-area-national.
Railroads	250-meter buffer	"Railroads." Federal Railroad Administration, n.d. https://ezmt.anl.gov/.
Water Features		"U.S. National Atlas Water Feature Areas." U.S. National Atlas, December 30, 2015. https://ezmt.anl.gov/.
Slope	Slope > 19 degrees for wind are excluded; Slope >= 10 degrees are excluded for solar	https://www.sciencebase.gov/catalog/file/get/5540ebe2e4b0a658d7939626?f=__disk__9c%2F24%2Fd5%2F9c24d5062c98ecf82988b4e6c827d07c374e9776&transform=1&allowOpen=true
Airports	Areas within 5000 meters not suitable for commercial wind development; 1000-meter buffer used for solar exclusions	"Airports, Runways." U.S. Department of Transportation (USDOT)/Bureau of Transportation Statistics' (BTS's) National Transportation Atlas Database (NTAD)., August 24, 2018. https://ezmt.anl.gov/.
Flood Zones	Flood Zone A	https://hazards.fema.gov/femaportal/wps/portal/NFHLWMS

Military Installations	Sources 1-4 are for wind, and 4 is for solar only	[1] WWWMP_military_restricted_airspace_and_mtr Sullivan, Robert, Zvolanek, Emily, and Smith, Karen. "West-Wide Wind Mapping Project." U.S. Bureau of Land Management, Argonne National Lab, October 2016. https://wwmp.anl.gov/index.cfm. [2] "U.S. Special Use Airspace." U.S. Department of Transportation, Federal Aviation Administration-Aeronautical Information Services., n.d. https://adds-faa.opendata.arcgis.com/datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=66.173%2C7.409%2C-60.390%2C78.288. [3] "Military Training Route (MTR) Segment." U.S. Department of Transportation, Federal Aviation Administration-Aeronautical Information Services, n.d. https://ais-faa.opendata.arcgis.com/datasets/0c6899de28af447c801231ed7ba7baa6_0?geometry=-154.771%2C19.488%2C141.948%2C62.840. [4] "DoD Locations." California Military Energy Opportunity Compatibility Assessment Mapping Project (CaMEO CAMP). Governor's Office of Planning and Research. https://opr.ca.gov/planning/land-use/military-affairs/
LandScan	After converting to persons per square kilometer, exclusion was applied for population density >= 100 persons/kilometer2	ORNL. "LandScan Datasets 2018." Oak Ridge National Laboratory (ORNL), 2019. https://landscan.ornl.gov/landscan-datasets.

Active Mines	Areas within 1000 m not suitable for commercial solar or wind development	"Active Mines and Mineral Plants in the US." USGS, March 2022 https://mrdata.usgs.gov/mineplant/.

Source: Table prepared by CEC staff with data provided by Montara Mountain Energy (consultant to the CPUC)

Table D-2: Datasets used in the legally protected exclusion layer

Category	Definition for Exclusion	Source
Conservation Easements		California Conservation Easement Database (CCED) - www.CALands.org (July 2022)
Inventoried Roadless Areas		"Inventoried Roadless Areas." US Forest Service. June 15, 2022. https://www.fs.usda.gov/detail/roadless/2001roadlessrule/maps/statemaps/?cid=stelprdb5400185
Units of the National Park System	'Primary, Secondary or Tertiary designation type IN 'National Park General Public Land', 'National Historical Park', 'National Historic Site', 'National Monument', 'National Preserve', 'National Recreation Area', 'National Scenic Area', 'National Seashore', 'Wild, Scenic and Recreation River', OR Primary, Secondary local designation p_loc_ds = 'National Wild & Scenic River' OR s_loc_ds IN 'National Wild, Scenic and Recreation River', 'National Wild, Scenic and Recreation Area'	"PAD-US (CBI Edition) Version 2.1b, California". Conservation Biology Institute. 2016. https://databasin.org/datasets/64538491f43e42ba83e26b849f2cad28.
State Parks and Recreation Areas	'Primary, Secondary or Tertiary designation type (p_des_tp etc) IN 'State Park','State Recreation Area'	"PAD-US (CBI Edition) Version 2.1b, California". Conservation Biology Institute. 2016. https://databasin.org/datasets/64538491f43e42ba83e26b849f2cad28.

