California Energy Commission

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

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California Energy Commission

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ABSTRACT

The *Land-Use Screens for Electric System Planning: Using Geographic Information Systems to Model Opportunities and Constraints for Renewable Resource Technical Potential in California* report (CEC Land-Use Screens Report) describes updates to land-use screens for electric system planning. The report provides technical updates to the method 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 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 inform electric system planning and help system planners focus on areas that have a greater potential for successful deployment of new utility-scale renewable energy capacity and electric transmission. 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.

The *Land-Use Screens for Electric System Planning: Using Geographic Information Systems to Model Opportunities and Constraints for Renewable Resource Technical Potential in California* report (CEC Land-Use Screens Report) describes updates to land-use screens for electric system planning. Land-use screens are map-based footprints delineating important environmental and physical characteristics of the land. The screens are assembled from an integration of raw data into modeled results at the statewide scale and can show land access limitations or competing land-use priorities. The report provides technical updates to the method 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 capacity (in megawatts [MW] or gigawatts [GW]) given technoeconomic, topographic, environmental, and land-use constraints. The CEC staff has created one model and assembled several categories of geospatial data to provide a transparent and data-driven means for assessing considerations in electric system planning, including renewable resource, biodiversity, and agricultural potential. Together, this information can be used to bring to light land access limitations or competing land-use priorities 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. Future enhancements include updating the land-use screening methods to include considerations for tribal cultural landscapes.

The model, categories of geospatial data, and land-use screens described in this report are for use in electric system planning and modeling. These 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 targets and the 2021 SB 100 Joint Agency Report

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 targets 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 assessed various pathways to achieve the SB 100 targets and an initial assessment of costs and benefits. One key finding from the report was that sustained record-setting renewable generation and energy storage capacity 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 need for new renewable generation and storage capacity, regardless of the SB 100 portfolio studied. This increase in new renewable generation and storage capacity will increase the land area required for successful implementation of SB 100. Recognizing the potential land use impacts

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.

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]

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. 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. Healthy landscapes can store carbon and build resilience to future impacts of climate change.[5] 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 locations that are 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

3 Ibid., page 18.

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 an area of higher biodiversity has *implications* for other land-use priorities.

5 California Natural Resources Agency. 2022. [*Expanding Nature-Based Solutions*.](https://resources.ca.gov/Initiatives/Expanding-Nature-Based-Solutions) 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 in historical publications in the CEC's Online Library Catalog at http://400.sydneyplus.com/CaliforniaEnergy_SydneyEnterprise/Portal/public.aspx?lang=en-US&p_AAAAIR=tab5&d=d.
Final RETI 2.0 report, available at http://docketpublic.energy.ca.gov/PublicDocuments/15-RETI-02/TN216198_20170223T095548_RETI_20_Final_Plenary_Report.pdf.

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 lands, lands used to produce crops, and cultural landscapes upfront in planning for large-scale future energy development (for example, onshore wind and utility-scale solar). This 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 targets and 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 and socially responsible renewable energy projects, and guiding transmission planning. Integrated planning is most effective when employed early, 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*. The geospatial datasets in a land-use screen may include technical, environmental, and other land-use priorities and considerations.

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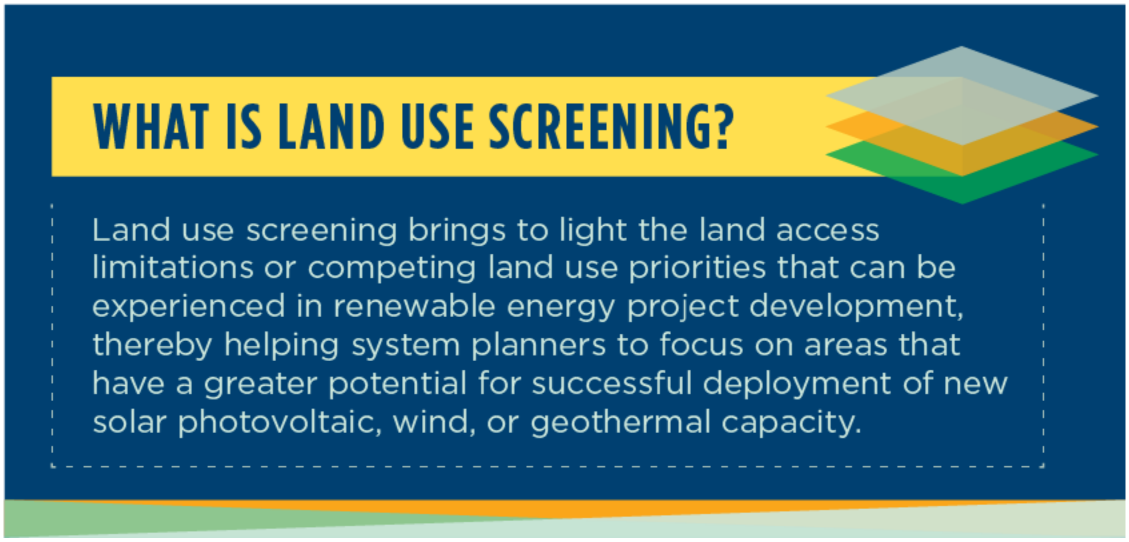
8 See *Desert Renewable Energy Conservation Plan,* available at https://www.energy.ca.gov/programs-and-topics/programs/desert-renewable-energy-conservation-plan.

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.



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 Renewables 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]

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 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

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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 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.

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 land-use 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. The six screens are:[13]

1. Base: This screen includes RETI Category 1 exclusions only.
2. Environmental Baseline (EnvBase): This screen includes RETI Category 1 and 2 exclusions.
3. NGO1: This screen is a modified version of RETI Category 1 screen, developed by environmental nongovernmental organizations (NGOs).
4. NGO1&2: This screen is a modified version of RETI Category 2 screen, developed by environmental NGOs.
5. DRECP/SJV: This screen 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 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 applies the most conservative value from the above five screens.

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.

14 See *A Path Forward: Identifying Least-Conflict Solar PV Development in California's San Joaquin Valley*, available at https://sjvp.databasin.org/datasets/b64959db3e694254818d97e51e2e6f42/.

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

The CEC, CPUC, and CARB (SB 100 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 process.

Between 2018 and 2021, the 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 process, 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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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 2018. "Areas of Conservation Emphasis." California Department of Fish and Wildlife. https://wildlife.ca.gov/Data/Analysis/Ace.

18 Degagne, R., J. Brice, M. Gough, T. Sheehan, and J. Strittholt. 2016. "Landscape Intactness (1 km), California." Conservation Biology Institute. From DataBasin.org: https://databasin.org/datasets/e3ee00e8d94a4de58082fdbc91248a65.

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

The 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 method 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 Energy Planning Library. The CEC staff sought input on the California Energy 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 February 2022 and April 2022 workshops, the CEC considered public comments and coordinated with state and federal agencies to revise relevant datasets and propose modifications to the existing land-use screening methods. The CEC held an October 10, 2022,

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19 2018. "California Agricultural Value (2018)." Conservation Biology Institute. From DataBasin.org: 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. https://efiling.energy.ca.gov/GetDocument.aspx?tn=239685&DocumentContentId=73101.

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

IEPR Workshop[25] to present a draft staff report[26] documenting proposed data and methodological updates and receive additional stakeholder comments. The CEC staff takeaways from the workshop and comments included:

- Additional public process steps needed before finalizing data and method modifications.
- Additional datasets are needed to better represent protected areas that preclude energy development (such as national scenic areas).
- Additional discussion is needed about solar resource potential in Critically Overdraft Basins, as defined by the Sustainable Groundwater Management Act.[27]

In response to the recommendation for additional public process steps, the CEC held a second land-use screens workshop March 13, 2023.[28] This workshop included agency presentations documenting proposed modifications to the draft land-use screens, informed by comments received following the October 10, 2022, workshop. The workshop also included a presentation from the National Renewable Energy Laboratory (NREL) on approaches to developing national technical potential estimates using geospatial data.

This CEC Land-Use Screens Report completes the current cycle of update to the land-use screens by proposing data and method updates in response to state and federal agency feedback gathered through four public workshops, as well as direct meetings with stakeholders between February 2022 and May 2023. The revised method for the land-use screens aims to improve on past efforts by:

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25 See October 10, 2022, IEPR Commissioner Workshop on Land Use Screens, available at https://www.energy.ca.gov/event/workshop/2022-10/iepr-commissioner-workshop-land-use-screens.

26 Hossainzadeh, Saffia, Erica Brand, Travis David, Gabriel Blossom, and Paul Deaver. 2022. *Land-Use Screens for Electric System Planning: Using Geographic Information Systems to Model Opportunities and Constraints for Renewable Resource Technical Potential in California*. California Energy Commission. Publication Number: CEC 700-2022-006-SD. https://efiling.energy.ca.gov/GetDocument.aspx?tn=246353.

27 The Sustainable Groundwater Management Act is composed from a three-bill legislative package and subsequent statewide regulations.
Assembly Bill 1739 (Dickinson, Chapter 347, Statues of 2014).
https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB1739.
Senate Bill 1168 (Pavley, Chapter 346, Statues of 2014).
https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB1168.
Senate Bill 1319 (Pavley, Chapter 348, Statues of 2014).
https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB1319.

28 See March 13, 2023. Commissioner Workshop on Land Use Screens, available at https://www.energy.ca.gov/event/workshop/2023-03/commissioner-workshop-land-use-screens.

1. Updating data to capture new information, including several newly designated and previously omitted protected areas.
2. Updating data to reflect new state conservation priorities and climate initiatives.
3. 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, the CEC staff recommends using the following two revised land-use screens for solar PV[29] and onshore wind technologies in electric system planning.

Table 1: Proposed Revised Land-Use Screens

Screen Name	Categories of Data Included
Core Land-Use Screen	base exclusions, biological planning priorities, landscape intactness, and cropland[30]
SB 100 Terrestrial Climate Resilience Study Screen	base exclusions, biological planning priorities, landscape intactness, cropland[31], and terrestrial climate resilience

Source: CEC staff

The two new land-use screens presented within this report build upon and update the land-use screens that were used by the CEC and CPUC.

Core Screen: This land-use screen addresses several state policy priorities, including sustaining agriculture and protecting natural lands that support biodiversity.[32] Further, this screen incorporates statewide information about intact landscapes (for example, lands with low levels of human disturbance). The CEC staff recommends use of the Core Land-Use Screen as the primary screen for estimating renewable resource technical potential for onshore

29 The land-use screen evaluation focused on solar photovoltaic because although solar thermal is a well-proven technology, little development is anticipated at this time, primarily because it cannot compete with solar photovoltaic on cost.

30 The cropland land-use screening factor applies to solar technology only.

31 Ibid.

32 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.

wind and solar PV for use in electric system planning (for example, capacity expansion modeling in SB 100 and CPUC IRP process).

SB 100 Terrestrial Climate Resilience Study Screen: This land-use screen addresses several state policy priorities, including sustaining agriculture and protecting natural lands that support biodiversity.[33] Further, this screen incorporates statewide information about lands that have a higher probability of serving as refugia[34] for species adapting to climate change. Conserving refugia is an important part of adaptation planning and a means of building resilience to climate change. The CEC staff recommends using the SB 100 Terrestrial Climate Resilience Study Screen as a sensitivity case in SB 100 modeling for the purposes of exploring land-use trade-offs.

For geothermal technologies, a single statewide screen and technical resource potential estimate was created for use in SB 100 analysis and the CPUC's IRP process. The limited approach was chosen because this technology can be developed only in discrete areas of the state and has a smaller technical resource potential than wind and solar PV.

The use of these land-use screens in electric system planning, including SB 100 analysis and the IRP process, 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.

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33 Ibid.

34 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 the CEC staff used to construct a high-level land-use evaluation or *land-use screening* 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,[35] 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 (referred to as the techno-economic exclusion layer).
2) Legally protected areas,[36] which also exclude resource potential (referred to as the protected area layer).
3) Land-use planning considerations related to biodiversity, croplands, landscape intactness, and terrestrial climate resilience.

The land-use planning considerations are evaluated, then partitioned into high and low implication, with high implication areas recommended for resource potential exclusion. Geospatial datasets that represent all these factors on a statewide scale are identified and compiled into a map so that the remaining low-implication areas can be quantified to estimate renewable resource technical potential for electric system modeling and energy resource planning.

The result of land-use screening is an estimate of renewable resource technical potential through the state of California. The outputs are reported in acres and capacity (for example, megawatt [MW] or gigawatt [GW]). For a description of the technical geographic information

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

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

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 screens 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 the latest information from state and federal agencies.
3. Created renewable resource potential basemaps for solar PV and onshore wind technologies by mapping areas of energy development restrictions into base exclusions.[37]
4. Created a renewable resource potential basemap for geothermal technology by estimating surface footprints of identified geothermal resources and applying mapped areas of energy development restrictions.
5. Added BLM development focus areas (DFAs), variance process lands (VPLs), and general public lands (GPLs) to the resource potential basemap within the boundaries of the DRECP. These are lands that are allocated for renewable energy development or accept renewable energy development applications.
6. Created the CEC Cropland Index Model which evaluates several factors of soil quality and farmland usage simultaneously in a multicriteria suitability analysis.
7. Combined several datasets that represent biological planning priorities into a single GIS layer.
8. Constructed two new land-use screens that reflect the preference for new renewable resource potential from a combination of the lower-implication regions of the priority land-use categories. The land-use screens are used in conjunction with the resource potential basemap to refine the areas within California for renewable resource potential study.
9. Adjusted the resource potential estimates from DFAs, VPLs, and GPLs footprints by the screens and BLM authorized project footprints.

37 A combined set of spatial datasets representing areas where (1) renewable resource potential is excluded based on technical or economic criteria, or (2) utility-scale renewable energy or transmission development is precluded by state or federal law, policy, or regulation. These two categories of base exclusions are referred to as the techno-economic exclusion layer and the protected area layer in this report and are the fundamental exclusions that additional criteria in the Core and SB 100 Terrestrial Climate Resilience Study Screens build upon.

The land-use evaluation summarized above attempts to quantify objectively 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 as an input into planning for the integration of new renewable energy resources necessary to achieve climate and clean energy targets.

All data used in this report to construct the land-use screens have been fully documented and shared in Appendix D of this report. Results and intermediate outputs have been compiled into an interactive GIS web-mapping tool[38] to clarify the methods described here.

Figure 1: Land-Use Evaluation Methods

Source: CEC staff

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

38 See "[CEC California Energy Planning Library, Land-Use Screens](https://www.energy.ca.gov/data-reports/california-energy-planning-library/land-use-screens)," available at https://www.energy.ca.gov/data-reports/california-energy-planning-library/land-use-screens.

Workflow Overview

The updates to geospatial datasets, development of the spatial multi-criteria analysis model, and development of the land-use screens were accomplished working through an iterative process in coordination with the 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 biodiversity component of the screens, the CEC staff:

1. Identified source datasets for consideration.
2. Consulted source data owners and partner agencies to partition the data to areas of highest rank, if applicable.
3. Combined the individual datasets into a single GIS layer.

To create the CEC Cropland Index Model, the CEC staff:

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 suitable 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 datasets 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.

An initial step in revising the land-use screens was defining the geographic scope of the analysis. The 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, or gathering, 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 the CPUC and California ISO in resource and transmission planning. In 2021, the CPUC and California ISO updated their resource and transmission planning processes to move away from a modeling approach based on geographic zones to a modeling approach based on a geospatial representation of transmission constraints.[39]

The land-use evaluation described in this report 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,[40] the CEC staff recommends using publicly available spatial datasets from the Western Electricity Coordinating Council (WECC) Environmental Risk Dataset[41] to map resources located outside California. Several public comments encouraged the CEC to expand the land-use screening methods applied in California to other western states instead of using the spatial datasets from WECC. The CEC staff plans to review the literature of publicly available geospatial data sources to evaluate a range of options for potential use in the next cycle of updates to the land-use screens.

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, NREL, and U.S. Geological Survey (USGS). There are two categories of input datasets used to develop the land-use screens for electric system planning:

- Exclusion datasets (which are combined to form the base exclusion layer).
- Environmental and land-use planning considerations (geospatial datasets that represent planning considerations related to biodiversity, croplands, landscape intactness, and terrestrial climate resilience).

39 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.

40 See *Inputs & Assumptions: 2022-2023 Integrated Resource Planning (IRP)*, available at https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2023-irp-cycle-events-and-materials/draft_2023_i_and_a.pdf.

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

Exclusion datasets came from past land-use screens, updated to reflect the availability of newer information and address omissions in the data. The exclusion datasets are divided into two categories — the techno-economic exclusion layer and the protected area layer — and are referred to as the **base exclusions** in this report. The techno-economic exclusion layer is provided by the CPUC and identifies regions of the state where renewable resource potential is excluded based on technical or economic criteria. The protected area layer includes areas where utility-scale renewable energy or transmission development is precluded by state or federal law, policy, or regulation. Datasets representing environmental and land-use planning considerations came from past land-use screens and were acquired from state and federal agencies. See Appendix D for tables showing input data for the exclusion datasets, the CEC Cropland Index Model, and other components of the screens.

In Appendix C, the CEC staff performed a comparative analysis for solar of the revised protected area layer to past agency and nongovernmental organization (NGO) studies that have used similar approaches to construct environmental exclusions. 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 the protected area layer in this report produced a total footprint area within the range of other efforts.

Resource Potential Basemaps

Once base 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 2. 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, the CEC staff includes renewable resource potential from variance process lands (VPLs) and general public lands (GPLs).[42]

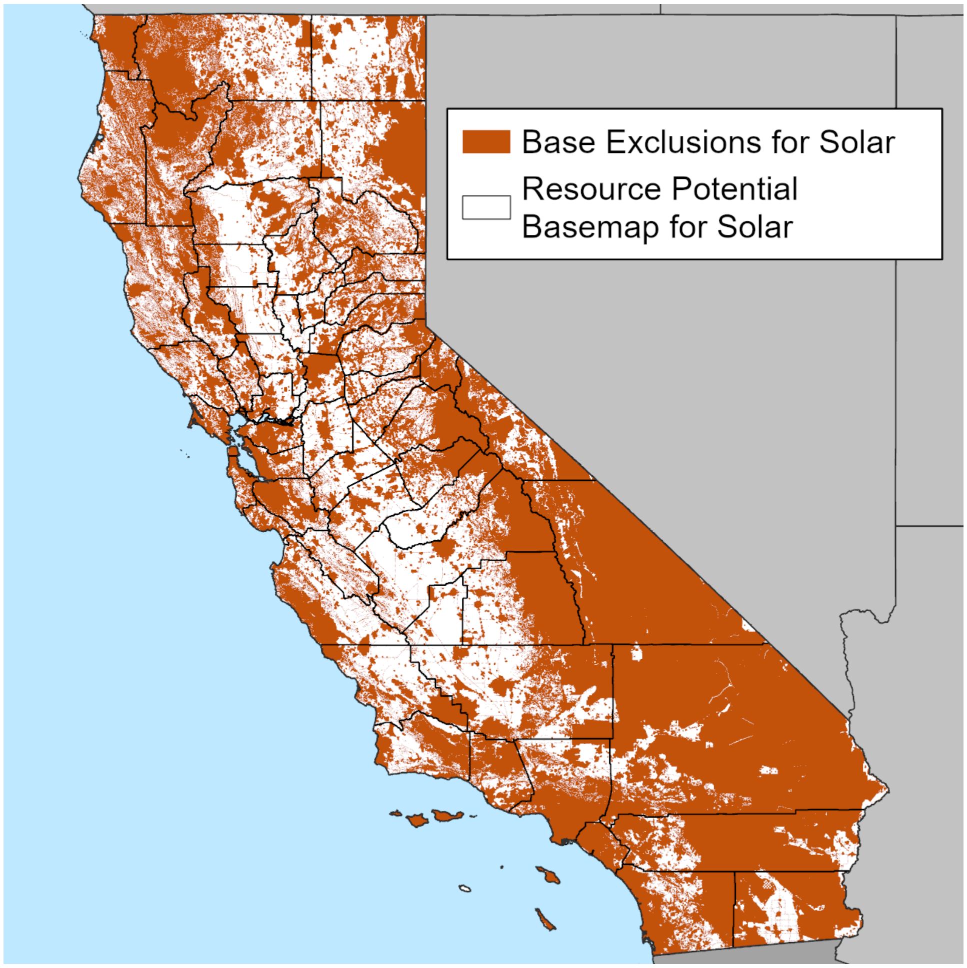
42 2016. "Record of Decision for the Land Use Plan Amendment to the California Desert Conservation Plan, Bishop Resource Management Plan, and Bakersfield Resource Management Plan." U.S. Bureau of Land Management. https://eplanning.blm.gov/public_projects/lup/66459/133460/163124/DRECP_BLM_LUPA_ROD.pdf.

Characterization of geothermal resources differs from solar and wind because these resources occur in discrete areas that have sufficient geothermal heat, while wind and solar PV generally occur at a landscape scale. The resource potential basemap for this technology consists of geothermal field boundaries where enough information is known about the underlying reservoir to quantify the associated electrical generation capacity. Figure 3 shows the geothermal fields with electric generation potential that make up the resource potential basemap. For more information, see Appendix C with detailed geospatial methods used in this analysis and Appendix D for a compendium of data sources.

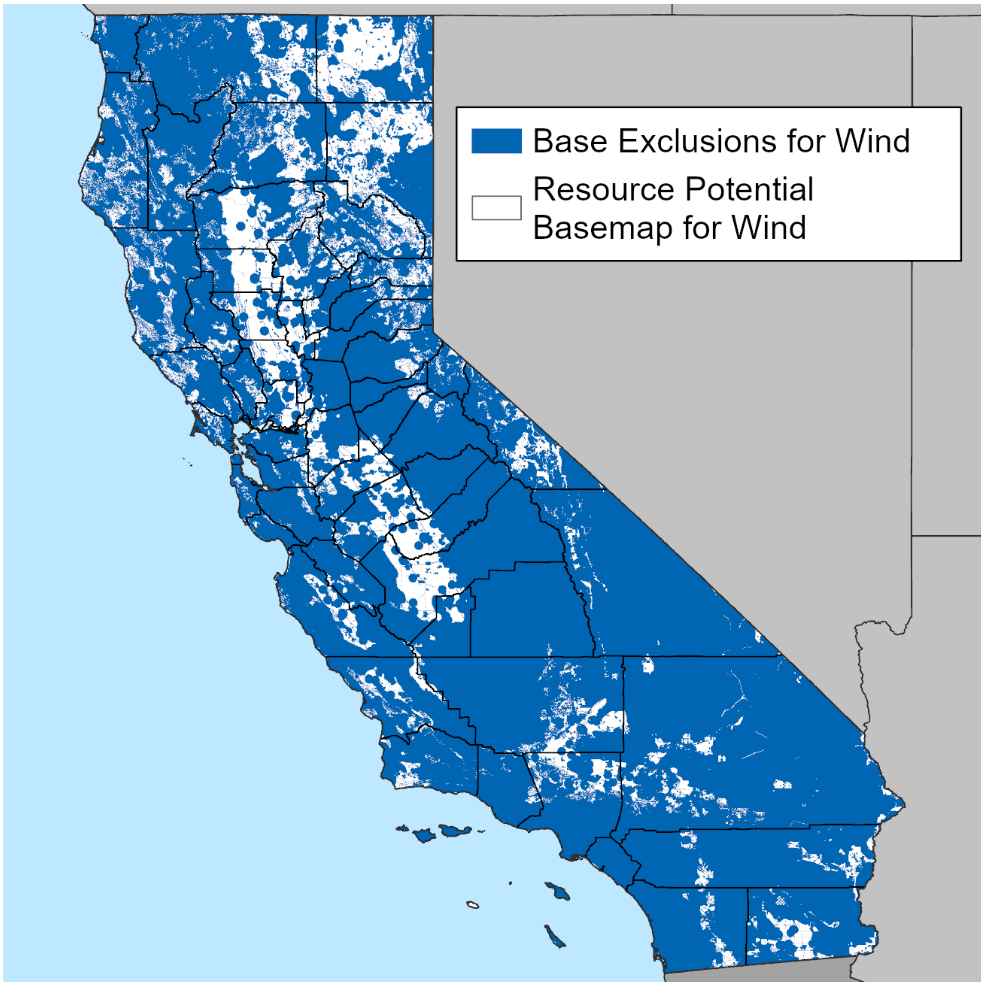
Spatial data retrieved from (1) 2016. "BLM LUPA Renewable Energy Designations." Conservation Biology Institute. From DataBasin.org: https://databasin.org/datasets/c61b0e256e494fc5b6958d6c3999a19a/.

(2) 2016. "BLM LUPA General Public Lands." Conservation Biology Institute. From DataBasin.org: https://databasin.org/datasets/1cb6eabad6bf48b5b8e24f45b33ff028/

Figure 2: Resource Potential Basemaps and Base Exclusions for Onshore Wind and Solar Technologies



(A)

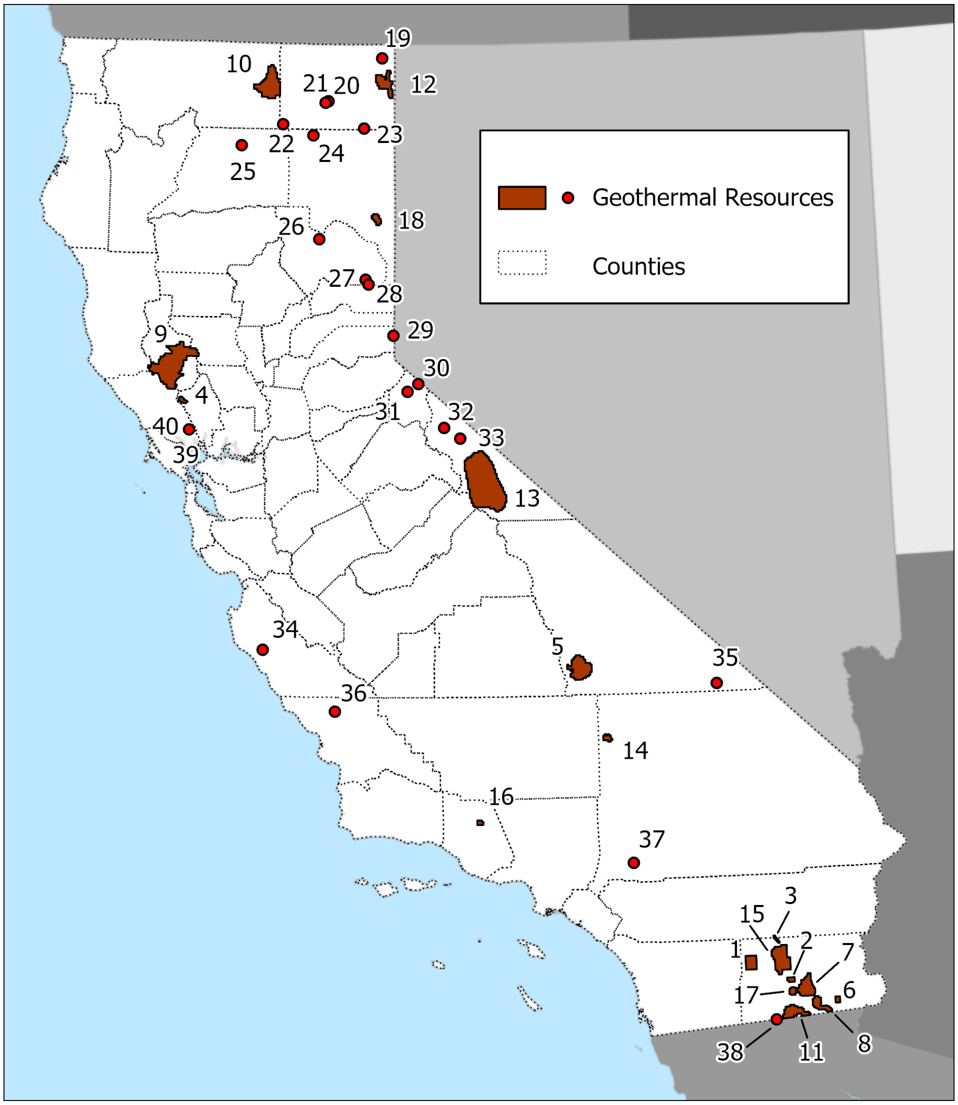


(B)

Source: CEC staff

(A) Base exclusion areas are shaded in orange for solar and (B) blue for onshore wind. The white areas remaining in each figure make up the resource potential basemaps for each technology.

Figure 3: Geothermal Resource Potential Basemap



ID	Name
1	Truckhaven
2	Brawley
3	Hot Mineral Spa
4	Calistoga
5	Coso Hot Springs
6	Dunes
7	East Brawley
8	East Mesa
9	Geysers
10	Glass Mountain
11	Heber
12	Lake City - Surprise Valley 1
13	Mono - Long Valley
14	Randsburg

ID	Name
15	Salton Sea
16	Sespe Hot Springs
17	South Brawley
18	Wendel - Amedee
19	Fort Bidwell
20	Kelly HS
21	Canby (I'SOT)
22	Little Hot Spring (Fall River)
23	West Valley Reservoir
24	Kellog HS
25	Big Bend HS
26	Indian Valley Hot Springs
27	Marble Hot Well
28	Sierra Valley

ID	Name
29	Brockway Hot Springs
30	Carson River
31	Grovers HS
32	Fales HS
33	Travertine HS
34	Tasajara HS
35	Tecopa HS
36	Paso Robles
37	Arrowhead HS
38	Mt. Signal
39	Boyes HS
40	Sonoma Mission Inn

Source: CEC staff

The resource potential basemap consists of the geothermal resource areas and fields where enough information is known about the reservoir to deem it capable of electricity generation. Geothermal resource areas indicated by red circular marker symbols are not drawn to scale. Locations numbered 2-18 follow naming conventions from California Department of Conservation geothermal KGRA and Field Administrative Boundaries. Locations numbered 19-40 follow naming conventions from the USGS 2008 report[43] that is one of the primary sources for the geothermal resource potential analysis.

Geospatial Analysis Overview

To explore planning considerations related to biodiversity, lands used to produce crops, terrestrial landscape intactness, and terrestrial climate resilience, the CEC staff developed a single GIS layer that combines several datasets for each of these factors. These planning consideration components are listed here and described at a high level in this chapter. The final use in the land-use screens is shown in Figures 4–7 below. A more complete description

43 Williams, Colin F., Marshall J. Reed, Robert H. Mariner, Jacob DeAngelo, and S. Peter Galanis, Jr. 2008. "Assessment of Moderate- and High-Temperature Geothermal Resources of the United States." U.S. Geological Survey Fact Sheet. 2008-3082. https://pubs.usgs.gov/fs/2008/3082/.

of the datasets and the geospatial analysis methods used to incorporate them in the screens is given in Appendix C.

- **Biological planning priorities:** Combines individual mapped delineations of USFWS critical habitat (including the proposed bi-state sage grouse), high ranks of CDFW's Areas of Conservation Emphasis (ACE) Terrestrial Connectivity, Biodiversity and Irreplaceability, and lands classified as wetlands. These layers are added — the footprints are merged — to represent the combined boundary of biological planning priorities. The datasets and ranks selected for this component of the screens came from past land-use screens, public comment, and agency comment. Areas of the state that fall within these areas have a higher implication[44] for biodiversity and state planning priorities, and the state's resource potential estimate is refined by excluding lands that fall in these areas of high biological importance. This result is shown in Figure 4 below.
- **Terrestrial landscape intactness:** 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. The Conservation Biology Institute (CBI) has created a multicriteria evaluation model using more than 30 data layers, or variables, each of which is numerically weighted to estimate landscape intactness at 1-kilometer resolution.[45]

  The CEC staff partitions this dataset at the mean to create two categories: areas that are already disturbed and have degraded ecosystem function and areas where development would impair the landscape and cause new disturbance. In this analysis, areas of low landscape intactness are most suited for exploration of renewable resource potential, whereas areas of high intactness are better suited for conservation. Therefore, the higher category of landscape intactness values is used to remove technical resource potential from the state. This result is shown below in Figure 5.
- **CEC Cropland Index Model:** For lands used to produce crops, CEC developed a multicriteria evaluation model, or suitability model, using the ArcGIS Pro Suitability

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44 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.

45 Degagne, R., J. Brice, M. Gough, T. Sheehan, and J. Strittholt. 2016. "Terrestrial Landscape Intactness 1 km, California." Conservation Biology Institute. From DataBasin.org: https://databasin.org/datasets/e3ee00e8d94a4de58082fdbc91248a65.

Modeler.[46] The multicriteria evaluation method, also used by CBI for Landscape Intactness described above, is common in geospatial analyses when multiple inputs affect an overall value decision for an area. This method allows each input data layer to be transformed onto a common scale and weights each dataset according to relative importance. The result is a summation of the input data layers into a single-gridded map. Input variables used in the CEC Cropland Index Model include information on soil quality, farmland designations, and current existence of crops. The CEC Cropland Index Model does not include statewide information for grazing lands or rangelands. Furthermore, it is only applied to solar technology because wind resource development has shown compatibility with farmland, with approximately half of existing wind projects located in farmland nationally.[47] For a description of the model development and results, see Appendix C.

This final model output provides a numerically weighted index of importance for croplands at a given location. The CEC staff partitioned the CEC Cropland Index Model results at the mean into areas of higher and lower implication[48] in the land-use screens. Areas of higher implication are incorporated as an exclusion in resource potential estimates and are shown in Figure 6 below.

- **Terrestrial Climate Change Resilience:** This is a dataset that is provided by CDFW's ACE project and used to help plan for climate change strategies. It identifies areas of the state that are likely to serve as climate refugia under changing climate conditions. Based on projections from climate models, this dataset indicates the relative likelihood that an area will experience shifts in temperature, precipitation, or other important climate variables that would negatively impact the current array of plants (and by extension animals) that can thrive under those future conditions. In this analysis, 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. Figure 7 below depicts the high-ranking subset of the dataset

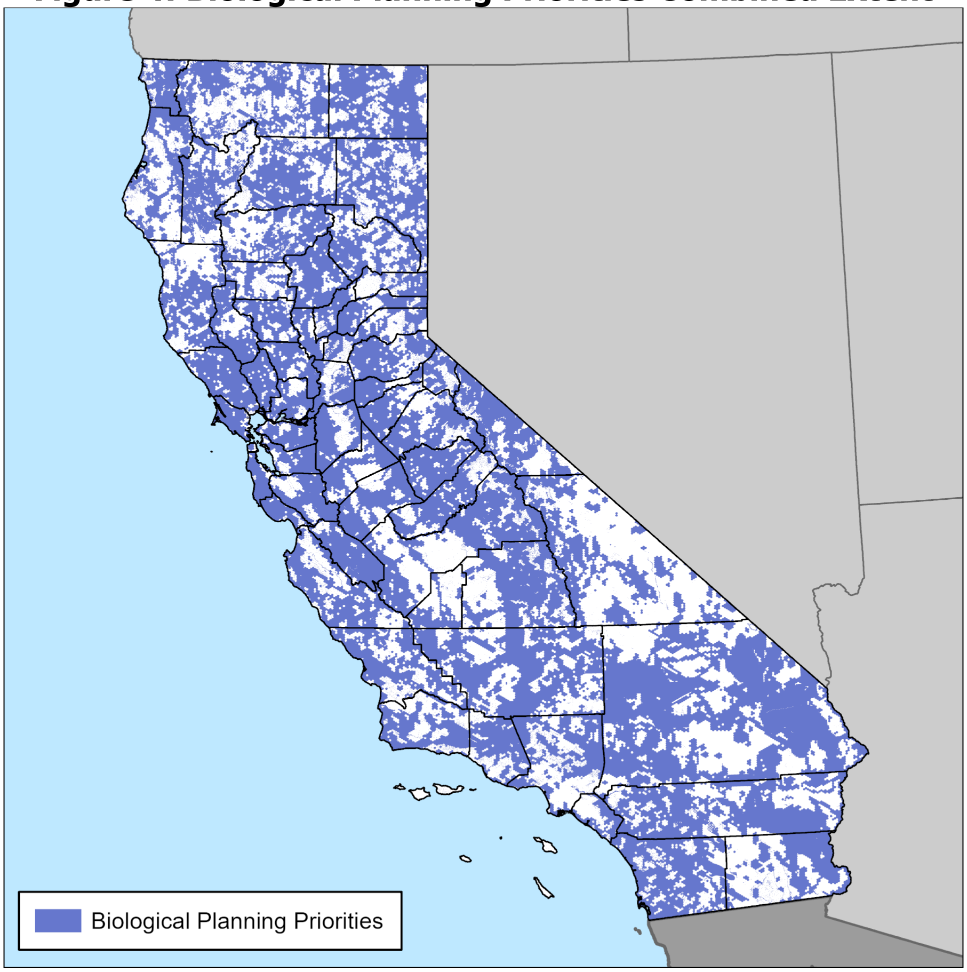
46 See *What is the Suitability Modeler*, available at: https://pro.arcgis.com/en/pro-app/latest/help/analysis/spatial-analyst/suitability-modeler/what-is-the-suitability-modeler.htm

47 Denholm Paul, Maureen Hand, Maddalena Jackson, and Sean Ong. 2009. *Land-Use Requirements of Modern Wind Power Plants in the United States*. National Renewable Energy Laboratory. Report No. NREL/TP-6A2-45834. https://www.nrel.gov/docs/fy09osti/45834.pdf.

48 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.

(Ranks 4 and 5) that removes additional areas of the state's technical resource potential under the SB 100 Terrestrial Climate Change Resilience Screen.

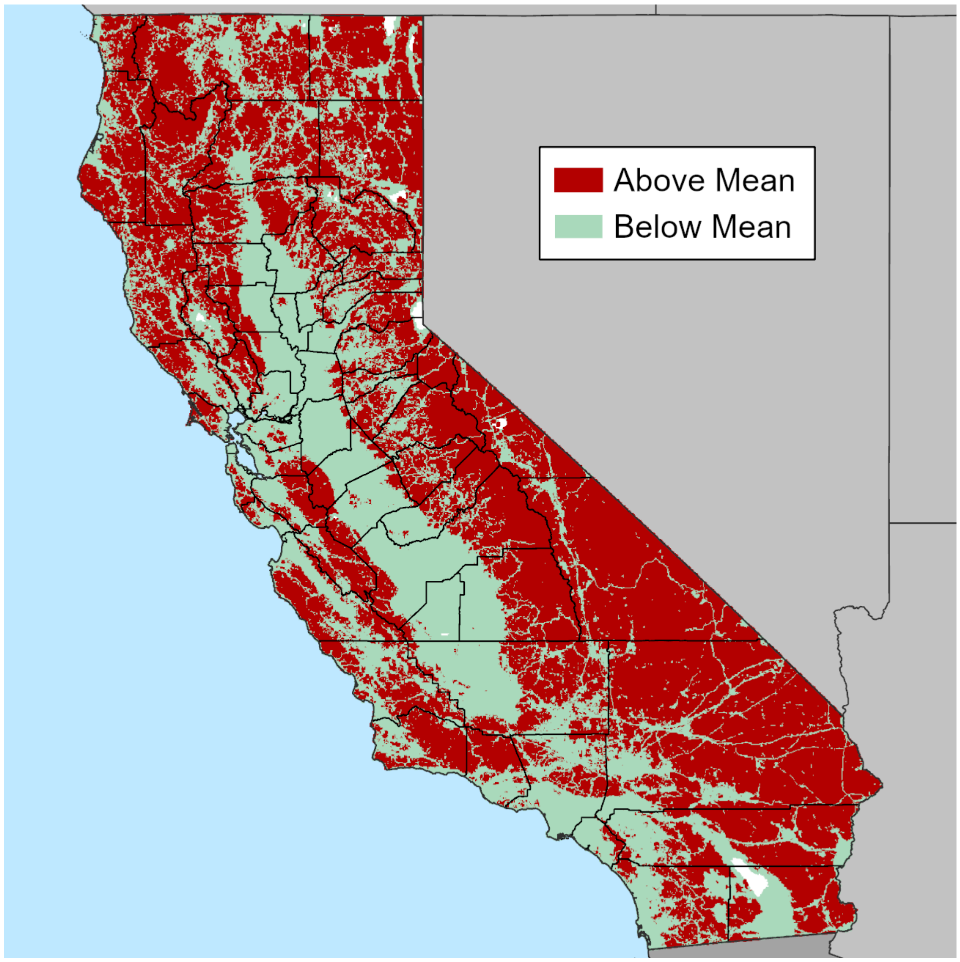
Figure 4: Biological Planning Priorities Combined Extent



Source: CEC staff

The combined footprint of the biological planning priorities used to represent the high implication areas for biodiversity regions of the state. This result is used in both screens (Core and SB 100 Terrestrial Climate Resilience Study).

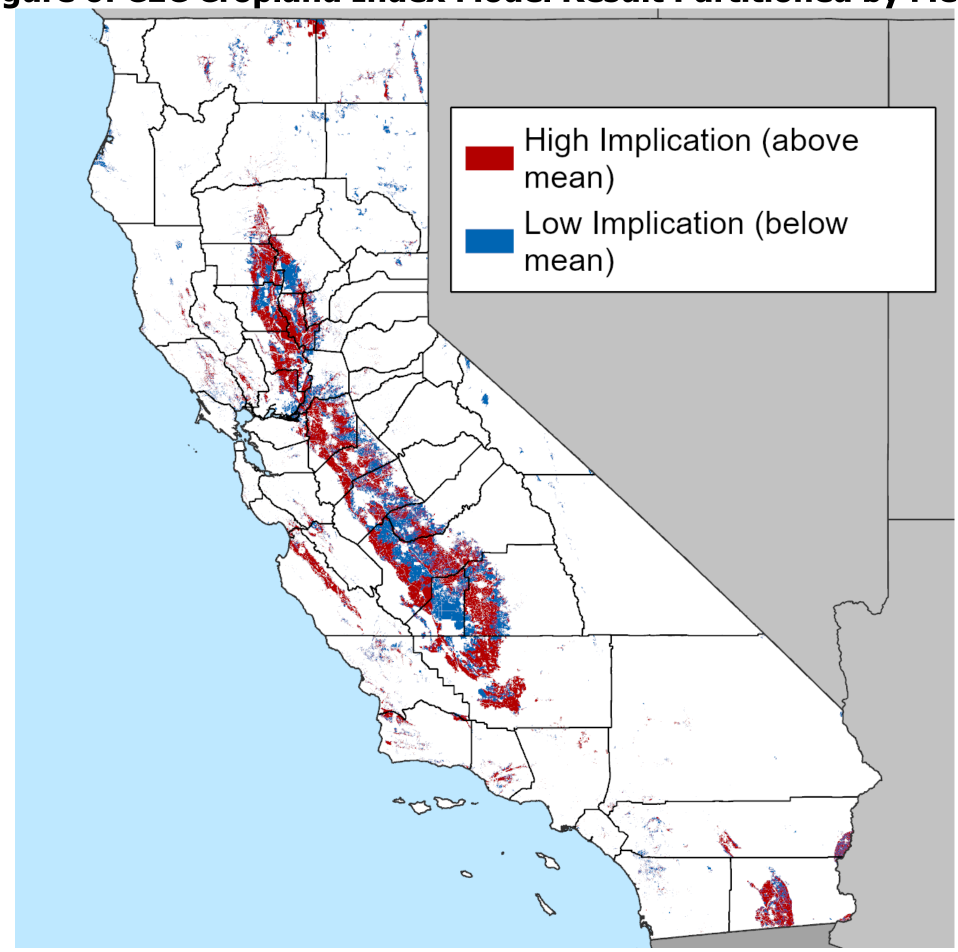
Figure 5: CBI Landscape Intactness Model Result Partitioned by Mean



Source: CEC staff

Landscape Intactness as calculated by CBI is partitioned into high and low categories based on the mean. The high implication category is used as an exclusion in the construction of both land-use screens.

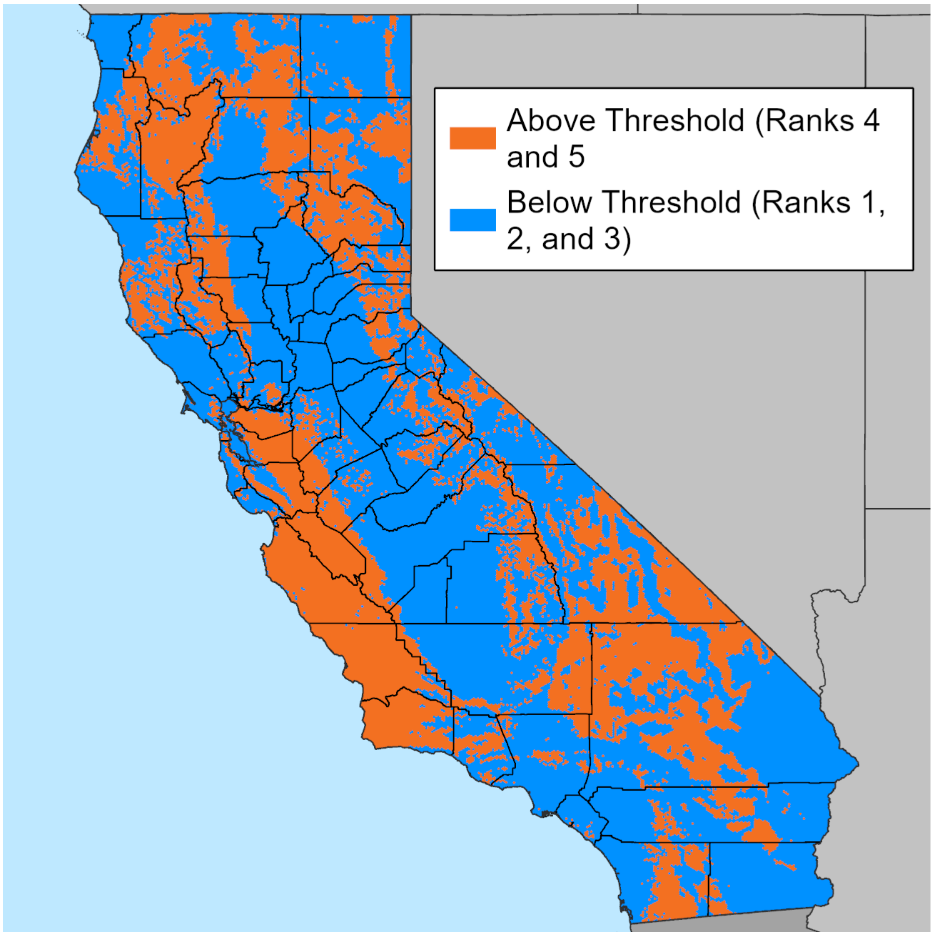
Figure 6: CEC Cropland Index Model Result Partitioned by Mean



Source: CEC staff

The CEC Cropland Index Model result partitioned at the mean. Areas with a higher suitability score for factors that support high-value croplands appear in red. Areas with a lower suitability score appear in blue. The high category is used as an exclusion in the construction of both land-use screens for solar PV.

Figure 7: Terrestrial Climate Change Resilience Screen Component



Source: CEC staff

ACE Terrestrial Climate Resilience partitioned into a high and low category based on a chosen threshold of Rank 4. The area in orange is the higher-ranking subset of the data layer and shows regions of the state that are more likely to support the current array of plant and animal life under future climate conditions. This area is used as an exclusion in the SB 100 Terrestrial Climate Resilience Study Screen.

The following chapter describes how the exclusion datasets, planning considerations, and spatial model outputs are combined into land-use screens to estimate resource potential for onshore wind, solar PV, and geothermal resources 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, the CEC staff recommends the following revised land-use screens for electric system planning for solar PV and onshore wind technologies. These revised land-use screens build upon and update the land-use screens that are in use by the CEC and CPUC.

1. Core Land-Use Screen: base exclusions, biological planning priorities, landscape intactness, and cropland[49]
2. SB 100 Terrestrial Climate Resilience Study Screen: base exclusions, biological planning priorities, landscape intactness, cropland,[50] and terrestrial climate resilience

Both screens were adjusted for projects that are authorized on Bureau of Land Management development focus areas, variance process lands, and general public lands within the DRECP. Authorized project footprints and the screen components listed above are removed from wind and solar PV resource potential estimates.

For geothermal technology, the CEC staff recommends using a single land-use screening approach that includes only the protected area layer.

Core Screen

The high-level statewide land-use evaluation in the Core Land-Use Screen includes the following statewide data and information described in Chapter 2 and Appendix C:

- Base exclusion datasets.
- Excluded lands identified in the biological planning priorities single GIS layer.
- Excluded lands identified as higher implication in the CBI Terrestrial Landscape Intactness Model.
- For solar PV, excluded lands identified as higher implication in the CEC Cropland Index Model.

49 This category of the land-use screens is applied for solar technology only.

50 Ibid.

This screen identifies 5.4 million acres of utility-scale solar PV resource potential (Figure 8) and 3.3 million acres of onshore wind resource potential (Figure 9). These numbers are illustrative to demonstrate the results of the land-use screen methods. Land-use screens are only one input into electric system modeling. Therefore, the final resource potential numbers used in a particular planning process may change depending on the other inputs and assumptions. For example, changes to techno-economic assumptions (such as, capacity factor) or the capacity density metric[51] applied may change the acres of resource potential available for study.

SB 100 Terrestrial Climate Resilience Study Screen

The high-level statewide land-use evaluation in the SB 100 Terrestrial Climate Resilience Study Screen includes the following statewide data and information described in Chapter 2 and Appendix C:

- Base exclusion datasets.
- Excluded lands identified in the biological planning priorities single GIS layer.
- Excluded lands identified as higher implication in the CBI Terrestrial Landscape Intactness Model.
- For solar PV, excluded lands identified as higher implication in the CEC Cropland Index Model.
- Excluded lands that have higher probability of serving as refugia for species adapting to climate change.

This screen identifies 3.7 million acres of utility-scale solar PV resource potential (Figure 8) and 2.5 million acres of onshore wind resource potential (Figure 9). These numbers are illustrative to demonstrate the results of the land-use screen methods. Land-use screens are only one input into electric system modeling. Therefore, the final resource potential numbers used in a particular planning process may change depending on the other inputs and assumptions. For example, changes in techno-economic assumptions (such as, capacity factor) or the capacity density metric applied may change the acres of resource potential available for study.

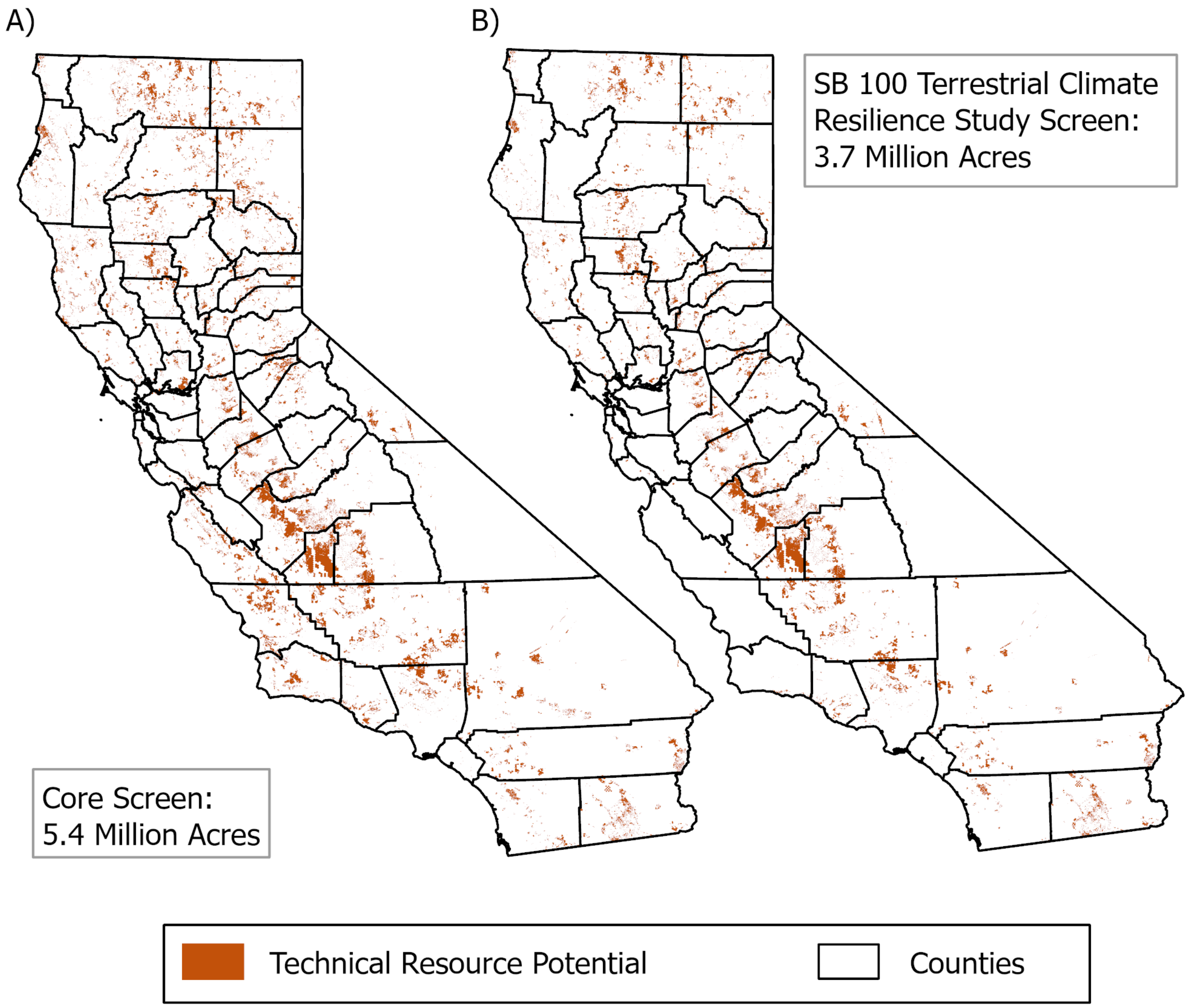
51 Capacity density is a leading metric for evaluating land area requirements. It is a metric that describes the amount of land area that is needed to support a megawatt of installed capacity.