Other State Owned Land	own_type='State Land' AND gap_sts IN ('1','2') AND p_des_tp NOT IN ('State Park','State Beach', 'State Ecological Reserve', 'State Wildlife Management Area','State Recreation Area','National Monument', 'National Wildlife Refuge','Research and Education Land') OR p_loc_ds IN ('State Vehicular Recreation Area', 'BLM Resource Management Area', 'Resource Management Area')	"PAD-US (CBI Edition) Version 2.1b, California". Conservation Biology Institute. 2016. https://databasin.org/datasets/64538491f43e42ba83e26b849f2cad28.
Designated Federal Wilderness Areas; National Wildlife Refuges and Ecological Reserves	'Primary, Secondary or Tertiary designation type IN 'Ecological Reserve', 'Wildlife Management Area', 'Natural Area', 'Research Natural Area', 'Wilderness Area'	"PAD-US (CBI Edition) Version 2.1b, California". Conservation Biology Institute. 2016. https://databasin.org/datasets/64538491f43e42ba83e26b849f2cad28.
State Wilderness Areas; State Wildlife Refuges and Ecological Reserves	Primary, Secondary or Tertiary Designation type = 'State Ecological Reserve', 'State Wildlife Management Area', 'State Beach', 'State Natural Area', 'State Nature Preserve/Reserve'	"PAD-US (CBI Edition) Version 2.1b, California". Conservation Biology Institute. 2016. https://databasin.org/datasets/64538491f43e42ba83e26b849f2cad28.
Wilderness Study Area	'p_des_tp = 'Wilderness Study Area' OR local designation p_loc_ds = 'Research and Educational Land'	"PAD-US (CBI Edition) Version 2.1b, California". Conservation Biology Institute. 2016. https://databasin.org/datasets/64538491f43e42ba83e26b849f2cad28.
Private Conservation Land	Own_type = 'Private Conservation Land'	"PAD-US (CBI Edition) Version 2.1b, California". Conservation Biology Institute. 2016. https://databasin.org/datasets/64538491f43e42ba83e26b849f2cad28.

Conservation Plans (Habitat, Natural Community)	Primary, Secondary (or Tertiary) designation type IN 'Area of Critical Environmental Concern', 'National Conservation Area'	"PAD-US (CBI Edition) Version 2.1b, California". Conservation Biology Institute. 2016. https://databasin.org/datasets/64538491f43e42ba83e26b849f2cad28.
GAP Status	gap_sts IN ('1','2')	"PAD-US (CBI Edition) Version 2.1b, California". Conservation Biology Institute. 2016. https://databasin.org/datasets/64538491f43e42ba83e26b849f2cad28.
BLM National Conservation Lands		BLM (2020) (1) https://data.cnra.ca.gov/dataset/blm-ca-nlcs-released-wilderness-study-areas-polygons (2) https://www.blm.gov/programs/national-conservation-lands/california
Greater Sage Grouse Habitat Conservation Areas	Solar: BLM_Managm IN ('PHMA', 'GHMA', 'OHMA') Wind: BLMP_Managm = 'PHMA'	"Nevada and Northeastern California Greater Sage-Grouse Approved Resource Management Plan Amendment." US Department of the Interior Bureau of Land Management Nevada State Office. 2015. https://eplanning.blm.gov/public_projects/lup/103343/143707/176908/NVCA_Approved_RMP_Amendment.pdf
Terrestrial 30x30 Conserved Areas	reGAP IN (1,2) AND cpad_PARK_NAME NOT IN ("Angeles National Forest")	"30x30 Conserved Areas, Terrestrial." CA Nature. August 3, 2022. https://www.californianature.ca.gov/datasets/CAnature::30x30-conserved-areas-terrestrial/about

Source: CEC staff

Table D-3: California Native American tribes' tribal lands

Title	Source
American Indian and Alaskan Native Land Area Representations (LAR)	American Indian and Alaska Native Land Area Representation (AIAN-LAR) https://biamaps.doi.gov/bogs/datadownload.html

Source: CEC staff

Table D-4: Biodiversity Index Input Data

Data Set Name	Source	Usage
Terrestrial Biodiversity	"Terrestrial Biodiversity Summary." California Department of Fish and Wildlife. August 3, 2022. https://wildlife.ca.gov/Data/Analysis/Ace#523731770-species-biodiversity	Biodiversity, Natural, and Working Lands Screen
Terrestrial Connectivity	"Terrestrial Connectivity." California Department of Fish and Wildlife. August 3, 2022. https://wildlife.ca.gov/Data/Analysis/Ace#523731772-connectivity	Biodiversity, Natural, and Working Lands Screen