Geothermal Land-Use Screen

The high-level statewide land-use evaluation for geothermal resources includes the following statewide data and information described in Chapter 2 and Appendix C: (1) Protected area layer. This screen identifies 3,354 MW of net undeveloped resource potential (Figure 10).

Figures 8, 9, and 10 illustrate the resource potential footprints for solar PV, onshore wind, and geothermal technologies for each of the screens where applicable.

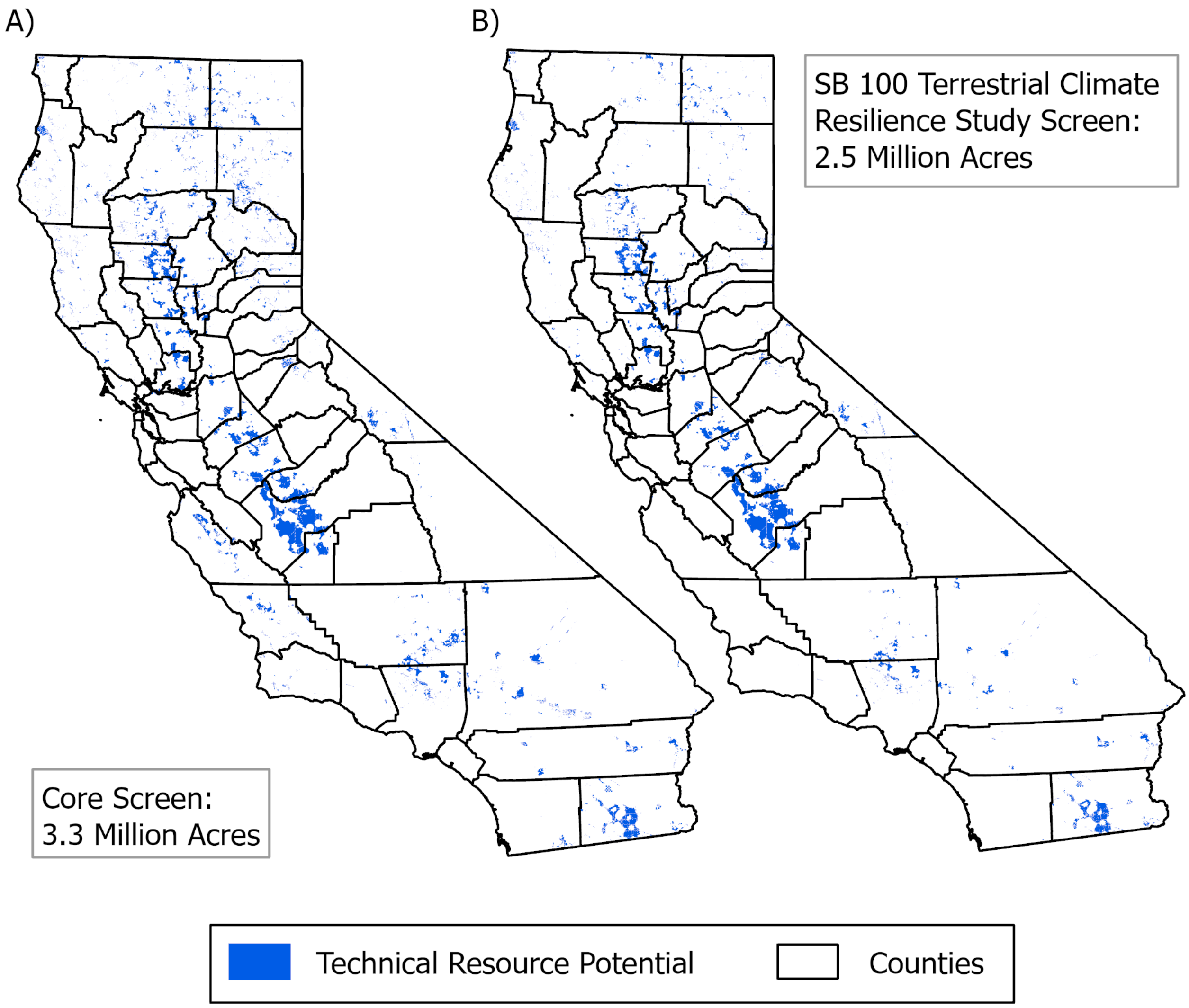
Figure 8: Lands With Solar Photovoltaic Resource Potential in Each Screen



Source: CEC staff

Lands with resource potential for solar PV after applying (A) the Core Land-Use Screen and (B) the SB 100 Terrestrial Climate Change Resilience Study Screen. The total acreage of technical resource potential under each screen is reported as well.

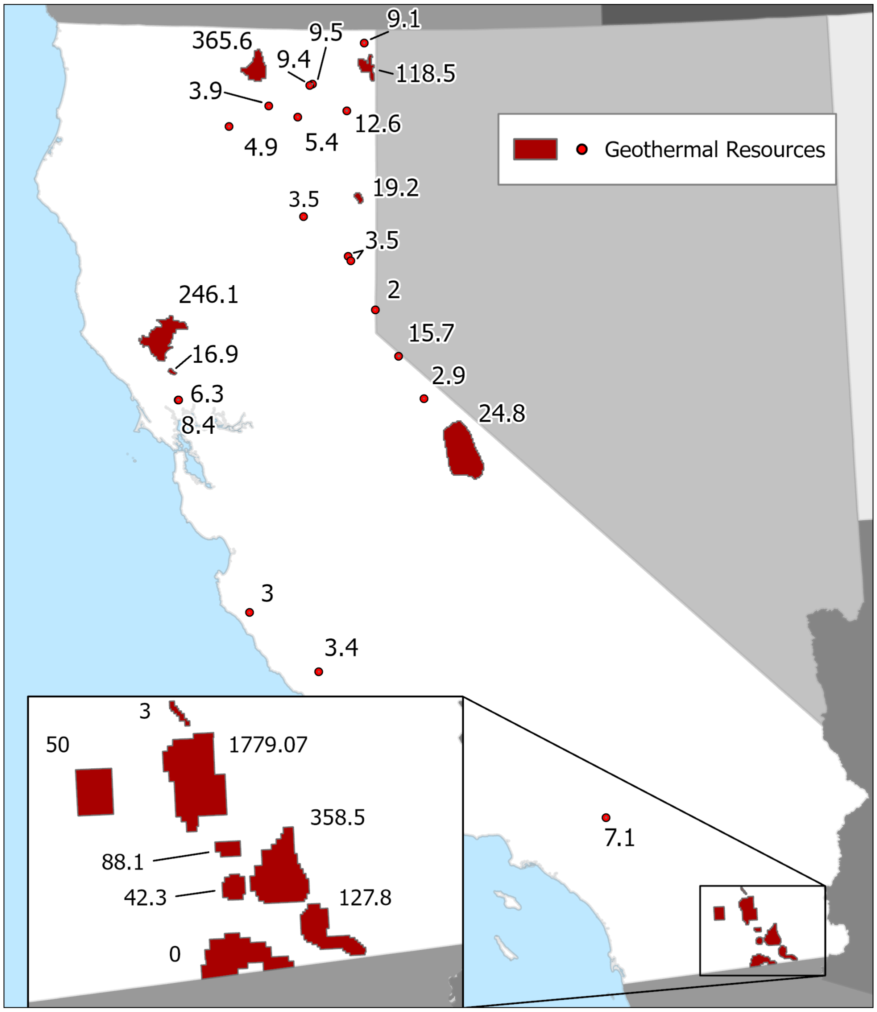
Figure 9: Lands with Onshore Wind Resource Potential in Each Screen



Source: CEC staff

Lands with resource potential for onshore wind after applying (A) the Core Land-Use Screen and (B) the SB 100 Terrestrial Climate Change Resilience Study Screen. The total acreage of technical resource potential under each screen is reported as well.

Figure 10: Geothermal Resource Potential (MW)

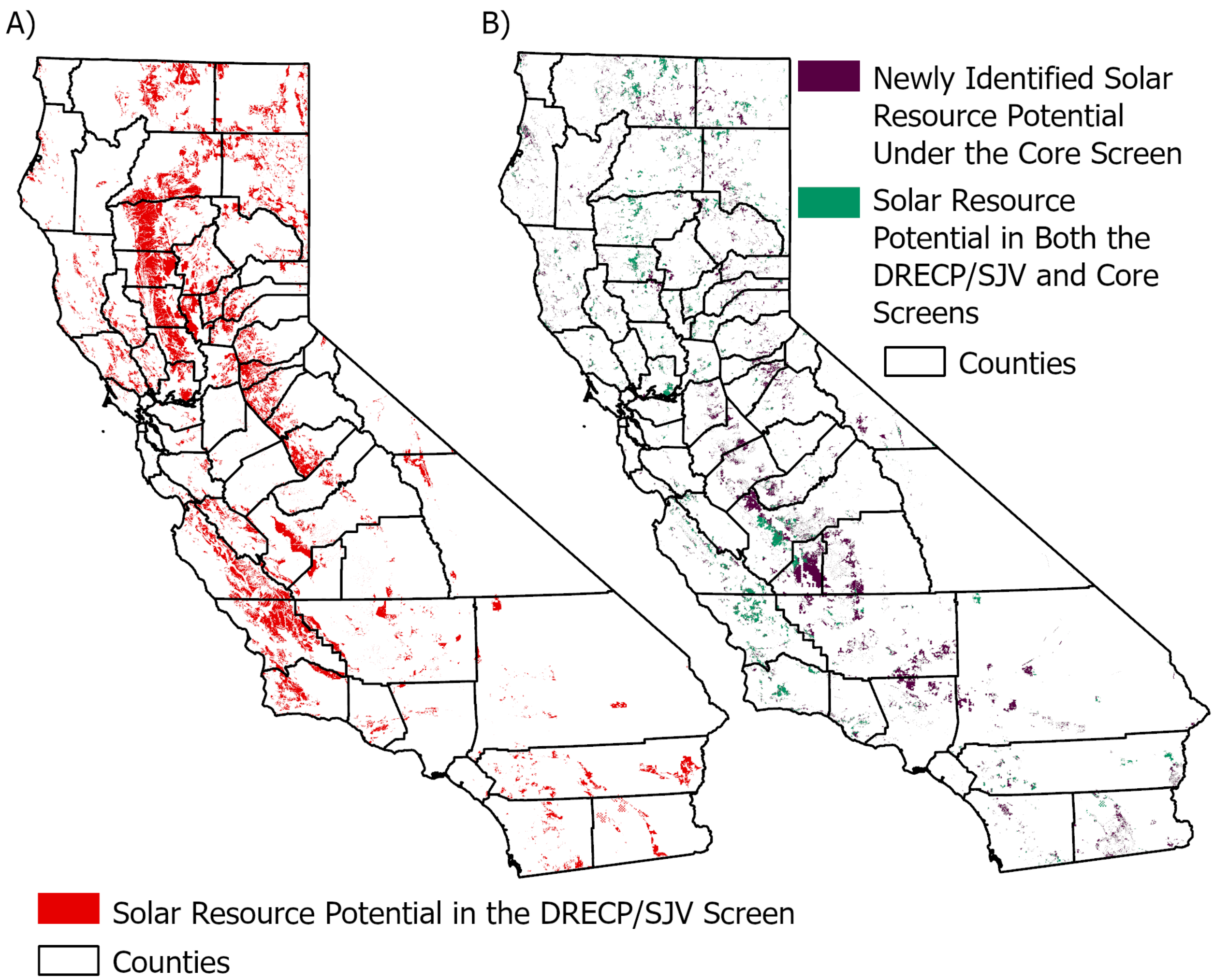


Source: CEC staff

Geothermal fields and resource areas labeled with net undeveloped resource potential in megawatts. The total net undeveloped resource potential is 3,354 MW. Note, red circular marker symbols are not drawn to scale.

Figure 11 compares lands with solar photovoltaic resource potential in the DRECP/SJV screen to lands with solar photovoltaic resource potential in the Core Land-Use Screen. 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 Joint Agency Report.

Figure 11: Comparison of Lands with Solar Photovoltaic Resource Potential in DRECP/SJV Screen and Core Land-Use Screen



Source: CEC staff

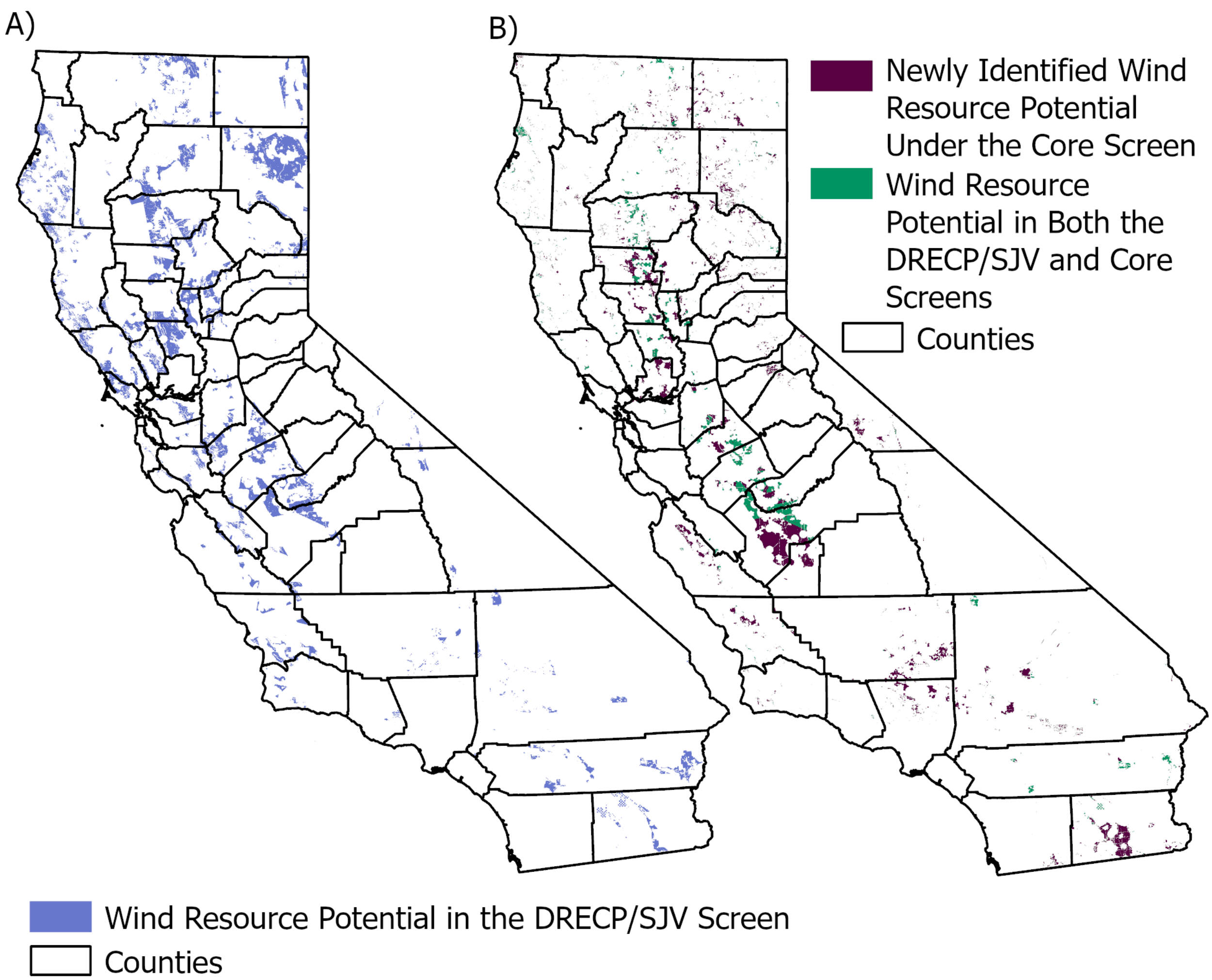
(A) Lands with solar photovoltaic resource potential in the DRECP/SJV screen are shown in red. (B) Lands with solar photovoltaic resource potential in the Core Land-Use Screen are shown in purple and green. The purple represents resource potential that was newly identified as a result of the change in screening.

Appendix C includes a comparison of land-use screen results for solar PV in Critically Overdrafted Basins, as defined by the Sustainable Groundwater Management Act.[52]

A similar comparison can be made of the resource potential for onshore wind. The DRECP/SJV screen and the Core Land-Use Screen resource potential footprints are shown below in Figure 12.

52 The Sustainable Groundwater Management Act is composed from a three-bill legislative package and subsequent statewide regulations.
Assembly Bill 1739 (Dickinson, Chapter 347, Statues of 2014).
https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB1739.
Senate Bill 1168 (Pavley, Chapter 346, Statues of 2014).
https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB1168.
Senate Bill 1319 (Pavley, Chapter 348, Statues of 2014).
https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB1319.

Figure 12: Comparison of Lands with Wind Resource Potential Under DRECP/SJV Screen and the Core Land-Use Screen



Source: CEC staff

(A) Lands with wind resource potential in the DRECP/SJV screen are shown in blue-violet. (B) Lands with wind resource potential in the Core Land-Use Screen are shown in green and purple. The purple represents resource potential that was newly made available as a result of the change in screening.

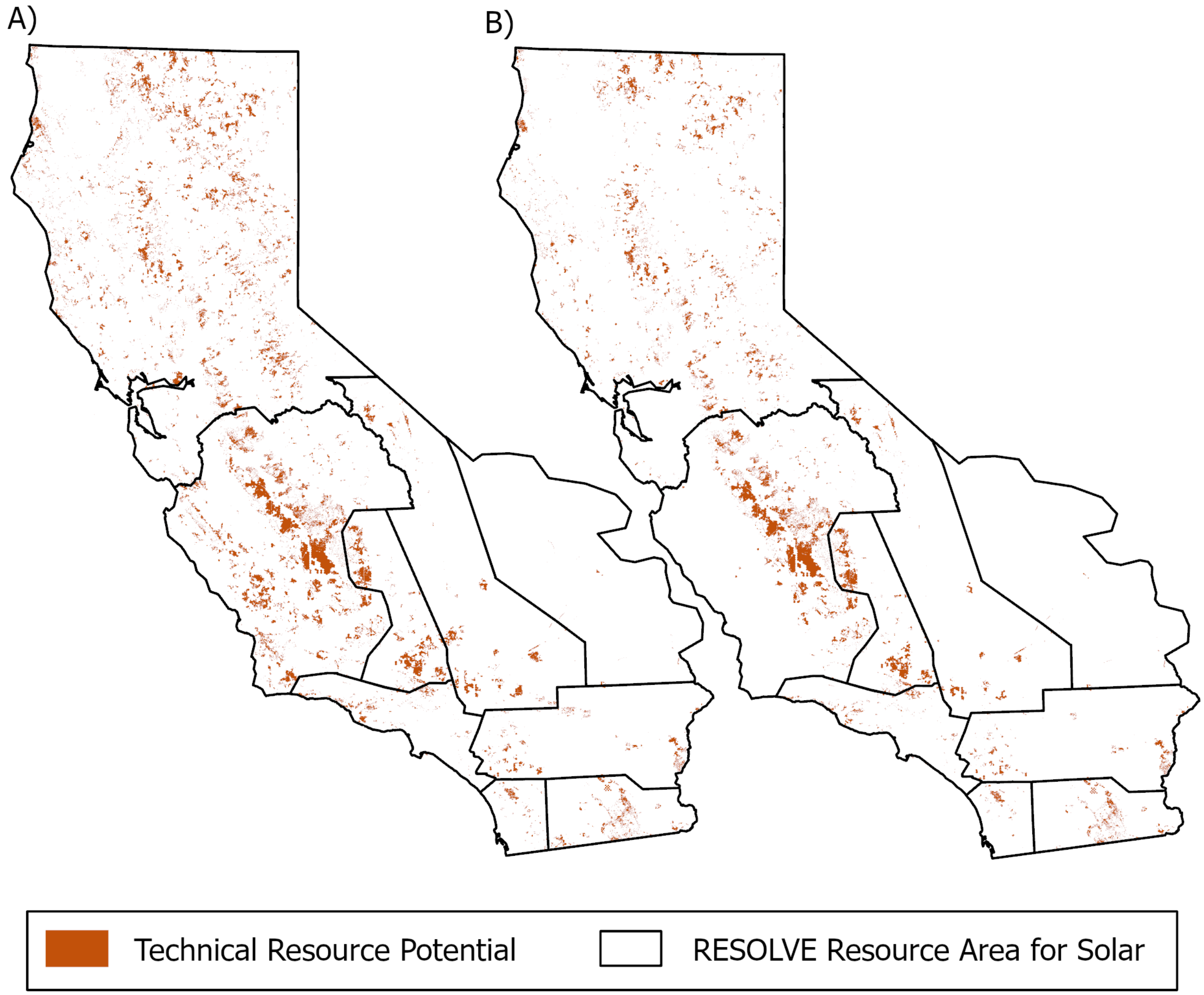
Geographic Aggregation of Resource Potential

In electric system planning, the areas with technical resource potential shown above are typically geographically aggregated into coarse regions of the state. These regions reflect attributes of the electric system (for example, transmission, substations, generation resource areas) and may differ across planning processes and power sector models. In the CPUC's IRP process, the RESOLVE model divides the state into 9 and 18 resource areas for solar and wind, respectively, with geothermal following the same resource area division as wind.[53] These regional boundaries are a geographic representation of transmission constraints.[54] The areas of identified technical resource potential for solar are shown with the boundaries of the RESOLVE resource area below in Figure 13.

53 See *Inputs & Assumptions: 2022-2023 Integrated Resource Planning*, available at https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2023-irp-cycle-events-and-materials/draft_2023_i_and_a.pdf.

54 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.

Figure 13: Solar Resource Technical Potential and RESOLVE Resource Areas

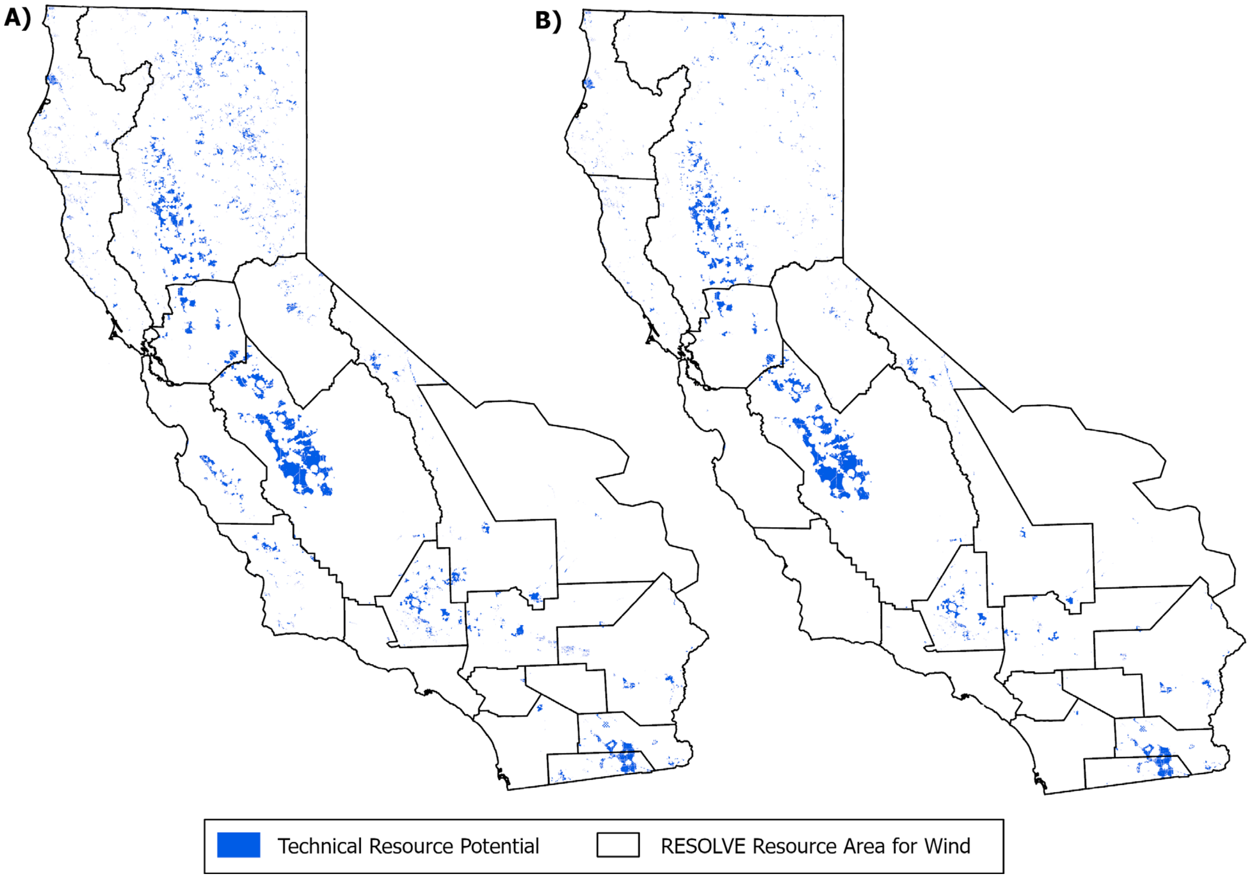


Source: CEC staff

(A) Solar resource potential under the Core Screen and (B) solar resource potential under the SB 100 Terrestrial Climate Resilience Study Screen with the boundaries of the RESOLVE resource areas for solar overlayed.

For wind, the areas of technical resource potential are shown below in Figure 14 with the RESOLVE resource area boundaries for both screen scenarios.

Figure 14: Wind Resource Technical Potential and RESOLVE Resource Area

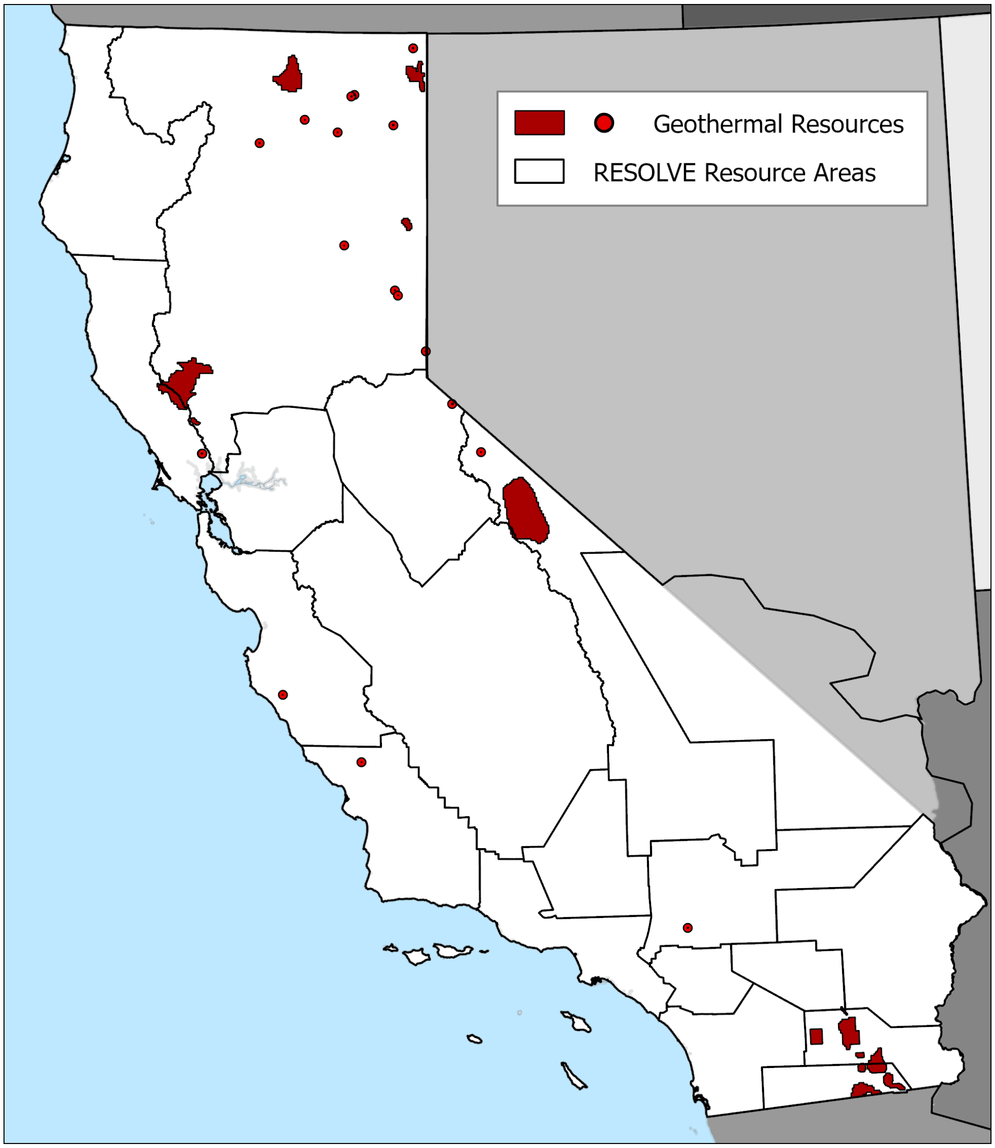


Source: CEC staff

(A) Onshore wind resource potential under the Core Screen and (B) SB 100 Terrestrial Climate Resilience Study Screen with the boundaries of the RESOLVE resource areas for wind overlayed.

The geothermal resource potential can also be aggregated by RESOLVE resource area and follows the same boundaries as the wind. Figure 15 below shows the final net undeveloped resource potential areas within each RESOLVE resource area. The centroid of each field is used to associate the resource potential with a RESOLVE area if the geothermal field stretches across two boundaries.

Figure 15: Geothermal Resource Technical Potential and RESOLVE Resource Areas



Source: CEC staff

The net undeveloped geothermal resource potential footprint with the RESOLVE Resource Areas overlayed. Note, red circular marker symbols are not drawn to scale.

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

CHAPTER 4: Applications and Path Forward

Applications in Electric System Planning

The CEC staff recommends applying the land-use screens described in this report in estimating renewable resource technical potential for onshore wind, utility-scale solar PV, and geothermal resources.

Application in SB 100: For SB 100 modeling, the CEC staff recommends using the Core Land-Use Screen to inform the renewable resource technical potential available for selecting new solar PV and onshore wind energy capacity. The CEC staff recommends using the SB 100 Terrestrial Resilience Climate Study Screen in a sensitivity case in SB 100 modeling to explore land use trade-offs. The CEC staff recommends using the geothermal land-use screening methods described in this report to inform the renewable resource technical potential available for selecting new geothermal capacity.

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 for selecting new solar PV, onshore wind, and geothermal capacity.

Application in busbar mapping: *Busbar mapping* is the refining of 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 January 2023, the CPUC released a document describing the busbar mapping method.[55] In busbar mapping, the CEC staff creates a GIS layer to identify the potential environmental and land-use implications of the RESOLVE-selected renewable resources. The categories of geospatial data (such as the protected area layer) and land-use screens (such as the Core-Land Use Screen) established in this report were developed in coordination with the CPUC and are available for use in busbar mapping. Details regarding data, methods, and implementation

55 See *Methodology for Resource-to-Busbar Mapping & Assumptions for the Annual TPP,* available at https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2022-irp-cycle-events-and-materials/2023-2024-tpp-portfolios-and-modeling-assumptions/busbarmethodologyfortppv20230109.pdf.

of the environmental and land-use evaluation for busbar mapping will be described in the CPUC's most current *Methodology for Resource-to-Busbar Mapping* document.[56]

Path Forward

It is critical that California's land-use screens for electric system planning continue to evolve and improve to keep pace with the changing dynamics of the energy sector. The CEC staff proposes to review and update the land-use screens every two years as needed. The CEC Land-Use Screens Report will be stored in the CEC's California Energy Planning Library. The California Energy Planning Library will provide a centralized location on the CEC website for the public to find analytic products and data.

Tribal Consultation and Cultural Landscapes in Statewide Energy Planning and Land-Use Screens

The CEC Tribal Consultation Policy[57] outlines the CEC's commitment to meaningful tribal engagement to foster relationship building with California Native American tribes concerning energy planning and development issues that may affect them. The CEC recognizes the critical role of California Native American tribes in achieving a clean energy future and addressing climate change.

Prior statewide land-use screening approaches focused on applying geospatial criteria related to biodiversity, habitat, and agricultural criteria in long-term electric system planning. Further, previous statewide land-use screens excluded California Native American tribes' tribal lands, including the DRECP/SJV screen described in Chapter 1.

Developments to California's energy system since the CEC and CPUC developed statewide land-use screening approaches include improved data availability, the centering of the CEC as the state's energy data repository, and the heightened importance of an equitable clean energy transition, including the CEC Resolution Committing to Support California Tribal Energy Sovereignty.[58]

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56 See Assumptions for the 2024-2025 TPP at https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-power-procurement/long-term-procurement-planning/2022-irp-cycle-events-and-materials/assumptions-for-the-2024-2025-tpp.

57 CEC. November 2021. *Tribal Consultation Policy,* https://www.energy.ca.gov/publications/2021/california-energy-commission-tribal-consultation-policy.

58 CEC. March 2023. *Resolution Committing to Support Tribal Energy Sovereignty*, https://www.energy.ca.gov/sites/default/files/2023-02/Item_09_Tribal_Energy_Sovereignty_Resolution_ada.pdf.

As such, there is an opportunity to update the land-use screening methods to include geospatial data related to cultural resources, tribal cultural resources, and cultural landscapes.

The CEC leveraged the *2022 IEPR Update* proceeding to inform including cultural landscapes in land-use screens by:

- Based on feedback from the October 10, 2022, workshop, there will no longer be an exclusion of California Native American tribes' tribal lands from the statewide land-use screens. The goal of this modification is to ensure that statewide resource and transmission planning initiatives account for renewable resource potential on tribal lands, which tribes may want to develop or may already have under development.
- Conducting an internal review of CEC cultural resource databases to determine available geospatial information related to cultural resources, tribal cultural resources, and cultural landscapes.

Moving forward, the CEC will leverage the process to develop the 2025 SB 100 Joint Agency Report to develop methods to further embed cultural landscapes in statewide land-use screens by:

- Consult with tribes to hear perspectives on issues related to energy and transmission planning, as well as the availability of geospatial data that could guide long-term planning and evaluation for SB 100.
- Host listening sessions to hear from tribes regarding their priorities and concerns related to planning to achieve SB 100 including land use. The CEC hosted scoping phase listening sessions March 7 and March 16, 2023.[59]
- Consider incorporating lessons from other outreach efforts (including past landscape-scale planning for renewable energy, such as the DRECP and *A Path Forward: Identifying Least-Conflict Solar PV Development in California's San Joaquin Valley*[60]) so as not to burden tribes and communities with repeated requests for similar feedback.

59 March 16, 2023. Tribal Listening Sessions – Scoping for the 2025 Senate Bill 100 Analysis and Report. https://www.energy.ca.gov/event/workshop/2023-03/tribal-listening-sessions-scoping-2025-senate-bill-100-analysis-and-report-0.

60 See "A Path Forward: Identifying Least-Conflict Solar PV Development in California's San Joaquin Valley," available at https://sjvp.databasin.org/datasets/b64959db3e694254818d97e51e2e6f42/.

Including consideration of cultural landscapes in statewide land-use screening could help guide electric system planners where to focus investments or highlight areas where clean energy and transmission development may encounter constraints, reinforcing the need for early, often, and meaningful outreach with tribes.

Appropriate Use

The models, geospatial datasets, and land-use screens described in this report are for use in electric system planning, including SB 100, the CPUC's IRP process, 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 resource area

LSE – load-serving entity

MW – megawatt

NRCS – Natural Resources Conservation Service

NREL – National Renewable Energy Laboratory

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

WECC – Western Electricity Coordinating Council

APPENDIX B: Glossary of Terms

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

Integrated Resource Planning — The Integrated Resource Planning (IRP) process is an "umbrella" planning proceeding to consider all of the CPUC's electric procurement policies and programs and ensure California has a safe, reliable, and cost-effective electricity supply. The proceeding is also the CPUC'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 economywide greenhouse gas emissions reductions goals.

Land-use implication — In this analysis, the term "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 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 nonprofit.

Protected area layer – A single GIS layer designed to encompass areas where utility-scale renewable energy or transmission development is precluded by state or federal law, policy, or regulation.

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 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 capacity (in megawatts [MW] or gigawatts [GW]) given technoeconomic, topographic, environmental, and land-use constraints.

Techno-economic exclusion layer — A GIS layer made up of spatial datasets that capture technical (for example, competitive wind resource locations), physical (for example, slope, water bodies), and socio-economic or hazardous criteria (for example, densely populated areas, railways, airports, highways, mines). This category also includes military lands. The datasets that were used in this exclusion category were provided by CPUC staff.

APPENDIX C: Technical GIS Methods

Appendix C provides a detailed accounting of the technical GIS methods applied by the 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, USGS, and NREL. See Appendix D for tables showing input data for the exclusion datasets, the planning considerations, and inputs to the CEC Cropland Index Model.

Raw Resource Potential Datasets

Raw solar and onshore wind resource potential and estimates of their electrical generation potential are incorporated into the land-use screens through the capacity factor based exclusion criteria of the techno-economic exclusion layer that is produced by the CPUC and their consultants, Energy + Environmental Economics (E3) and Montara Mountain Energy. For more information, please see *Inputs & Assumptions: 2022–2023 Integrated Resource Planning*.[61] Electric power generation potential for identified geothermal systems are derived following the volume method.[62] The *Assessment of Moderate- and High-Temperature Geothermal Resources of the United States*[63] provides the majority of the hydrothermal

61 See *Inputs & Assumptions: 2022-2023 Integrated Resource Planning*, available at https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2023-irp-cycle-events-and-materials/draft_2023_i_and_a.pdf.

62 Two references: (1) Brook, C.A., R.H. Mariner, D.R. Mabey, J.R. Swanson, M. Fuggganti, and L.J.P. Muffler. 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. https://pubs.usgs.gov/circ/1979/0790/report.pdf (2) Williams, C.F., M.J. Reed, and R.H. Mariner. 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. http://pubs.usgs.gov/of/2008/1296/.

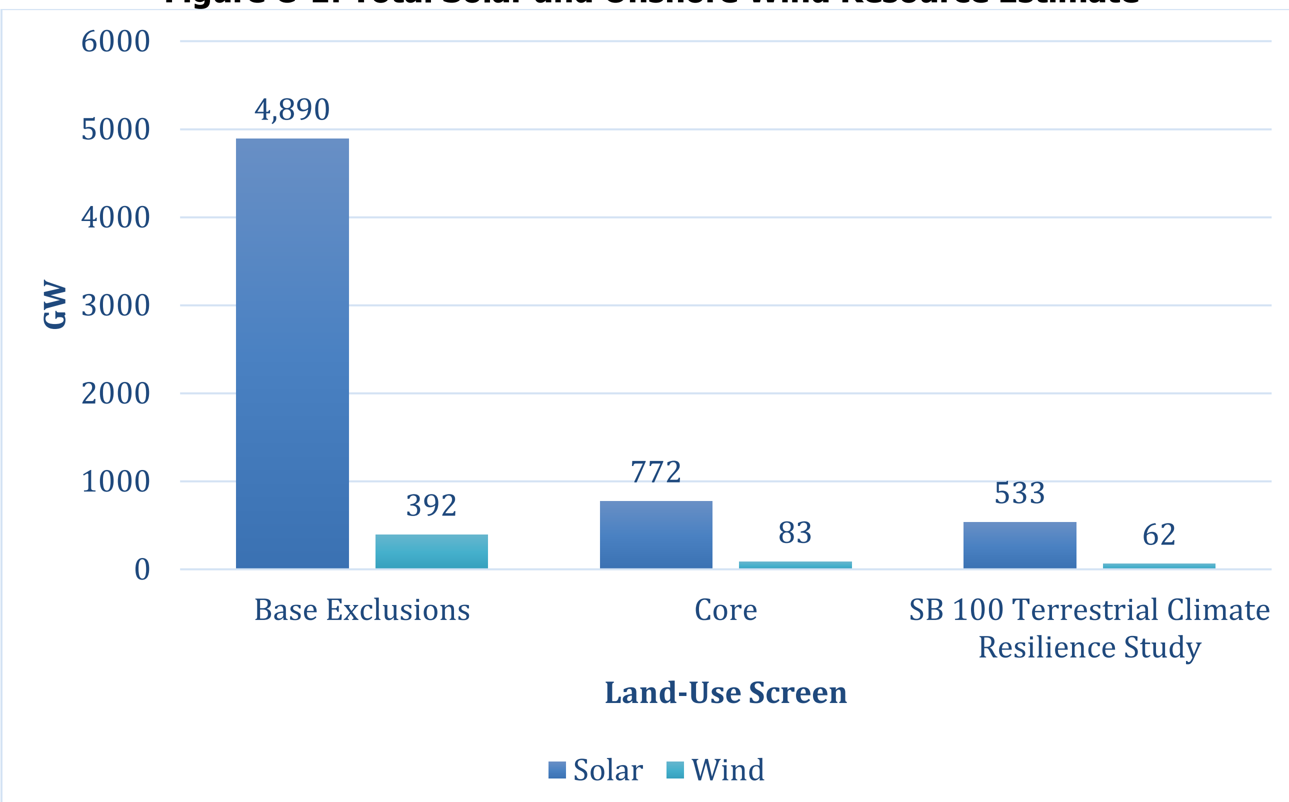
63 Williams, Colin F., Marshall J. Reed, Robert H. Mariner, Jacob DeAngelo, and S. Peter Galanis, Jr. 2008. "Assessment of Moderate- and High-Temperature Geothermal Resources of the United States." U.S. Geological Survey Fact Sheet. 2008-3082. https://pubs.usgs.gov/fs/2008/3082/.

resources used in this report. The CEC staff supplements this statewide resource potential estimate with the BLM Environmental Impact Statement (EIS) estimate for Truckhaven.[64]

Area to Capacity Conversion for Solar and Onshore Wind

An estimate of the resource potential in units of capacity (such as megawatts) can be obtained by multiplying the land area identified through the land-use screening by the capacity density for each technology. Capacity densities used in prior CEC reports are 7 acres/MW and 40 acres/MW for solar and onshore wind, respectively, yielding the resource potential in MW shown below in Figure C-1.[65]

Figure C-1: Total Solar and Onshore Wind Resource Estimate



Source: CEC staff

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

65 Bartridge, Jim, Melissa Jones, Eli Harland, Judy Grau. 2016. "[Final 2016 Environmental Performance Report of California's Electrical Generation System](https://efiling.energy.ca.gov/GetDocument.aspx?tn=214098&DocumentContentId=24638)." California Energy Commission. Publication Number: CEC-700-2016-005-SF. https://efiling.energy.ca.gov/GetDocument.aspx?tn=214098&DocumentContentId=24638

The total solar and onshore wind resource potential in GW throughout the state after the base exclusions have been applied and then after each screen was applied using capacity densities of 7 and 40 acres/MW for solar and wind, respectively.

The area estimates, converted to capacity, establishes an upper boundary of the technical resource potential available. The mapped technical resource potential footprints contain 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. These may be removed, and other conditions may be applied before incorporating the resource potential estimate as an input into a capacity expansion model. Thus, the resource potential estimates are expected to decrease from the values shown here in the next steps of electric system planning. In summary, as land-use screens are only one input into electric system modeling, the resource potential estimates described above, including the capacity density values, are illustrative and may change depending upon the other inputs and assumptions of a particular planning process.

Exclusion Datasets

The 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: techno-economic criteria,[66] legally protected areas criteria,[67] 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, including from public participants' input to the CEC draft staff report (October 2022). In this update to the land-use screens, California Native American tribes' tribal lands are not treated as exclusions. See Appendix D, Tables D-1 and D-2, for the complete list of data sources and subsets used in the construction of the protected area layer.

Techno-Economic Exclusion Layer

The techno-economic exclusions for solar and onshore wind technology types were provided by the CPUC and their consultants, E3 and Montara Mountain Energy. This dataset included six

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

67 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.

components of exclusions categories that were merged into a 250m-resolution raster[68] for CEC use in the land-use evaluation in this report. For more information, please see *Inputs & Assumptions: 2022–2023 Integrated Resource Planning*.[69]

The Protected Area Layer

The geospatial data reflecting protected areas, compiled by the CEC staff and referred to in this report as the protected area layer, were heavily based on RETI 1.0 blackout areas[70] and pertain to natural and wilderness areas where development of utility-scale renewable energy is prohibited. The PAD-US (CBI Edition)[71] was the main source used to identify these lands. A manual approach was used to identify which fields and values in the database were appropriate for 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 preclude 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 was created to extract the appropriate designations known to preclude 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 the land of a certain type, and the primary local designation (p_loc_ds) field was used instead. The precise selection query used on the PAD-US (CBI Edition) is given in Table D-2 of Appendix D.

The CA Nature 30x30 Conserved Areas, Terrestrial dataset[72] 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 by the data curators, and this dataset has been more recently updated than the PAD-US (CBI Edition)

68 A type of spatial data organization consisting of a matrix of grid cells that store a value. For more information, see *Introduction to image and raster data*, available at https://pro.arcgis.com/en/pro-app/latest/help/data/imagery/introduction-to-raster-data.htm

69 See *Inputs & Assumptions: 2022-2023 Integrated Resource Planning (IRP)*, available at https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2023-irp-cycle-events-and-materials/draft_2023_i_and_a.pdf.

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

71 2016. "PAD-US (CBI Edition) Version 2.1b, California." Conservation Biology Institute. https://databasin.org/datasets/64538491f43e42ba83e26b849f2cad28.

72 2022. "30x30 Conserved Areas, Terrestrial." CA Nature working group. https://www.californianature.ca.gov/datasets/CAnature::30x30-conserved-areas-terrestrial/about.

data source. 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 the CEC staff found that many city and county lands that hold such a preservation status had been missed from the manual approach described above. To address this omission, the CEC staff supplemented local lands that preclude energy development with the California Protected Areas Database (CPAD). Using a similar approach as the PAD-US (CBI Edition) analysis to identify tags in the attribute table that isolate lands under county and city jurisdiction, areas designated as open spaces and parks were accounted for, especially in the Owens Valley, where the Los Angeles Department of Water and Power manages large swaths of land. The precise SQL query used for subsetting this dataset, as well as the list of all datasets and queries used in the protected area layer, is given in Tables D-1 and D-2 of Appendix D.

The final major component of natural lands and wilderness areas that are protected under a conservation designation comes from the BLM. The National Conservation Lands (part of the National Landscape Conservation System)[73] brings in wilderness areas, wilderness study areas, national monuments, national conservation areas, and Conservation Lands of the California Desert, among other similar designations as exclusion areas. Other BLM lands that restrict renewable energy development include Areas of Critical Environmental Concern (ACECs), Recreation Management Areas (Special Recreation Management Areas (SRMA), Extensive Recreation Management Areas (ERMA), Off-Highway Vehicle [OHV] areas), and very recent designations that were not part of the standard data sources described above.[74] Greater Sage-Grouse Habitat Management Areas[75] also preclude solar and wind renewable energy development under unique allocation decisions. A complete list of the BLM data sources used in the protected area layer and the query definition used to partition this dataset is listed in Tables D-1 and D-2.

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

74 Recent designations such as Vinagre Wash Special Management Area and Alabama Hills National Conservation Areas were included separately from the standard datasets publicly available online. The shapes of these areas were obtained from personal communication with BLM. In addition, ACECs that are under Arizona State BLM jurisdiction but that lie within California have been included in the Protected Areas Layer.

75 *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

A few miscellaneous conservation categories were also included based on prior sources and methods as well as specific input based on public comment from the draft staff report (October 2022). Within USFS lands, Inventoried Roadless Areas,[76] the Mono Basin National Forest Scenic Area, and components of the Special Interest Management Areas were captured as exclusions. The California Conservation Easements Database[77] was brought in independently as some of these datasets fell under management decisions that were made after the last update of the PAD-US. In response to public comment, a single proposed conservation area — the Molok Yuluk expansion to the Berryessa Snow Mountain National Monument – was also included in the protected area layer. Figure C-2 highlights the additional protected areas that were identified and used in this latest update to the protected area layer.

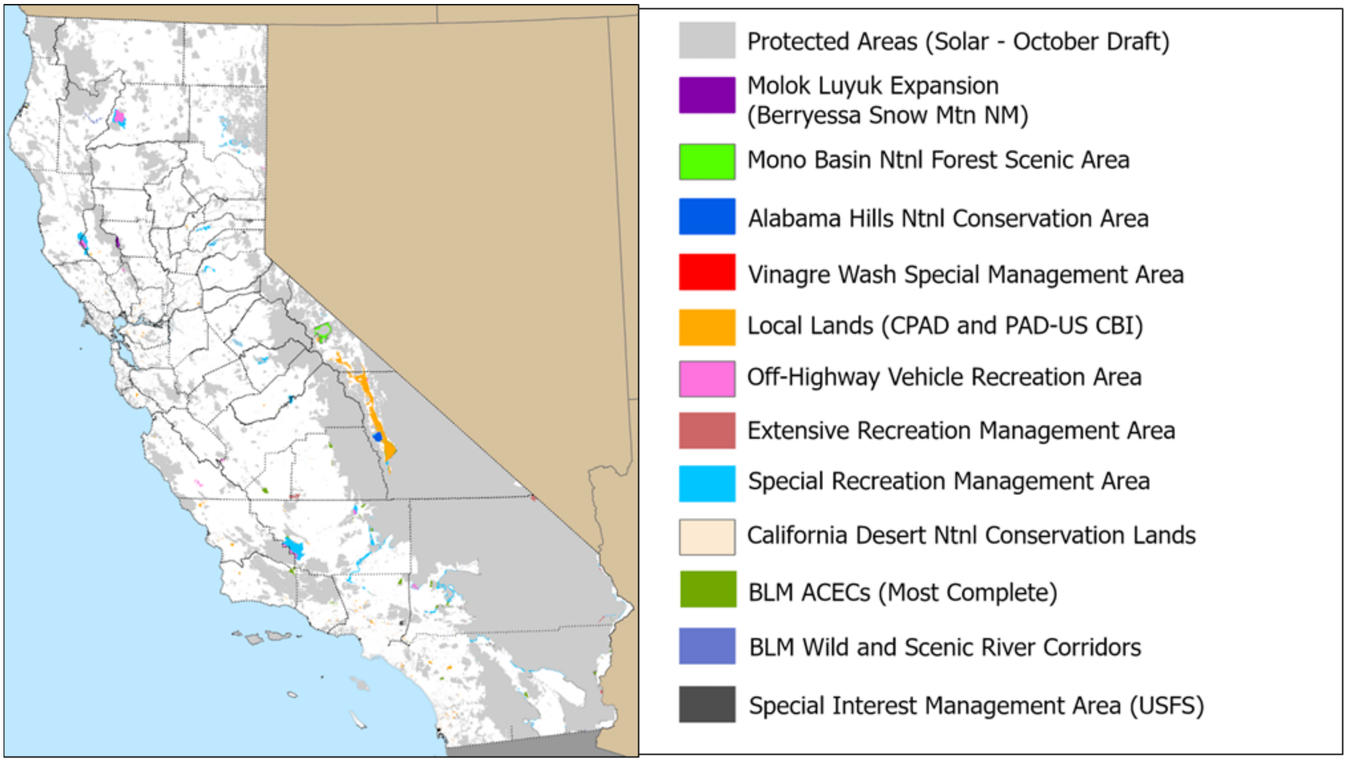
Once all protected area components were acquired, they were merged into an exclusion layer for utility-scale solar PV, onshore wind, and geothermal resource types. The Greater Sage-Grouse Habitat Management Area is the only dataset that distinguishes between resource type in this layer, creating a 1-million- to 2-million-acre change in total footprint area between technologies. The Union Tool[78] 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. Figure C-3 (A), (B) and (C) depict the protected area layer for each technology type. The difference in footprints in the northeast portion of the state is due to Greater Sage-Grouse Habitat Management areas.

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

77 2022."California Conservation Easement Database." Protected Areas Data Portal. https://www.calands.org/cced/.