Source: CEC staff

Table D-5: Cropland Index Input Data

Data Set Name	Source	Usage
Gridded Soil Survey Geographic (gSSURGO) Database	"Gridded Soil Survey Geographic (gSSURGO) Database." MUPOLYGON, Component, and Horizon. USDA. 2020 https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053628	Cropland index model
California Important Farmland	"2018 California Important Farmland." Farmland Mapping and Monitoring Program." California Department of Conservation. July 2022. https://www.conservation.ca.gov/dlrp/fmmp	Cropland index model

California Statewide Crop Mapping (2019)	"2019 California Statewide Crop Mapping ." California Department of Water Resources. 2022 https://data.cnra.ca.gov/dataset/statewide-crop-mapping	Cropland index model

Source: CEC staff

Table D-6: Intactness and Proximity to Protected Areas Model Input Data

Data Set Name	Source	Usage
Landscape Intactness	Degagne, R., J. Brice, M. Gough, T. Sheehan, and J. Strittholt. Terrestrial Landscape Intactness 1 kilometer, California. Conservation Biology Institute, December 2016. https://databasin.org/datasets/e3ee00e8d94a4de58082fdbc91248a65/	Land-Use Screen 2

Source: CEC staff

Table D-7: Additional Input Data Sets for Screens

Data Set Name	Source	Usage
Terrestrial Climate Change Resilience	Terrestrial Climate Change Resilience." California Department of Fish and Wildlife. August 3, 2022. https://wildlife.ca.gov/Data/Analysis/Ace#523731773-climate-resilience	Land-Use Screen 3

Table D-8: Raw Resource Potential Data

Energy Resource	Source	
Direct Normal Irradiance and Global Horizontal Irradiance (kWh/m^2/day)	Sengupta, M., Y. Xie, A. Lopez, A. Habte, G. Maclaurin, and J. Shelby. 2018. "The National Solar Radiation Data Base (NSRDB)." *Renewable and Sustainable Energy Reviews* 89 (June): 51-60.	This data is output from the NREL's Physical Solar Model at a spatial resolution of ~2-kilometers. This is the solar radiation available to solar energy systems.
Wind Speed at 80 meters height (meter/second)	[1] Draxl, C., B.M. Hodge, A. Clifton, and J. McCaa. 2015. "The Wind Integration National Dataset (WIND) Toolkit." *Applied Energy* 151: 355366.	The Wind Integration National (Wind)Toolkit provides numerical model (Weather Research and Forecast,

	[2] Draxl, C., B.M. Hodge, A. Clifton, and J. McCaa. 2015. *Overview and Meteorological Validation of the Wind Integration National Dataset Toolkit* (Technical Report, NREL/TP-5000-61740). Golden, CO: National Renewable Energy Laboratory.	WRF) output of wind speed from 2007-2013 at 2-kilometer resolution every 5 minutes.

Source: CEC staff

Table D-9: Geothermal Resource Assessment

Source	Usage
Lovekin, James W., Subir K. Sanyal, Christopher W. Klein. 2004. "New Geothermal Site Identification and Qualification." Richmond, California: California Energy Commission: Public Interest Energy Research Program. Accessed September 14, 2022.	Provided generating capacity estimates for all geothermal fields except for Truckhaven
Youngs, S. *California Low-Temperature Geothermal Resources Update -1993*. State of California Department of Conservation, 1994.	Provided spatial footprints of KGRAs
El Centro Field Office, Bureau of Land Management (2007). Final Environmental Impact Statement for the Truckhaven Geothermal Leasing Area (Publication Index Number: BLM/CA/ES-2007-017+3200). United States Department of the Interior Bureau of Land Management.	Provided spatial footprint of BLM Geothermal Leasing Area and estimated generating capacity for Truckhaven
Geothermal Map of California, S-11. California Department of Conservation, 2002. https://www.conservation.ca.gov/calgem/geothermal/maps/Pages/index.aspx	Provided spatial footprint of North Brawley geothermal field

Source: CEC staff