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

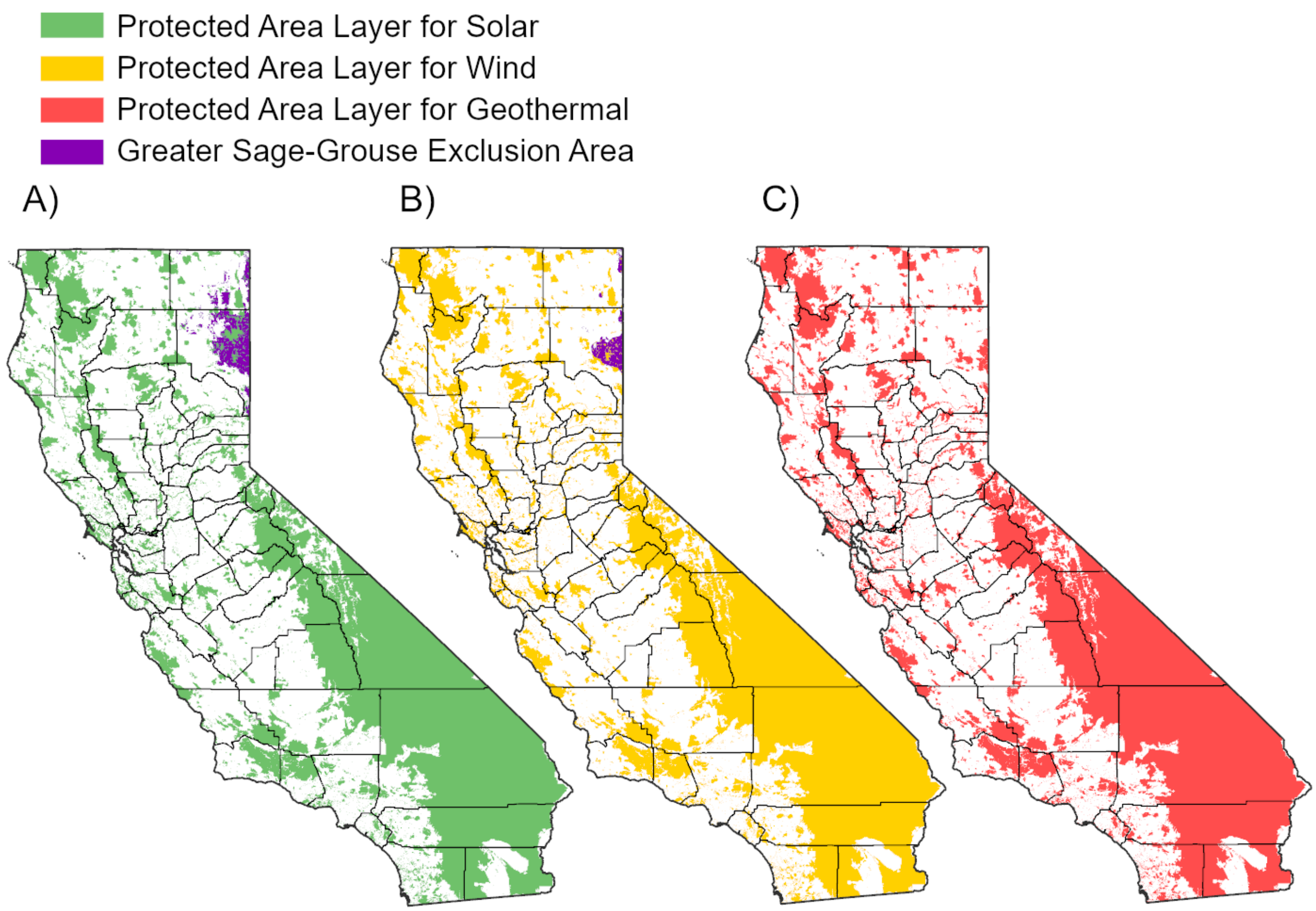
Figure C-2: Protected Area Layer (Solar)



Source: CEC staff

The protected area layer for solar with new additions since the last CEC Land-Use Screens draft report was released in October 2022, highlighted in various colors.

Figure C-3: Protected Area Layers for Each Technology Type



Source: CEC staff

(A) The footprint of the protected area layer for solar PV with the Greater Sage-Grouse Habitat Management areas of exclusion for this technology highlighted. (B) The footprint of the protected area layer for wind with the Greater Sage Grouse Habitat Management exclusion areas highlighted. (C) The protected area layer for geothermal technology. There are no habitat management areas for the Greater Sage-Grouse that precludes geothermal energy development.

Comparison of Protected Area Layer to Previous Studies

The protected area layer, developed with updated data and methodology as described above, is compared to past studies that use a similar categorization of environmental exclusions for energy resource and transmission planning. The WECC Environmental Data Task Force, The

Nature Conservancy's (TNC) Power of Place – California Study,[79] and the RETI process created several composite geospatial layers that represent increasing levels of protection for lands with high conservation value. Table C-1 below shares the levels that most closely resemble the CEC protected area layer and how their footprints compare to the CEC results. RETI Category 1 land areas have legal restrictions against energy development, while RETI Category 2 land areas include areas that have a high level of protection in place, but not a legal or clear regulatory exclusion. TNC's Environmental Exclusions Categories 1 and 2 follow a similar break-down. The TNC footprints tend to be larger than RETI for both categories of exclusions, leaving a smaller area of the state with renewable resource potential. WECC Risk Class 4 includes both legal and administratively protected lands, though these land areas were designated based on preclusions to transmission development, not energy development in general. Its footprint is smaller, yielding 84 million acres remaining for resource potential, as listed in Table C-1.

The CEC protected area layer leaves about 56 million acres of the state with renewable resource potential, which falls between the Category 1 and combined Category 1 and 2 areas of both RETI and TNC. The challenge in directly comparing these studies is how each category defines the land designations that are part of each exclusion category. Although RETI and TNC Category 1 exclusions are defined similarly to the CEC protected area layer (lands with legal or administrative prohibitions against renewable energy development), the CEC protected area layer covers between 5 and 13 million more acres than the past studies. This is likely due to the current method's inclusion of local lands and recent protections or easements that have been put in place since the data gathering efforts took place for the RETI and TNC studies. In addition, RETI's focus on transmission and linear infrastructure restrictions removed certain categories of land (like ACECs) from its Category 1 umbrella. At the same time, the CEC protected area layer is not as extensive as the RETI and TNC Categories 1 and 2 because Category 2's definition expands beyond the clear energy prohibition definition. Category 2 lands include areas like critical habitat and wetlands – areas that do not preclude energy development outright but may trigger additional siting and administrative review. Table C-1 shows the total acres of the state remaining under each category of environmental exclusions from past studies and the area of the state remaining after applying the CEC protected area layer. A comparison of the areas remaining demonstrates that the current CEC protected area

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79 Wu, Grace C., E Leslie, D Allen, O Sawyerr, D Cameron, E Brand, B Cohen, M Ochoa, and A Olson. 2019. "A Power of Place: Land Conservation and Clean Energy Pathways for California." https://www.scienceforconservation.org/assets/downloads/Technical_Report_Power_of_Place.pdf

Environmental exclusion spatial data is available at: https://tnc.maps.arcgis.com/apps/webappviewer/index.html?id=71b0605e44bf475ea55f6d369e668b2c or https://tnc.app.box.com/s/yxyiu8fp6bsqckvmkayqxz5ib1xik7mh layer produces a total footprint area for solar resource potential within the range of the other efforts.

Table C-1: Comparison of the Protected Area Layer for Solar Across Agency and External Analyses

	Protected Area Layer Land-Use Screens Report (2023)	RETI Category 1 ("Blackout" Areas)	RETI Categories 1 and 2 ("Blackout" and "Yellow" Areas)	The Nature Conservancy (TNC) Environmental Exclusions Categories 1	TNC Environmental Exclusions Categories 1 and 2	WECC Risk Categories 4
Area Remaining in CA (Million Acres)	55.8	68.3	50.0	60.9	48.0	84.2

Source: CEC staff

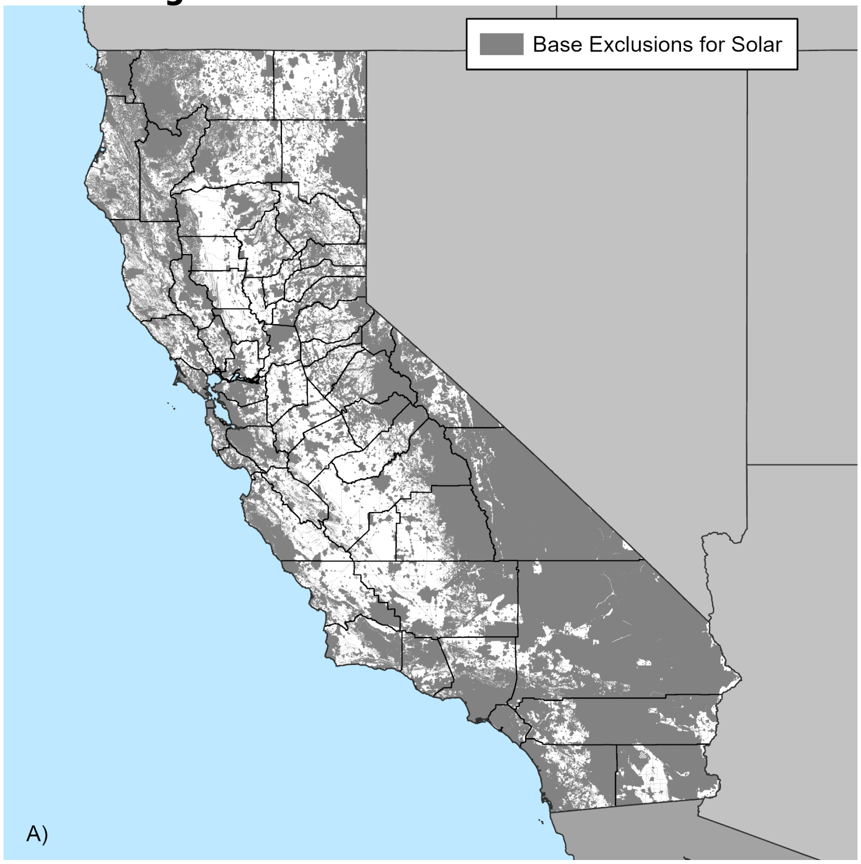
The statewide area remaining after applying the protected area layer is shown in millions of acres.

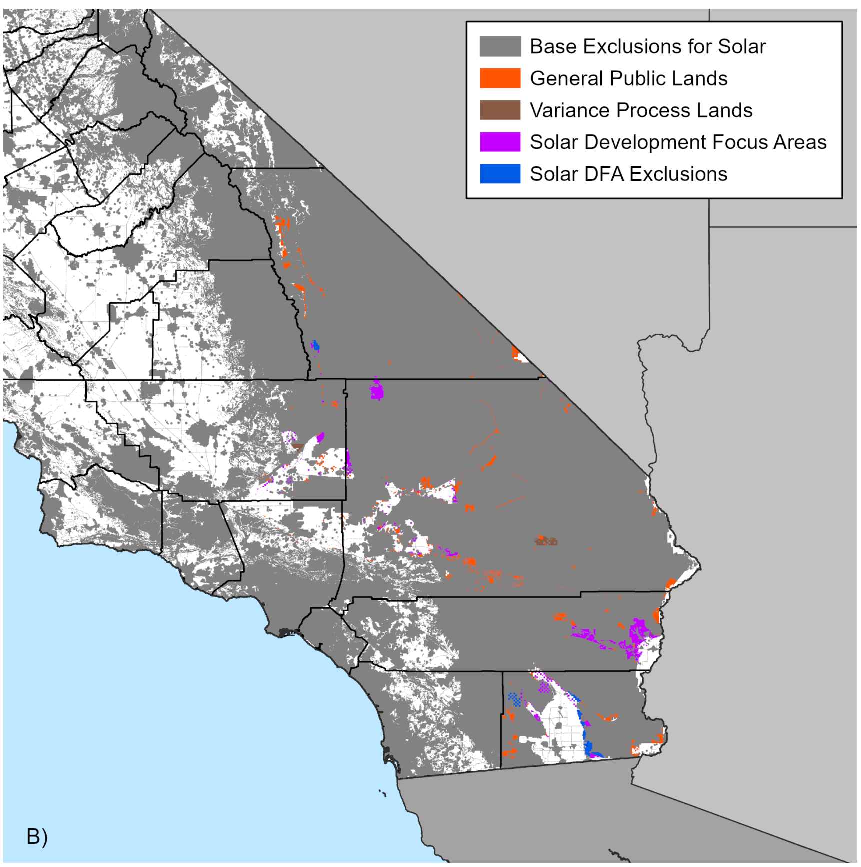
Resource Potential Basemaps

The protected area layer and the techno-economic exclusion layer make up the main components of the base exclusions. The base exclusion footprint is also modified by the BLM DRECP Land Use Plan Amendment (LUPA) development focus areas, and the variance process lands (VPLs) and general public lands (GPLs) within the DRECP. The DFAs are partitioned by technology type according to the precise query definition listed in Table D-5. DFAs (the subset that is allowed for each technology type), VPLs and GPLs were removed from the merged footprint of the protected area layer or techno-economic exclusion layer in the creation of the base exclusions for each technology type. Any DFA that only allows for geothermal technology was used as an additional exclusion and removed from the base exclusions for solar and wind.

These results, the compilation of all two categories of base exclusions and the partition of the BLM lands in the DRECP, are shown below in Figure C-4 for solar and Figure C-5 for wind, with a detailed image of the DRECP area depicting BLM designated areas for resource potential and differences arising from the DFAs for each technology type. The area remaining outside of the base exclusions are used in all subsequent analyses for technical resource potential estimates by applying the land-use screens. For geothermal, the only exclusion layer applied is the protected area layer due to this resource type's small land use intensity and flexibility with surface placement of well heads. This result and a full explanation of the geothermal resource potential estimation is given at the end of this appendix.

Figure C-4: Base Exclusions for Solar

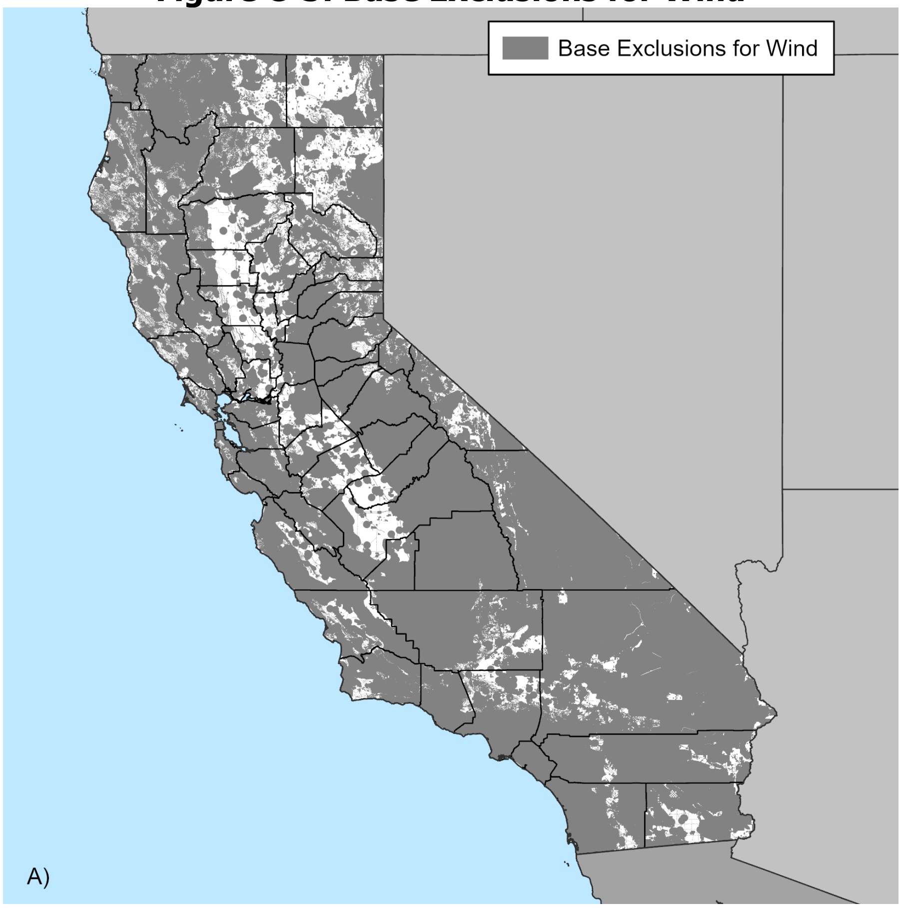


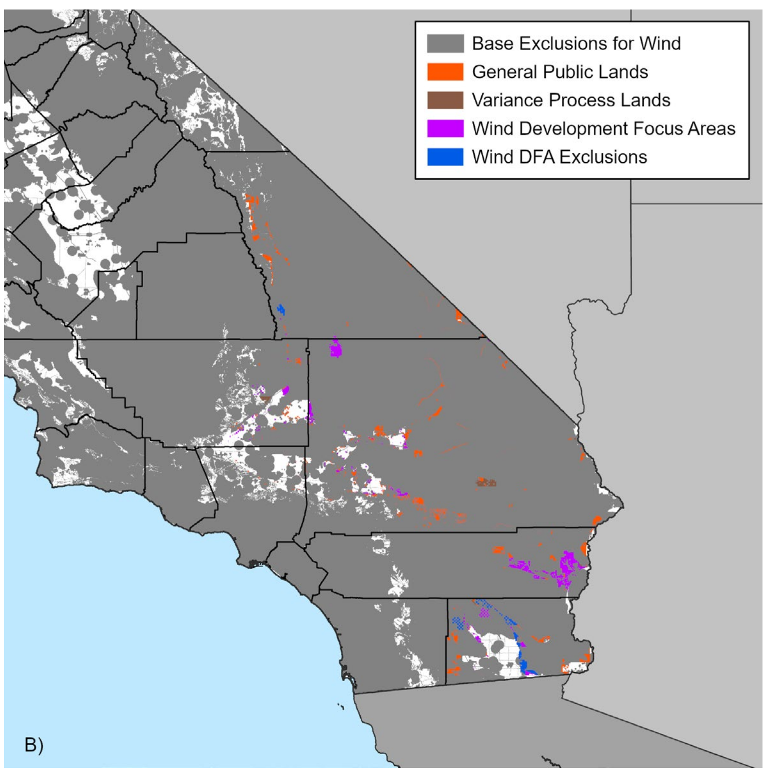


(A) The merged footprint of the base exclusions for solar. (B) The base exclusions for solar with

the modifications by BLM DFAs, VPLs and GPLs in the DRECP highlighted. The DFAs that are classified as 'All Technologies' or 'Solar and Geothermal' are explicitly shown. DFAs that are classified for geothermal technology are excluded as part of the base exclusions.

Figure C-5: Base Exclusions for Wind





Source: CEC staff

(A) The merged footprint of the base exclusions for wind. (B) The base exclusions for wind with the modifications by the BLM DFAs, VPLs and GPLs in the DRECP highlighted. The DFAs that are classified as 'All Technologies' are explicitly shown. DFAs that are classified for geothermal technology are excluded as part of the base exclusions.

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, terrestrial landscape intactness, and terrestrial climate change resilience, the CEC staff developed categories of exclusions based on various methods of combining geospatial data.

For cropland areas of the state, the CEC staff developed a spatial model using the ArcGIS Pro Suitability Modeler. This suitability modeling toolset 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 datasets.

The biodiversity component of the screening data combines multiple data sources into a single layer, collectively termed biological planning priorities. If any region of the state fell into one of the input data categories, the entire region was excluded from resource potential consideration. In the terrestrial landscape intactness planning consideration, staff used a single dataset that was the result of a suitability model produced by CBI. The terrestrial climate change resilience category used a single dataset as well, but it was the result of processing eight climate models at two different future time periods.

The CEC staff consulted source data owners, associated subject matter experts, and partnering agencies to develop a list of authoritative source datasets, determine best practices for working with those datasets, develop a modeling methodology, and determine value ranges from each dataset that represent the impact of each category of planning consideration. Redundant source datasets were removed, best practices were noted, source data was acquired, and in the case of the CEC Cropland Index Model, transformed to be used in the suitability model methodology. Source datasets for each planning consideration category are described below. Please see Tables D 3 – 5 of Appendix D for a list of each dataset used in the planning categories.

Biological Planning Priorities

The datasets selected for this component of the land-use screens rely 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 of relative biodiversity levels for birds, amphibians, plants, mammals and reptiles across each USDA ecoregion. Biodiversity measures the native species richness (diversity of all currently tracked species in the state), rare species richness (diversity of special status 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 animal movement and general ecological flow. It includes information on corridors that allow for species migration, including narrow channels through highly disturbed areas which are critical for retaining the last threads of connectivity in these areas, as well as high usage areas between large, contiguous and natural landscapes which are described as intact. The ACE Ranks are used to indicate level of connectivity conservation urgency, with essential corridors and linkages emphasized with highest level scores of 4 or 5. Areas that have high connectivity, but have not been identified as having channelized areas for species corridors or habitat linkages, are given a rank 3. Large, intact regions which also contribute to connectivity but possess greater redundancy on account of their size, are given a lower rank of 2. Areas that show no opportunity for connectivity are given the lowest rank of 1.
- ACE Terrestrial Irreplaceability is one of the measurements that the Terrestrial Biodiversity dataset is based on and describes the relative importance of an area based on the number of California endemic, special-status species found there, and the breadth of their distribution, so that species which are more geographically constrained produce a higher score. This geographic weighting system makes a site more ‘irreplaceable’ because it supports species which are found in fewer locations. Rare endemic species are identified by the California Species of Special Concern reports, the California Rare Plant Rank 1B plants, State or Federally-listed species (threatened, endangered, or candidate species), and fully-protected species.

Each of these datasets span the entire state using 2.5 square mile hexagon cells. Each cell is ranked on a scale of 1 through 5, with higher values indicating greater conservation value for maintaining biodiversity. The subsets of these data layers that refine the technical resource potential estimate further are:

Table C-2: Partitioning ACE Data to Low and High Implication Areas

ACE Component	Subset used in Screen (Rank)
Terrestrial Biodiversity	5
Terrestrial Connectivity	4 and 5
Terrestrial Irreplaceability	4 and 5

Source: CEC staff

The table shows how the ACE data is partitioned into low and high implication categories based on their ranks. The areas of high rank or high implication for biodiversity conservation are screened out from statewide resource potential estimates.

Partitioning these datasets to the higher-ranking subsets that are used in the screen ensures that areas of technical resource potential identified through screening avoid lands with higher conservation value for biodiversity.

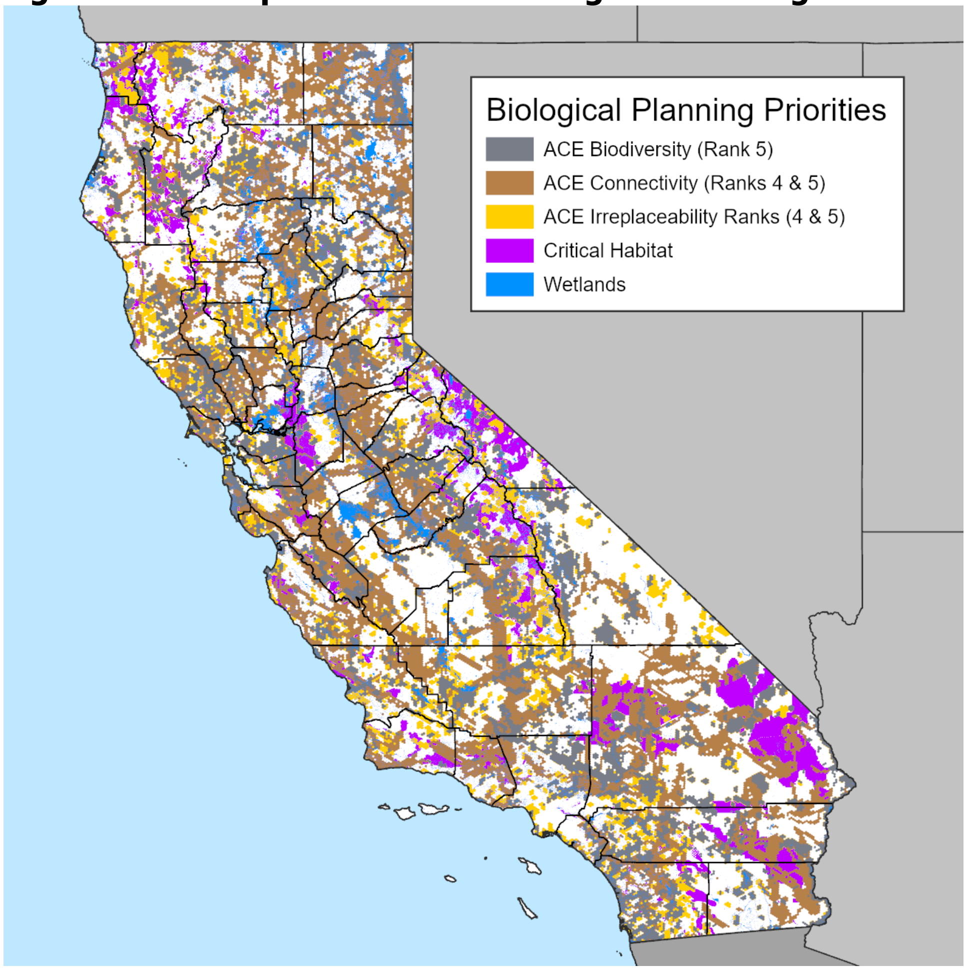
The final two components of the biological planning priorities include critical habitat and wetlands.

- The critical habitat layer from USFWS, as well as the proposed Bi-State Sage-Grouse critical habitat, are added to ensure that areas with endangered or threatened species would be removed from consideration in estimates of statewide resource potential.
- Wetlands in California are protected by several federal and state laws, regulations, and policies.[80] This category was extracted from the broader vegetation data layer from the CA Nature project and recently enhanced to include a more comprehensive definition of wetlands. It is part of a ~25-meter resolution raster dataset and is converted to polygon (with no simplification).

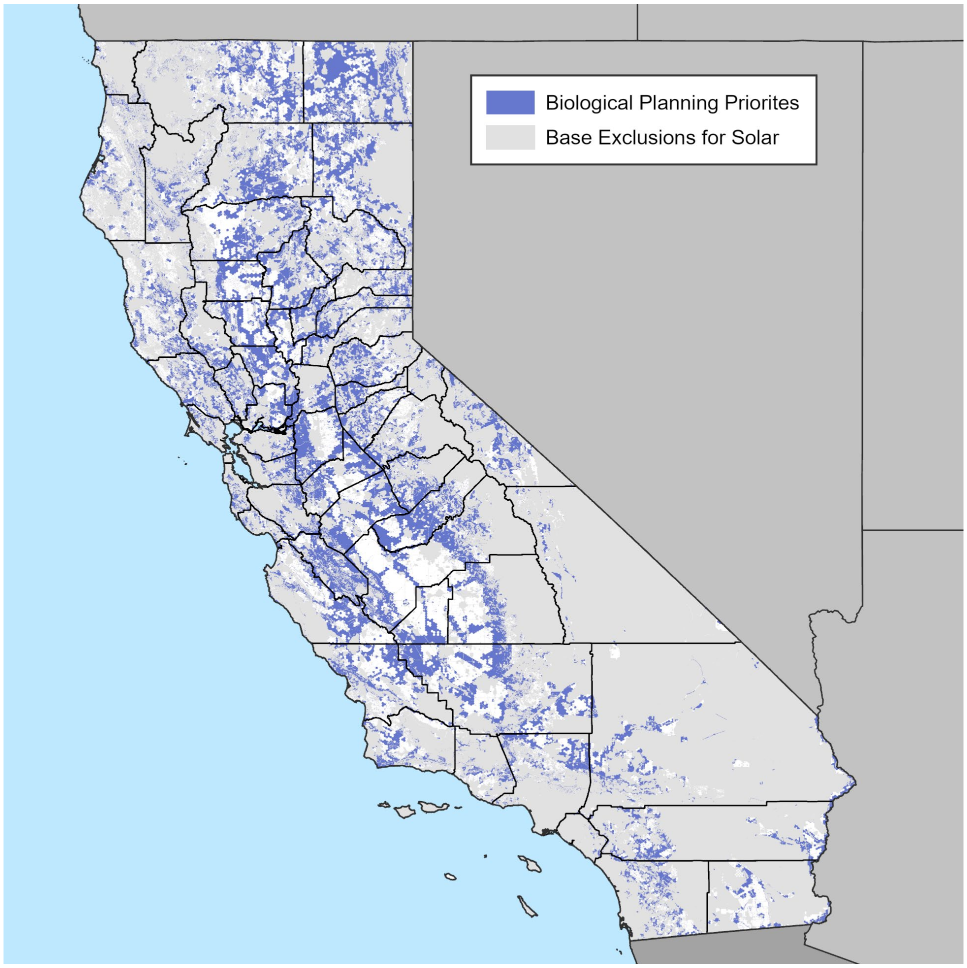
The individual components of the biological planning priorities are shown below in Figure C-6 (A). There is overlap among many of these layers, but the layering order in Figure C-6 (A) was chosen to account for maximum visibility of each layer. The combined footprint of these individual data layers forms the biological planning priorities that are used in both the Core and SB 100 Terrestrial Climate Resilience Screens. The merged and dissolved footprint of the high-ranking ACE Biodiversity, Irreplaceability, and Connectivity layers, critical habitat, and wetlands polygons is shown in Figure C-6 (B) with the base exclusions for solar overlayed in grey. Application of the biological planning priorities alone reduces the resource potential basemap for solar and wind 62% and 61%, respectively.

80 California Water Monitoring Council. 2019. *What laws, regulations, and policies protect the wetlands?* https://mywaterquality.ca.gov/eco_health/wetlands/improvements/regulations.html

Figure C-6: Components of the Biological Planning Priorities



(A)



(B)

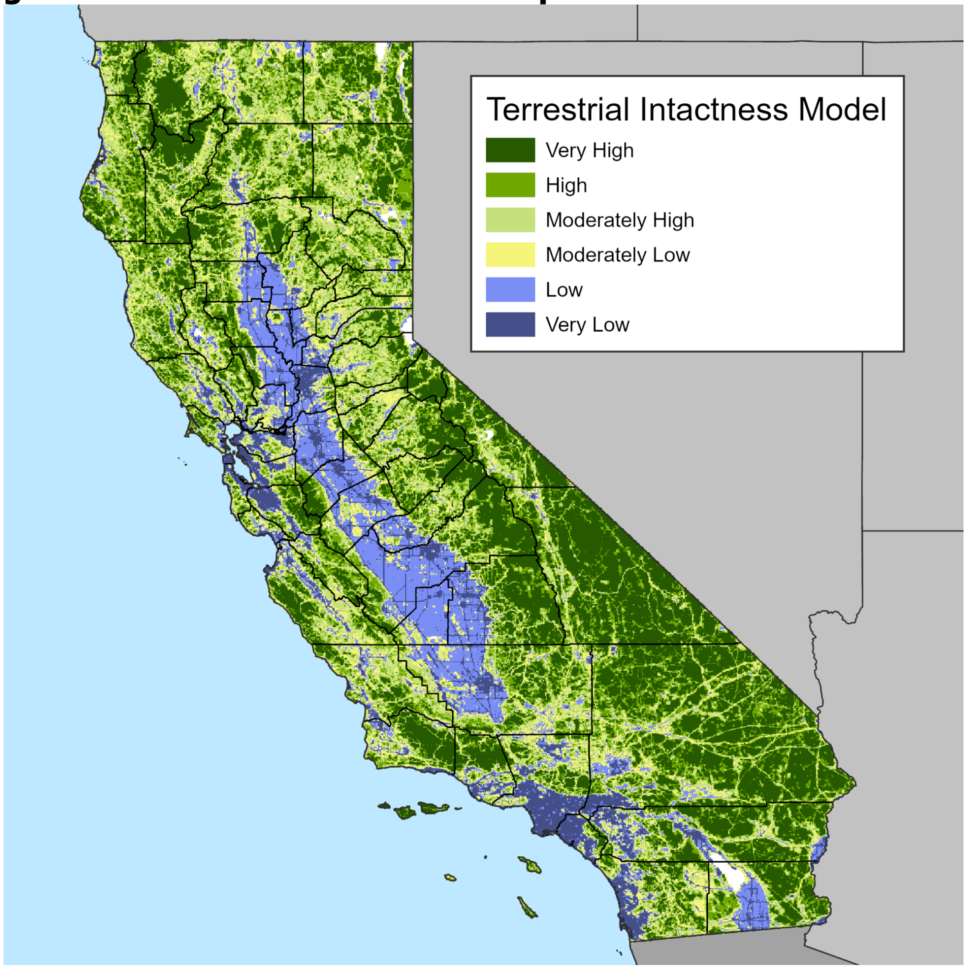
Source: CEC staff

(A) The individual components of the biological planning priorities. (B) The combined footprint of the biological planning priorities with the base exclusions for solar overlayed in grey. The biological planning priorities are used in both screen scenarios.

Landscape Intactness

This category of planning priorities provides an estimate of terrestrial 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 the State of California. It is based on a suitability or multi-criteria analysis model constructed by CBI. Terrestrial intactness values are higher in areas where these impacts are lower. The full model results are shown below in Figure C-7, where values range from one, indicating low levels of disturbance to negative one, indicating high levels of human disturbance.

Figure C-7: CBI Terrestrial Landscape Intactness Model Results

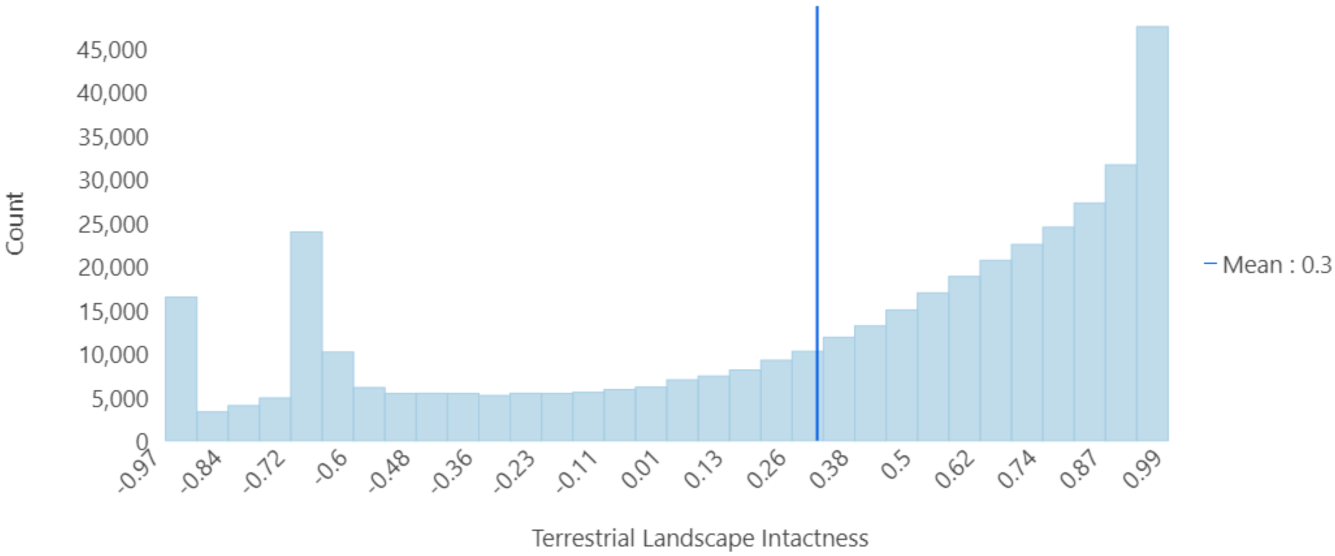


Source: Conservation Biology Institute

The suitability model results of landscape intactness where values range from highly intact (green) to highly disturbed (purple).

For the land-use evaluation described in this report, the terrestrial landscape intactness data layer is partitioned into high and low categories based on the mean. Values of the dataset that lie above 0.3 are considered highly intact and are used as an exclusion. Values of the dataset that are less than or equal to 0.3 are allowed to remain in consideration for resource potential. Figure C-8 below shows the histogram of the terrestrial landscape intactness dataset. Applying the partition at the mean allows for lands that are relatively more intact than disturbed to be considered for resource potential in this component of the screens. This is because there are large counts of cells that have a very high level of intactness that push the mean value to the positive range of the scale, with a value of 0.3.

Figure C-8: Distribution of Landscape Intactness Input Dataset

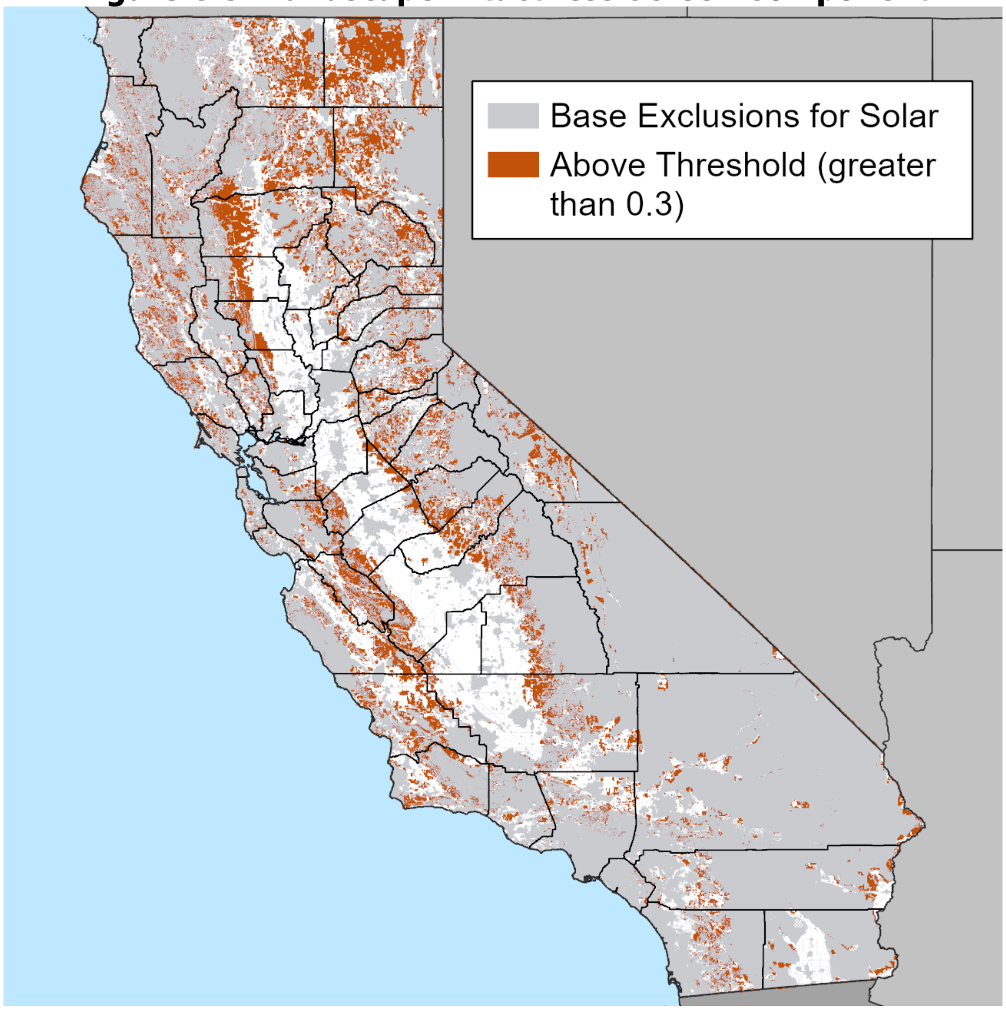


Source: CEC staff

The distribution of terrestrial landscape intactness. Higher values depict lands that have lower levels of human disturbance. The mean value is used to partition the dataset into high and low categories.

The high category of the partitioned landscape intactness dataset is used as an additional component of the screens. The areas of exclusion based on high landscape intactness are shown below in Figure C-9, with the base exclusions for solar overlayed in grey. This planning consideration, if applied alone to the areas outside of the base exclusions (the resource potential basemap), would reduce the resource potential area by 45 percent and 50 percent for solar and wind, respectively. With the application of the base exclusions, the biological planning priorities, and the high landscape intactness, the technical resource potential is reduced by a total of 76 percent and 79 percent for solar and wind, respectively.

Figure C-9: Landscape Intactness Screen Component



Source: CEC staff

The high category of landscape intactness used in both screens is overlayed by the base exclusions for solar.

CEC Cropland Index Model

The CEC Cropland Index Model 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).

The 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. This land must have been used for irrigated agricultural production at some time during the four years prior to the mapping date.

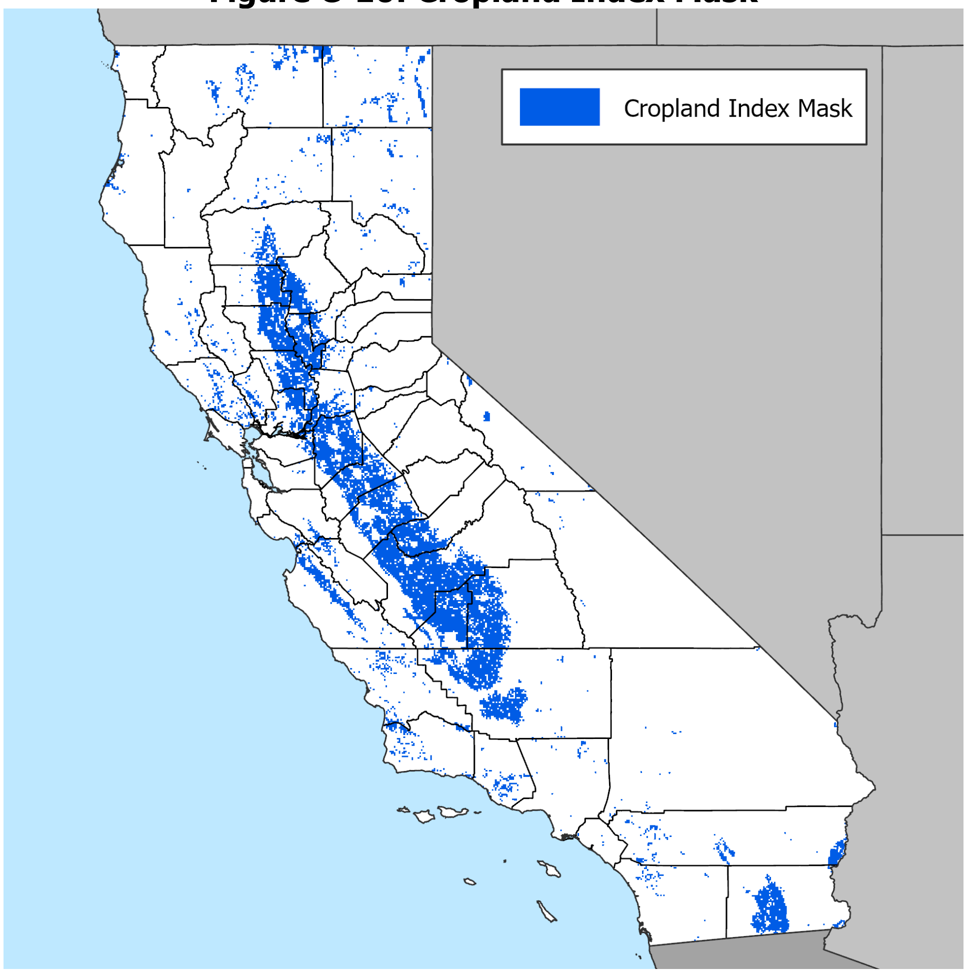
  - Farmland of Statewide Importance – farmland similar to Prime Farmland but with minor shortcomings, such as greater slopes or less ability to store soil moisture. This land must have been used for irrigated agricultural production at some time during the four years prior to the mapping date.
  - Unique 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. This 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 of the United States and the Territories, Commonwealths, and Island Nations served by the USDA-NRCS. This 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 Celsius (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.

- The footprint of the data was used as an input to define the Cropland Index Mask.

- Cropland Index Mask – This is a constructed dataset used to define the model domain. Its footprint is defined by combining the area 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-10.

Figure C-10: 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 a null value are removed, resulting in the cropland mask shown here.

The CEC Cropland Index Model Methods and Evaluation section describes how the input data was incorporated into the suitability model. The model results are described, including their categorization into higher and lower classes in preparation for construction of the land-use screens.

Terrestrial Climate Resilience

The ACE Terrestrial Climate Resilience dataset is based upon the work by Thorne et al.[81] 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 as future conditions under eight climate model projections.

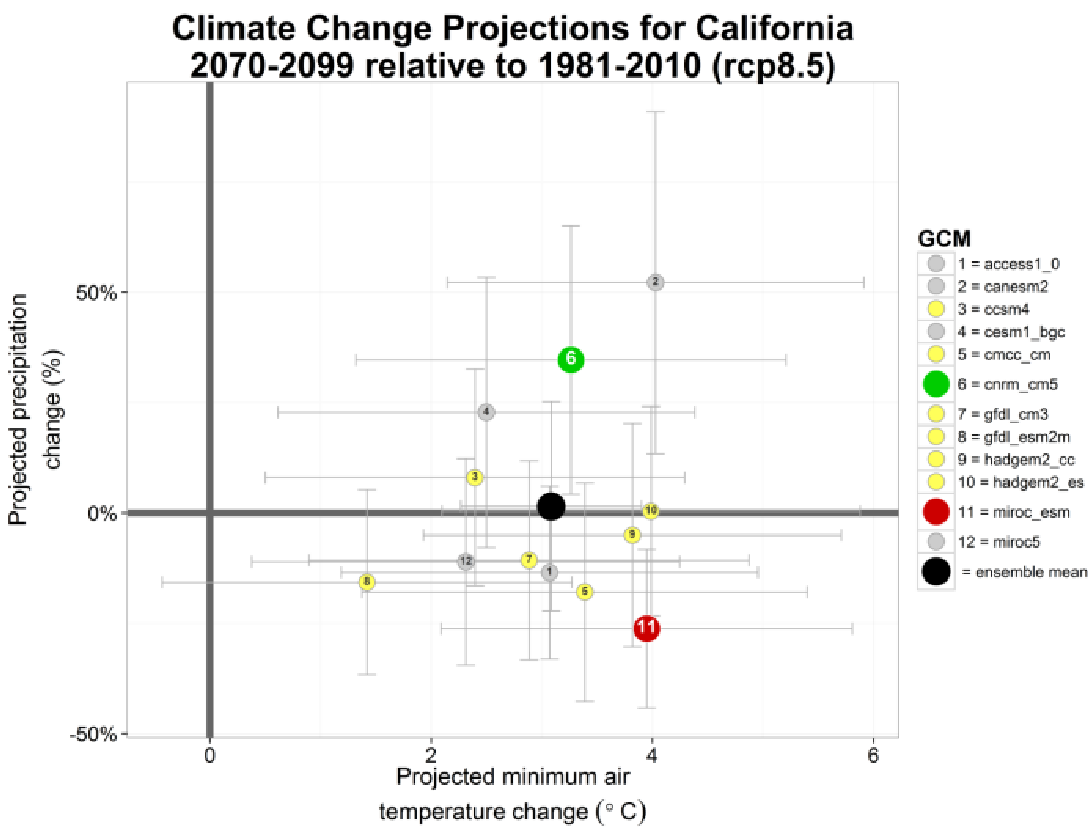
The MIROC ESM and the CNRM CM5 global climate models were chosen under two time horizons (mid-century and end-of-century), and under two different representation concentration pathways (RCP) of future greenhouse gas emissions (the RCP 8.5 and RCP 4.5 scenarios).[82] These models were chosen because they represent a broad range of possible future climate trajectories in California. As shown in Figure C-11 below (reproduced from Figure 6 in the original Thorne et al. 2016 report),[83] 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.

81 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. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=116208&inline.

82 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.

83 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. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=116208&inline.

Figure C-11: 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.

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[84] 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.

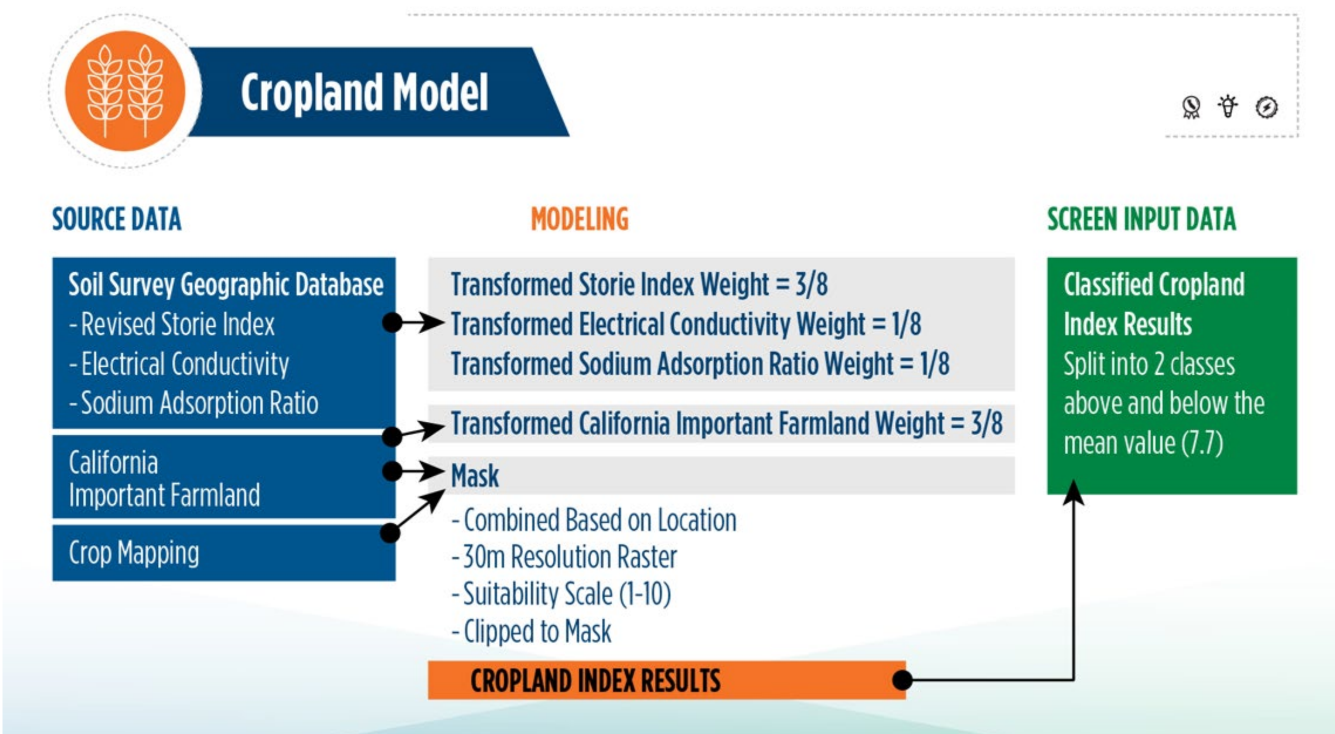
The CDFW then generalized these model results to the 2.5 square mile hexagon units of the ACE project. The binary results, indicating whether a 270-meter vegetation cell would remain in suitable conditions under each of the eight climate projections, were summed and then divided by eight to get a score 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 exclusion areas under the SB 100 Terrestrial Climate Resilience Study Screen.

84 See *Kernel Density Estimation*. Full documentation available at https://stat.ethz.ch/R-manual/R-devel/library/MASS/html/kde2d.html.

The CEC Cropland Index Model Methods and Evaluation

The Cropland Index Model was created by using each of the input datasets (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 maintains a manageable file size. Data was transformed using appropriate thresholds across each dataset's range to categorize the data according to a level suitable for agriculture. A common scale of 1-10 was chosen for all of the input datasets, where 1 represents the lowest levels of suitability for cropland of that particular dataset and 10 represents characteristics of the input data that have highest suitability for cropland. 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. An overview of these steps is depicted in the diagram below in Figure C-12. Additionally, Table C-3 below describes how the raw data was converted into the transformed scale and what weights were assigned to each variable or input dataset for use in the suitability model toolset.

Figure C-12: 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.

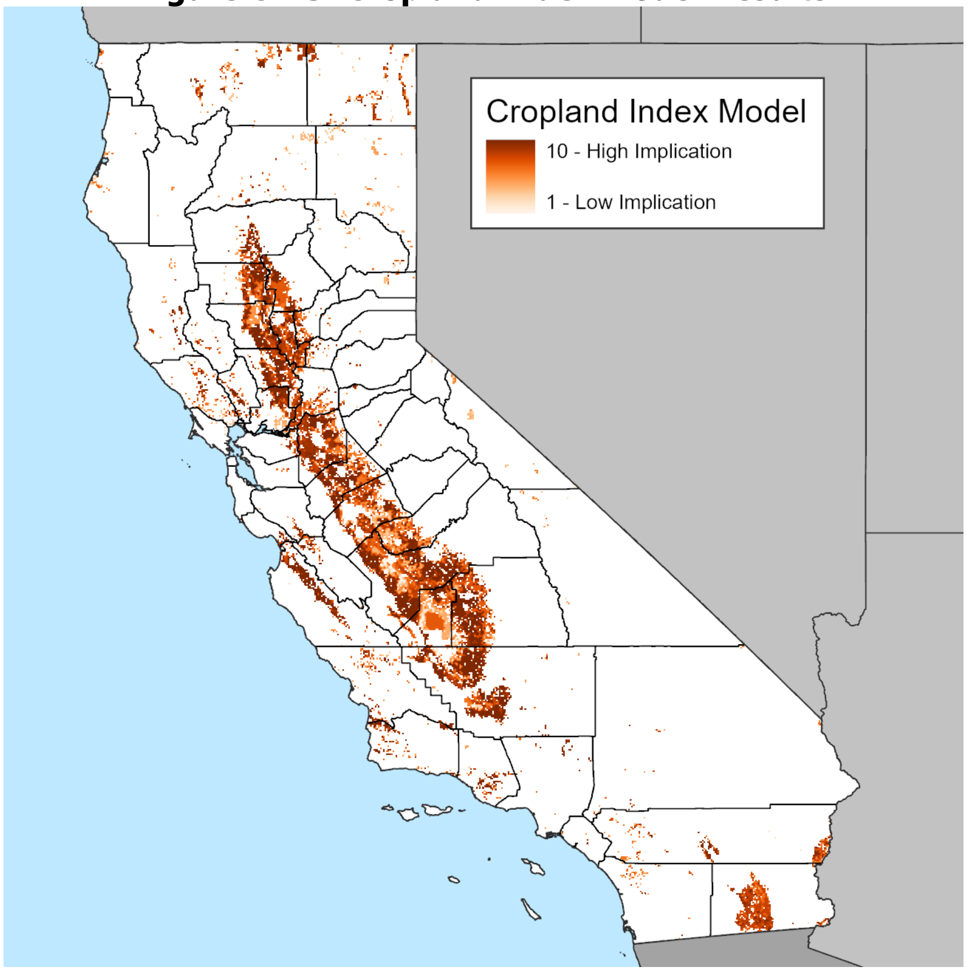
Table C-3: Weights and Categories Assigned to CEC Cropland Index Model Input Datasets

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 datasets, 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-13

Figure C-13: Cropland Index Model Results

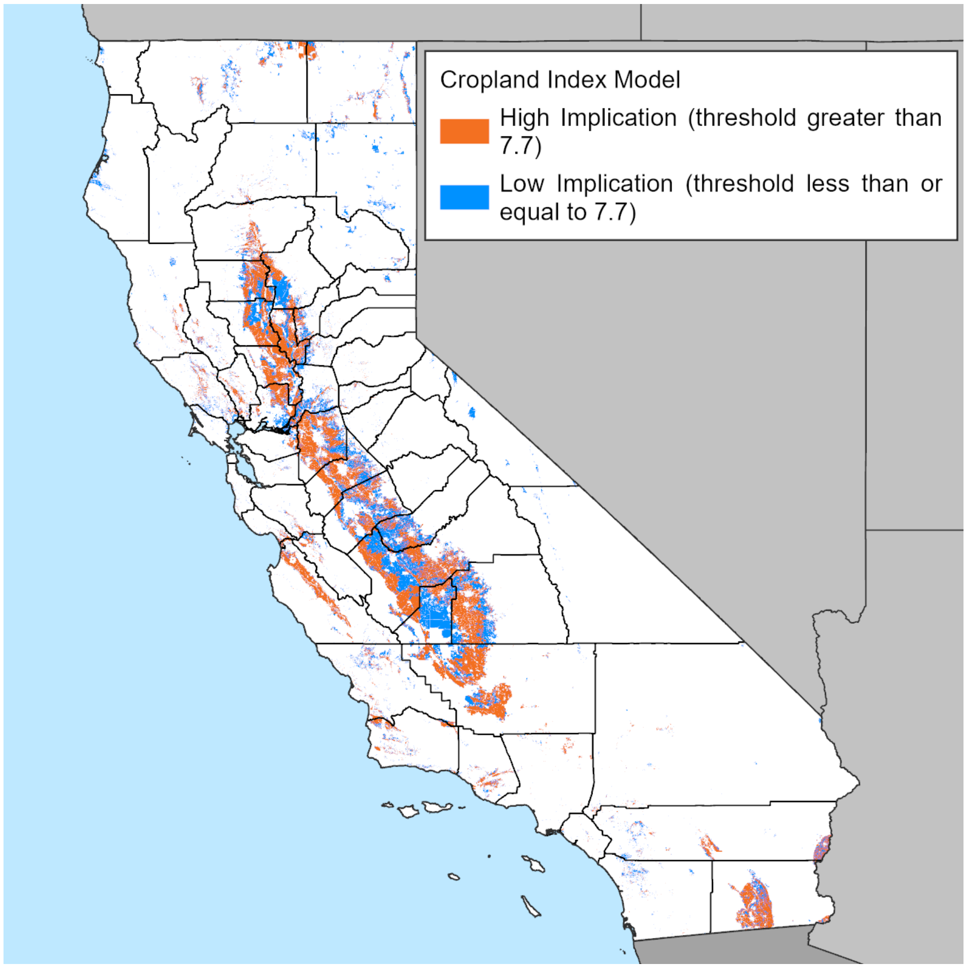


Source: CEC staff

The result of the Cropland Index Model is shown above. Dark reds have the higher scores (locations with more factors that support high-value croplands) and lighter hues have the lower scores (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 a value of 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 the mean value of the model results. The model scores that are greater than the mean, 7.7, are deemed higher implication for cropland and should be preserved for that land use category. The model scores that are less than or equal to 7.7 are deemed lower implication.

Figure C-14: Cropland Index Model Partitioned at the Mean



Source: CEC staff

The result of the Cropland Index binned into two categories partitioned at the model mean. Areas in the higher category have higher implication for crop production and are used as part of the two screen scenarios for solar technology.

There are 4.4 million acres (43 percent of the area) identified in the lower implication category, or areas that are suited for exploration of renewable resource technical potential. The remaining 5.9 million acres (57 percent of the area) are in the higher implication category, where cropland value is high. The high mean value and close to 60 percent coverage of the high category of the Cropland Index Model domain fits with the setup of the model since it is evaluating areas with existing cropland, which tend to have higher suitability for 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, the 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 Agricultural Value Model.[85]

Design of the CEC Cropland Index Model was heavily influenced by the CBI Agricultural Value model. All variables present in the CEC Cropland Index Model are present in the CBI model, and agreement with the CBI model therefore represents a reasonable quality check. The CEC Cropland Index 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**	34.35	6.23	40.58
	% Not Optimal	6.25	53.17	59.42
	total	40.60	59.40	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 the percent of the area where both models are in agreement as 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 or more is considered acceptable.[86]

85 2018. "California Agricultural Value." Conservation Biology Institute. From DataBasin.org: https://databasin.org/datasets/f55ea5085c024a96b5f17c7ddddd1147.

86 Landis, J.R., and G.G. Koch. "The measurement of observer agreement for categorical data." *Biometrics,*33, no. 1, 159-74 (1977). 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, the CEC staff used the Band Statistics Tool[87] to identify correlation coefficients[88] across each of the input datasets, 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 relative 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 Ratio, 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

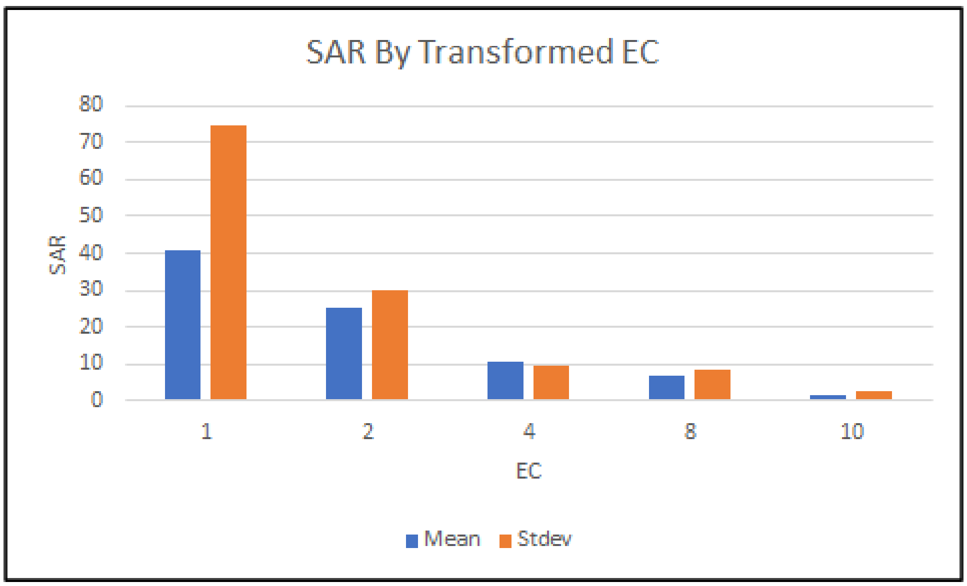
87 See *Band Statistics Tool*, ArcGIS Pro. Complete documentation available at https://pro.arcgis.com/en/pro-app/2.8/tool-reference/spatial-analyst/band-collection-statistics.htm.

88 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.

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 Cropland Index Model. From this evaluation, the 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, data noise), 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, sodium adsorption ratio (SAR) and electrical conductivity (EC) have the strongest correlation (0.55, see Table C-5), which could be explored further in future analyses. See Figure C-15.

Figure C-15: 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.

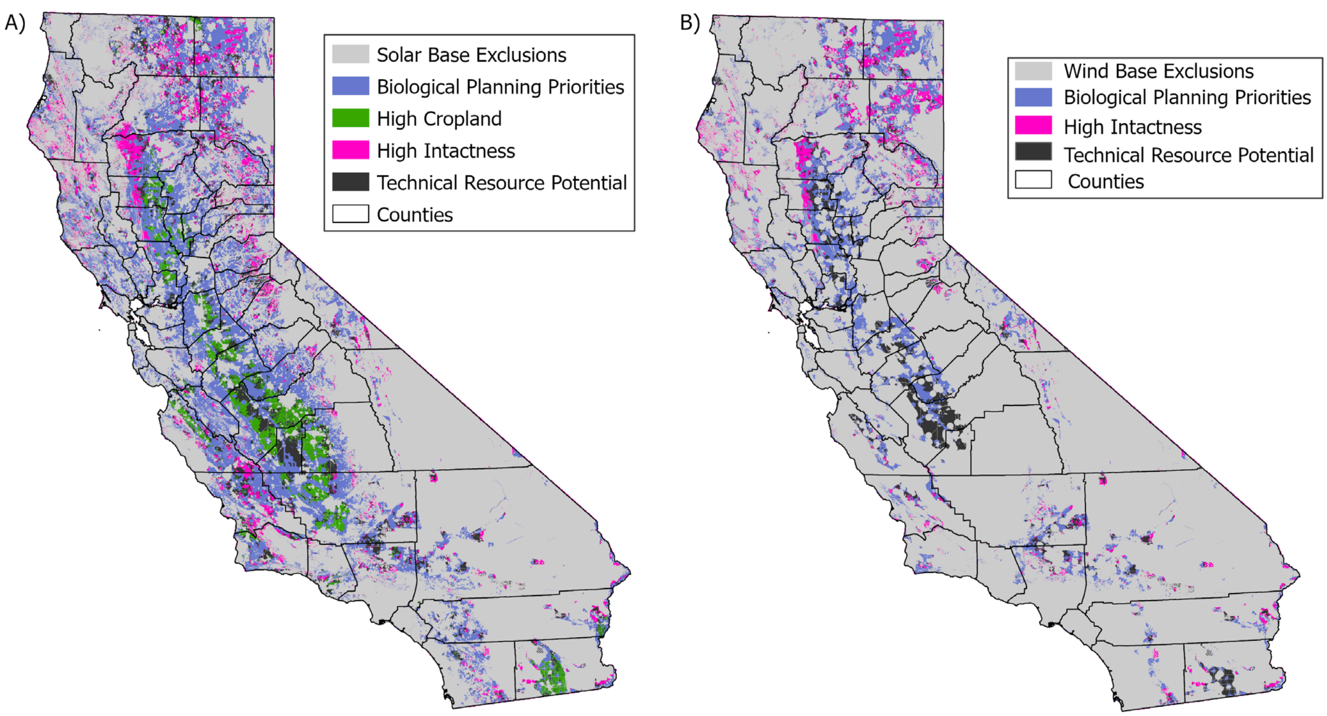
Construction of the Land-Use Screens for Onshore Wind and Solar

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. The CEC staff combines these lower implication areas into two screens to test how these ensembles of land-use scenarios influence energy resource planning.

Core Land-Use Screen

This screen applies the base exclusions, the higher category of landscape intactness, and the biological planning priorities for solar and onshore wind. For solar, the higher category of model output for the CEC Cropland Index Model is also applied. The areas of the state that fall within these areas are excluded from renewable energy resource potential consideration. The areas remaining have modeled lower implication to croplands, biodiversity and landscape intactness. Each of these components of the Core Land-Use Screen are shown in Figure C-16 below for solar and onshore wind. The areas remaining encompass the renewable resource technical potential for onshore wind and solar PV and are explicitly shown in Figure C-17.

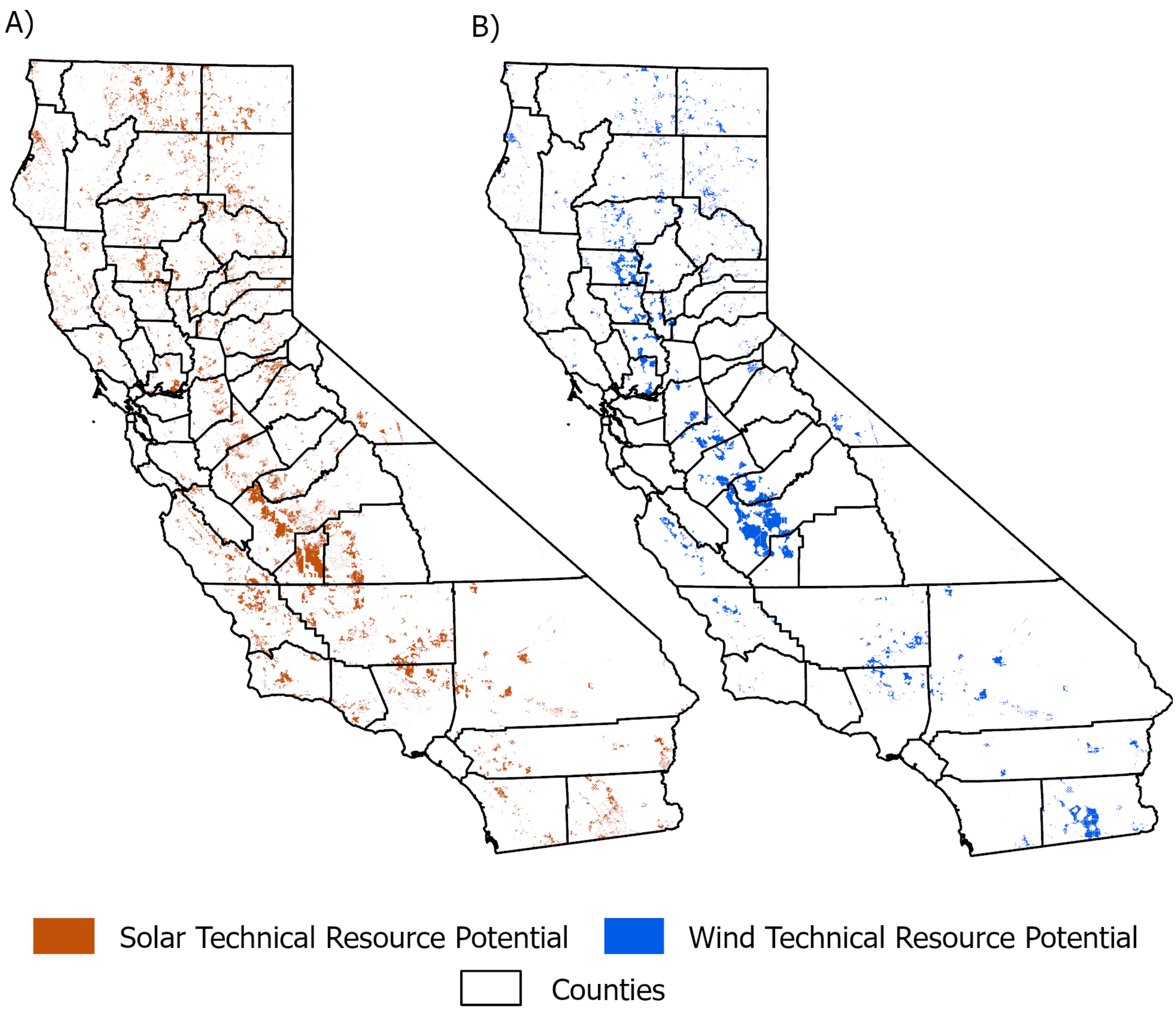
Figure C-16: Components of the Core Land-Use Screen for Solar and Wind



Source: CEC staff

(A) The components of the exclusions used in the Core Land-Use Screen for solar. (B) The components of the exclusions used in the Core Land-Use Screen for wind. Areas of overlap amongst the screens and base exclusions exist. Areas remaining in black make up the technical resource potential.

Figure C-17: Technical Resource Potential under the Core Screen



Source: CEC staff

(A) The technical resource potential available after applying the Core Screen for solar. (B) The technical resource potential after applying the Core Screen for wind.

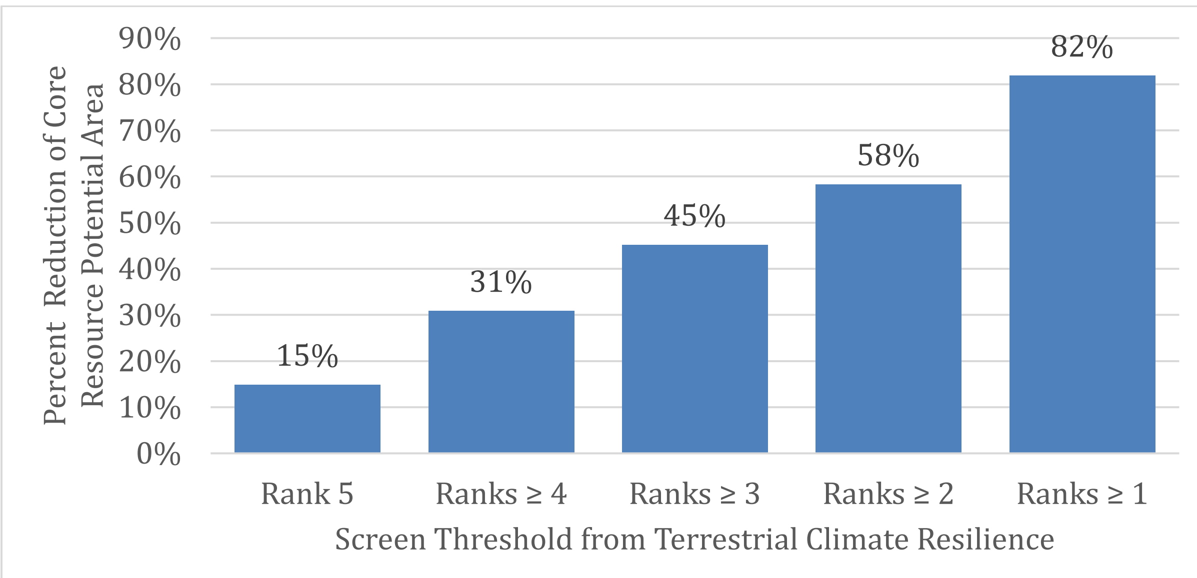
By applying each component of the Core screen, the solar and wind resource potential basemaps are reduced by approximately 84 percent and 79 percent, respectively to create the renewable resource technical potential map depicted in Figure C-17.

SB 100 Terrestrial Climate Resilience Study Screen

This screen applies the base exclusions, the higher category of landscape intactness, and the biological planning priorities for solar and onshore wind resource types. For solar, the higher category of model output for the cropland index is also applied. Further, this screen excludes areas of the state that are likely to serve as climate refugia[89] under changing climate conditions. To construct this screen, the CEC staff chose an appropriate threshold on the ACE Terrestrial Climate Change Resilience dataset as a partition between areas that would be omitted from energy resource potential consideration and areas that would remain with technical resource potential. These higher category areas from the Terrestrial Climate Resilience dataset would further reduce the land area with renewable resource potential compared to the Core Land-Use Screen. The climate resilience ranks with higher values indicate a greater concentration of modeled climate refugia at that location. A rank of 4 and 5 indicates a hexagonal grid cell should contain refugia as predicted by more than 60 percent and 80 percent, respectively, of the models.

The CEC staff explored using every rank as the threshold under this scenario and calculated how much land would be removed from the Core Land-Use Screen resource potential with each possible screen definition. The percentage reduction in lands with renewable resource technical potential for each possible partition of the ACE Terrestrial Climate Resilience data layer is shown in Figure C-18 below.

Figure C-18: Sensitivity of Solar Resource Potential with Varying ACE Terrestrial Climate Resilience Threshold



Source: CEC staff

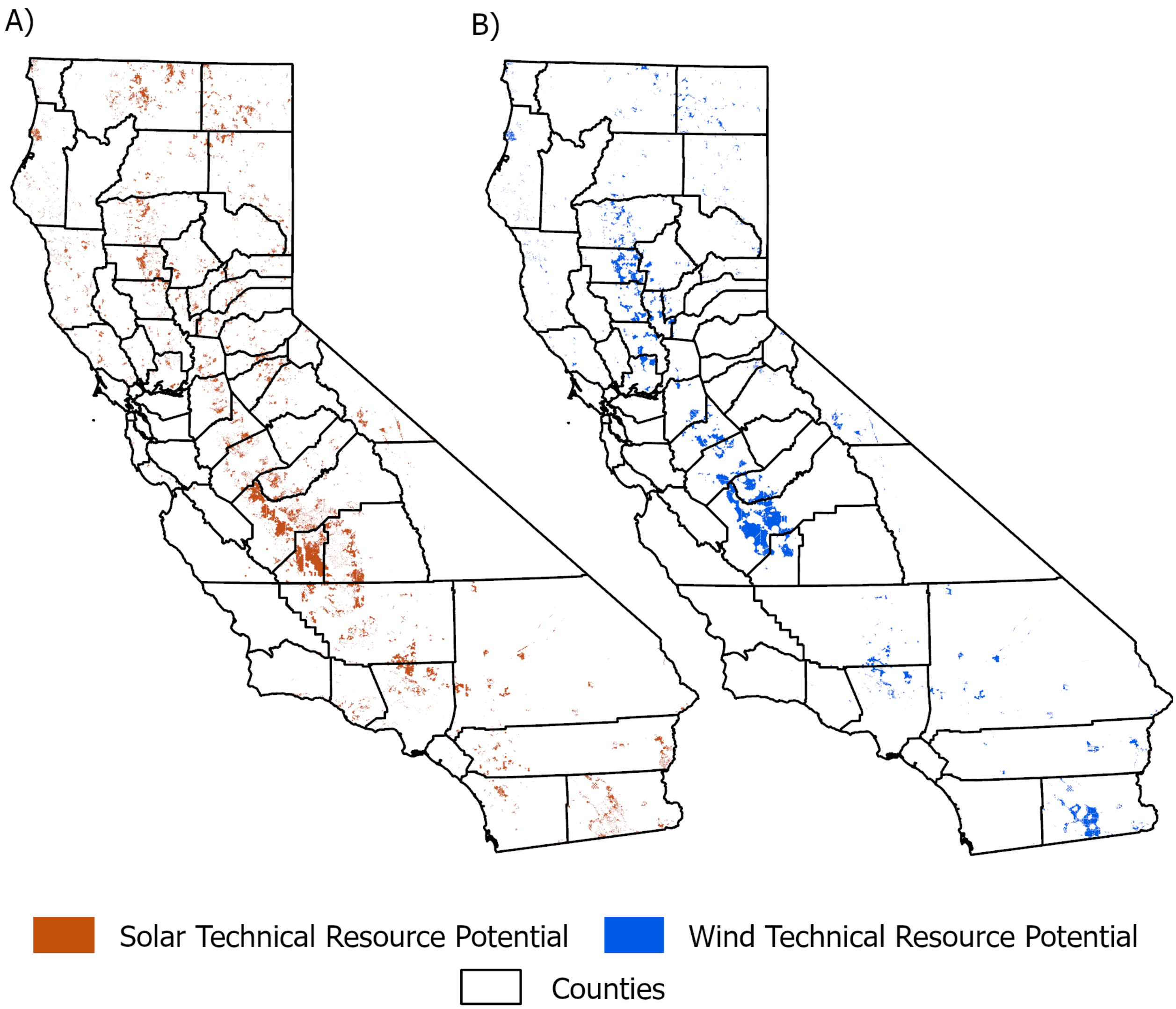
89 Refugia are areas relatively buffered from the effects of climate change, where conditions will likely remain suitable for the current array of plants and wildlife that reside within a location, and where ecological functions are more likely to remain intact. Available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=150836&inline.

The percentage reduction in lands with renewable resource technical potential under various thresholds of the ACE Terrestrial Climate Change Resilience data layer. 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 with renewable resource potential by 82 percent, whereas using a threshold of 5 reduces the land area with renewable resource potential by 15 percent.

Using a rank of 5 as the definition for the screen removes approximately 15% of the land area remaining with solar resource potential under the Core Land-Use Screen, while using a rank of 2 as the threshold removes close to 60% of the land area. The CEC staff chose a rank of 4 as the threshold for the SB 100 Terrestrial Climate Study Screen because it removes areas where the majority of the models indicate the likely presence of climate refugia and creates a meaningful sensitivity study by removing 30% of the land area to compare with the Core Screen. 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 data layer and therefore are not screened out under the chosen screen definition.

The footprint of the technical resource potential under the SB 100 Terrestrial Climate Resilience Study screen is shown in Figure C-19 below.

Figure C-19: Resource Potential under the SB 100 Terrestrial Climate Resilience Study Screen



Source: CEC staff

(A) The solar technical resource potential available after applying the SB 100 Terrestrial Climate Resilience Study Screen. (B) The onshore wind technical resource potential available after applying the SB 100 Terrestrial Climate Resilience Study Screen.

In summary, the total technical resource potential for solar PV and wind technologies under the Core and SB 100 Terrestrial Climate Resilience Study Screens range from 2.5 to 5.4 million acres, as shown in Table C-6 below.

Table C-6: Summary of Resource Potential After Applying Land-Use Screens

	Technical Resource Potential (Million Acres)	
	Solar PV	Wind
Core Land-Use Screen	5.4	3.7
SB 100 Terrestrial Climate Resilience Study Screen	3.3	2.5

Source: CEC staff

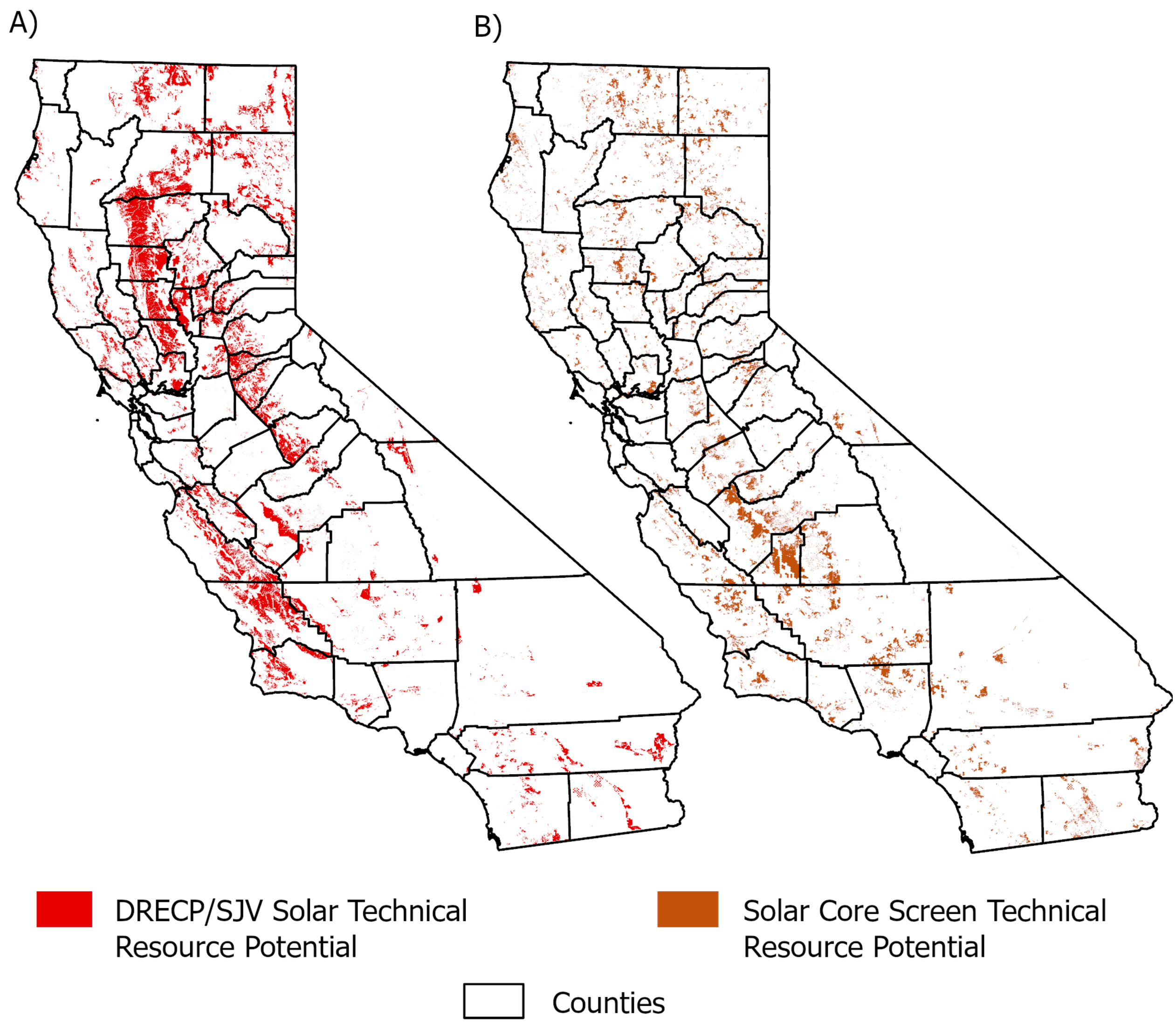
The technical resource potential under each screen and for each technology in acres.

These numbers are illustrative to demonstrate the results of the land-use screen methods. Land-use screens are only one input into electric system modeling. Therefore, the final resource potential numbers used in a particular planning process may change depending on the other inputs and assumptions. For example, changes in techno-economic assumptions (such as, capacity factor) or the capacity density metric applied may change the acres of resource potential available for study.

Core Screen Comparison with DRECP/SJV Screen

The previous screen used in the CPUC's IRP process and modeling for the 2021 SB 100 Joint Agency Report, the DRECP/SJV Screen, is compared to the current Core Land-Use Screen constructed in this report. The CEC staff highlight that the current Core Land-Use Screen provides a much different spatial distribution of the technical resource potential compared to the DRECP/SJV Screen, especially for solar. The maps identifying technical resource potential under both screens are shown below in Figure C-20 and Figure C-21 for solar and wind, respectively.

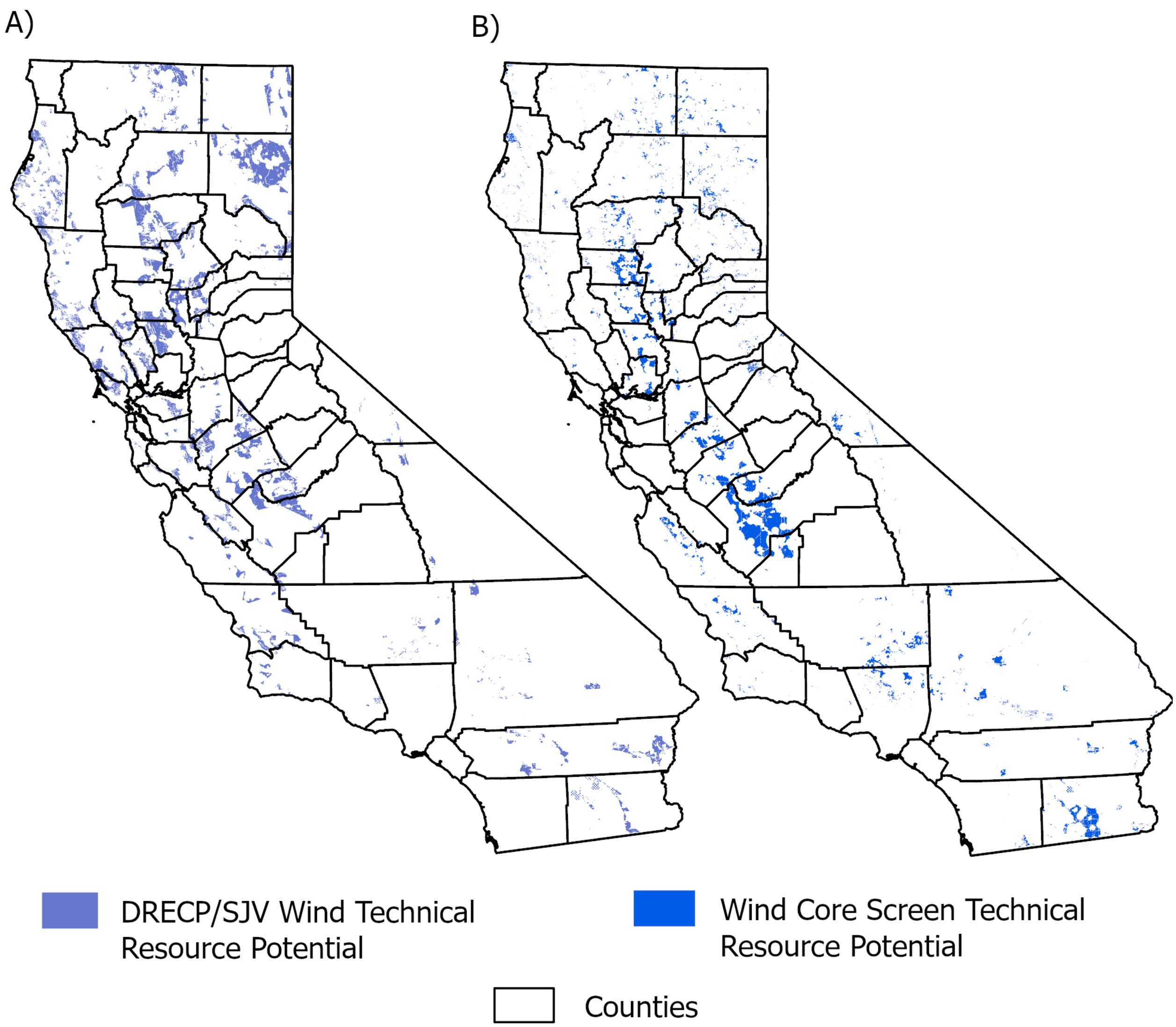
Figure C-20: Solar Technical Resource Potential under the Core and DRECP/SJV Screens



Source: CEC staff

(A) The technical resource potential available after applying the DREC/SJV Screen for solar.
(B) The technical resource potential available after applying the Core Screen for solar.

Figure C-21: Wind Technical Resource Potential under the Core and DRECP/SJV Screens

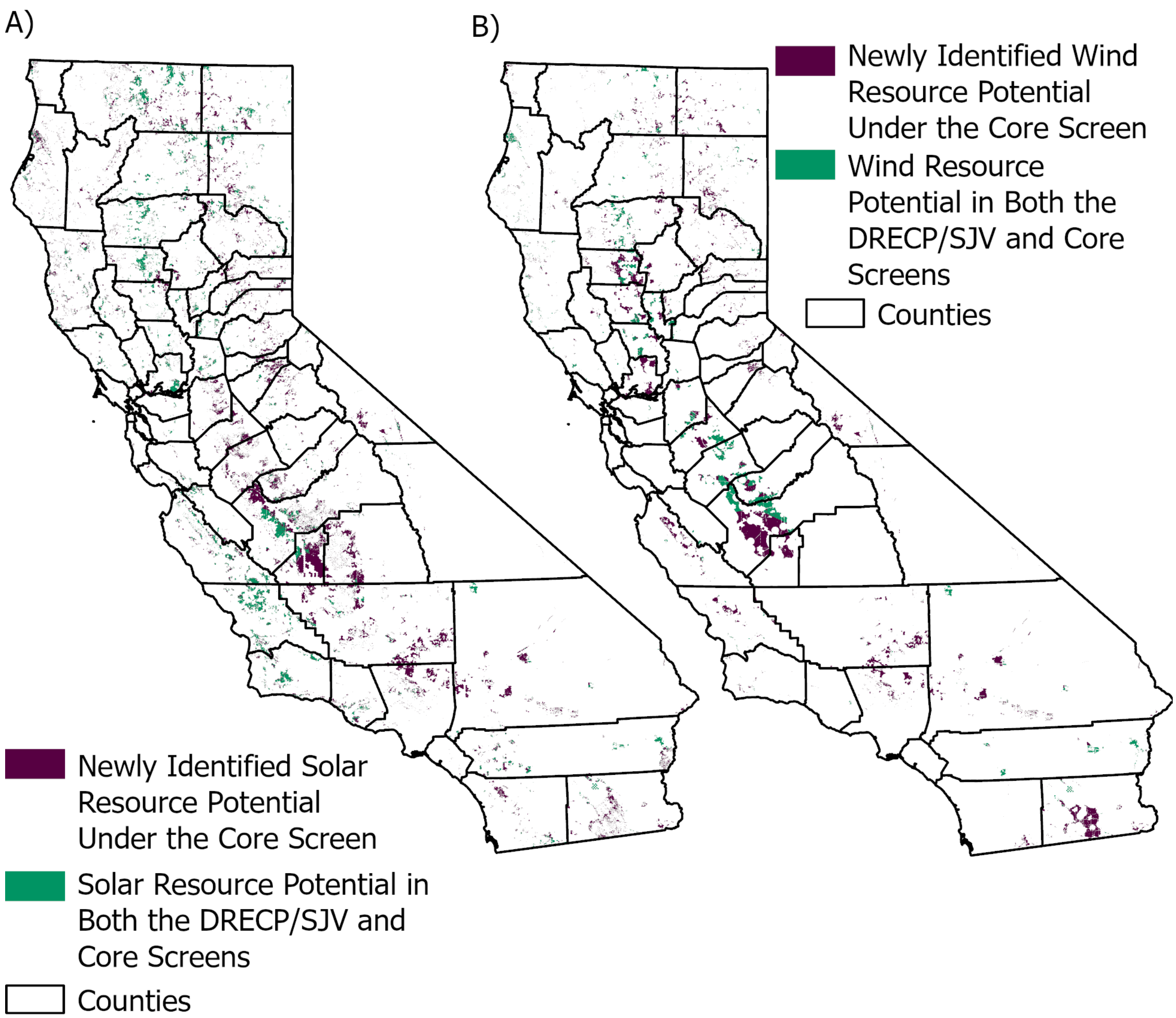


Source: CEC staff

(A) The technical resource potential available after applying the DREC/SJV Screen for wind.
(B) The technical resource potential available after applying the Core Screen for wind.

Visual inspection and Figure C-22 below depict where resource potential is in agreement between the two screens, and where new resource potential has been identified in the most recent CEC construction of the land-use screens as documented in this report. For solar, large areas of resource potential in northern California have been greatly diminished in the Core Screen. In the current Core Screen, the largest contiguous blocks of resource potential are located in the San Joaquin Valley. This shift in emphasis of solar resource potential from Northern California to the San Joaquin Valley is more aligned with commercial interest.

Figure C-22: Comparison of Resource Potential for Solar and Wind under the Core and DRECP/SJV Screens



Source: CEC staff

(A) The solar technical resource potential that has been identified only in the Core Screen compared to the DRECP/SJV Screen. Areas of overlap between the resource potential remaining under both screens are also shown. (B) The same areas of overlap and new areas identified under the Core Screen for wind technology.

Solar Resource Potential in the San Joaquin Valley

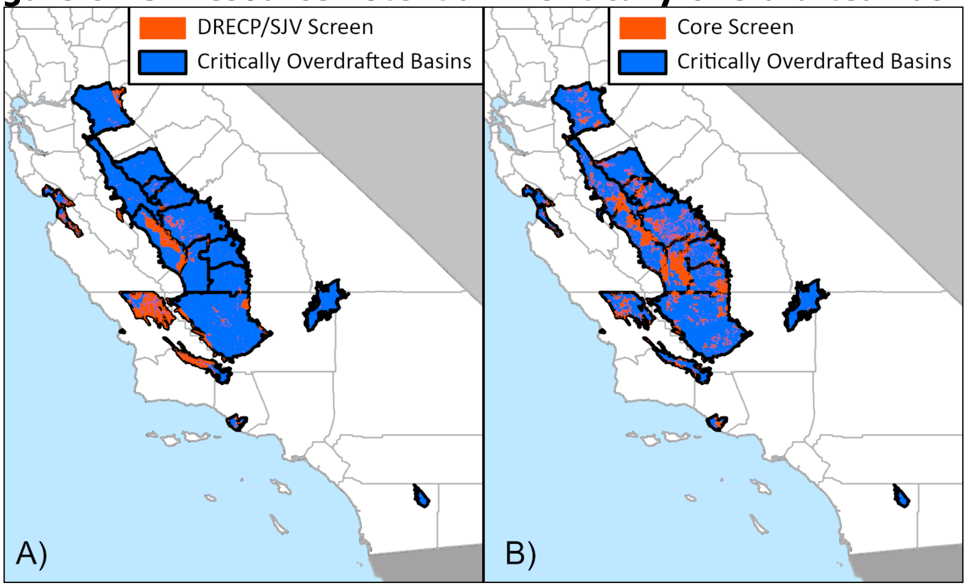
Public comments and prior planning processes identify the San Joaquin Valley as a priority region for utility-scale solar planning and development. Further, public comments highlight the importance of identifying solar resource potential for statewide electric system planning within

Critically Overdrafted Basins, as defined by the Sustainable Groundwater Management Act.[90] Within Critically Overdrafted Basins, local agencies are leading efforts to achieve groundwater sustainability through integrated land use planning and repurposing agricultural lands to less water intensive use. Clean energy development, including utility-scale solar, is one potential repurposing option. Figure C-23 below depicts how much solar resource potential under the DRECP/SJV and Core Screens (shaded in orange) are within the critically overdrafted groundwater basins (shaded in blue),[91] which are primarily located in the San Joaquin Valley. The total resource potential under the DRECP/SJV screen within these basins is 920,000 acres (A), while approximately 1,600,000 acres of resource potential is identified in the same regions in the Core Screen (B). The Core Screen yields an almost 74% greater footprint for solar resource potential that is more widely distributed among the critically overdrafted basins than the previous screen used in electric system planning for the state.

90 The Sustainable Groundwater Management Act is composed from a three-bill legislative package and subsequent statewide regulations.
Assembly Bill 1739 (Dickinson, Chapter 347, Statues of 2014).
https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB1739.
Senate Bill 1168 (Pavley, Chapter 346, Statues of 2014).
https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB1168.
Senate Bill 1319 (Pavley, Chapter 348, Statues of 2014).
https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB1319.

91 California Department of Water Resources has identified groundwater basins that are in condition of critical overdraft as part of the Sustainable Groundwater Management Act (SGMA). California's Critically Overdrafted Basins map is available at: https://water.ca.gov/programs/groundwater-management/bulletin-118/critically-overdrafted-basins

Figure C-23: Resource Potential in Critically Overdrafted Basins



Source: CEC staff

The figures show in orange the resource potential remaining after application of the DRECP/SJV Screen (A) and the Core Screen (B) within Critically Overdrafted Basins

Geothermal Technical Resource Potential Analysis

California produces the largest amount of electricity from geothermal energy in the United States. In 2021, geothermal energy supplied about 5% of the state's total mix of power generated for electricity, or about 2700 MW.[92] The role of geothermal energy has been scrutinized lately as costs are projected to decrease, coproduction with lithium or other minerals could provide additional revenue streams, and technological advancements could greatly expand its use as a firm, clean energy source. In this report, the CEC staff estimates net undeveloped electrical energy production from geothermal resources using conventional methods of heat extraction after application of a land-use screening method for geothermal technology.

Creating an explicit spatial representation of the geothermal resource potential across the state requires two components of analysis: the quantity of the resource potential and the spatial footprint of where the heat from the geothermal reservoir is available from the surface. This is the land area that has the potential to be impacted by geothermal energy development

92 See *2021 Total System Electric Generation*, available at https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2021-total-system-electric-generation

and should be screened as part of the land-use evaluation for this technology. The area that would ultimately be developed for actual power generation could be much smaller, and this could also allow for more selective locations of development that still abide by the limitations of the protected area layer, used as the only screening layer for this technology.

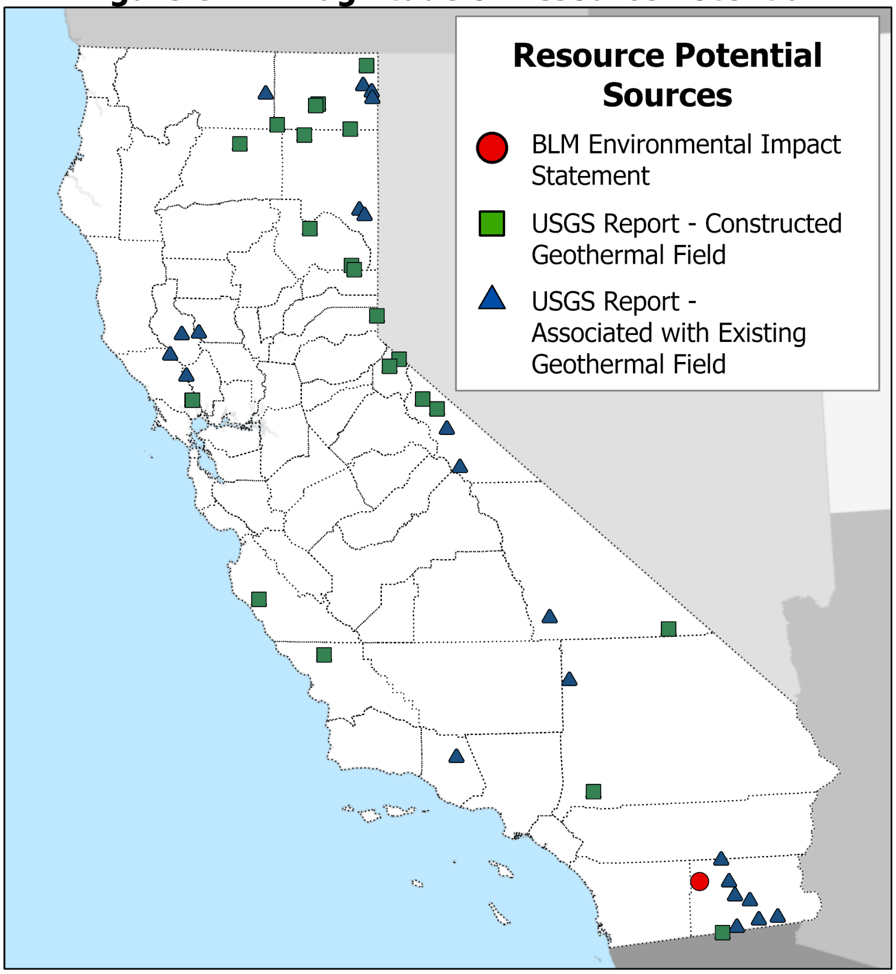
To estimate the quantity of geothermal potential, the CEC staff used the values determined by the USGS *Assessment of Moderate- and High- Temperature Geothermal Resources of the United States*[93] (hereinafter referred to as the USGS 2008 report) for the majority of the magnitudes of resource potential used in this report. Each of the geothermal resources in this study is given by a point location and includes an estimate of the underlying reservoir volume and temperature. USGS provides a 5%, Mean, and 95% confidence value for the electrical generation capacity, or resource potential, for each resource.[94] The mean estimate is used in this report because it appears to be the most reasonable value consistent with known geothermal generation in California. Since the USGS study was published, BLM has identified the Truckhaven geothermal lease area (50 MW)[95] in southern California west of the Salton Sea. This generation estimate has also been included here for a total generation potential estimate of 5,444 MW. Figure C-24 shows the locations of the geothermal systems identified by USGS, with the addition of Truckhaven west of the Salton Sea. The differentiated marker symbols indicate the source of each resource potential and how the spatial footprint of the resource was estimated, which is explained below.

93 Williams, Colin F., Marshall J. Reed, Robert H. Mariner, Jacob DeAngelo, and S. Peter Galanis, Jr. 2008. "Assessment of Moderate- and High-Temperature Geothermal Resources of the United States." U.S. Geological Survey Fact Sheet. 2008-3082. https://pubs.usgs.gov/fs/2008/3082/.

94 See *Geothermal Systems*, in the Web Tool available at https://www.usgs.gov/node/278416

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

Figure C-24: Magnitude of Resource Potential



Source: CEC staff

The locations of identified geothermal resources used in this report to estimate the magnitude of the geothermal resource potential used in electric system planning. All but the Truckhaven geothermal resource potential estimates (indicated by the circular marker symbol) are provided by the USGS 2008 report. Those points are split in this figure between those whose spatial footprint is associated with an existing known geothermal field boundary (triangular marker symbol) and those that are estimated by the CEC staff using a power-density and assumed circular buffer around the USGS 2008 point location (square marker symbol).

The second component of analysis required in the land use-evaluation for geothermal resources requires estimating a surface boundary of the resource from which the geothermal heat can be extracted. To provide a spatial footprint of the point based USGS electrical power generation magnitudes, the CEC staff utilized mapped boundaries of geothermal fields produced by DOC's Geologic Energy Management Division (CalGEM).[96] This data shows surface footprints of Known Geothermal Resource Areas (KGRAs) and other known geothermal fields. Where point locations identified by USGS overlapped or were within 2-kilometers of a KGRA or field, those resources were summed and used as an estimate for that geothermal field boundary. Where the USGS point locations were outside any 2-kilometer area around a geothermal field, a separate boundary was constructed by CEC staff by buffering the point by a certain radius needed to reach the estimated generation potential using a constant power density.[97] The Truckhaven geothermal resource boundary was provided by the BLM Environmental Impact Statement.[98] Figure C-25 depicts the raw USGS 2008-point data of geothermal resource magnitudes that are summed to inform the magnitude of resource potential within each spatial delineation of a geothermal field.

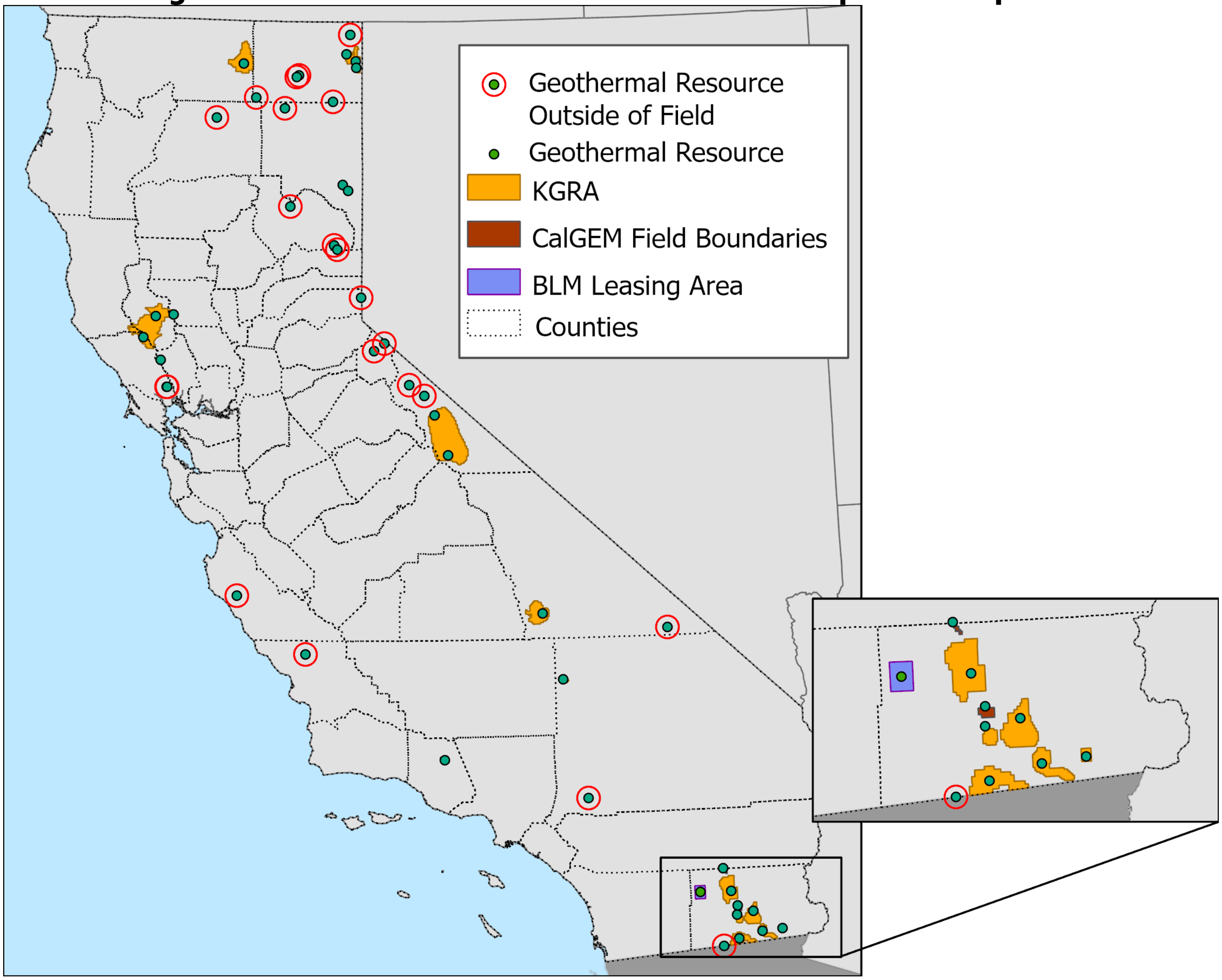
For those geothermal resources outside of a 2-kilometer area around a geothermal field, a power density estimate is required to approximate the land footprint that can be used to access and develop the geothermal field.

96 See *Geothermal Map of California, S-11*, available at https://www.conservation.ca.gov/calgem/geothermal/maps/Pages/index.aspx and *CalGEM Field Administrative Boundaries*, 'FIELD_CODE IN ('G1-','G2-','G3-'),' available at https://gis.conservation.ca.gov/portal/home/item.html?id=07b08eaaee0842caa8fc258cbdc7d319#overview

97 The same method was applied in *Power of Place: Land Conservation and Clean Energy Pathways for California*, available at https://www.scienceforconservation.org/products/power-of-place

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

Figure C-25: Conversion of Point Resources to Spatial Footprints

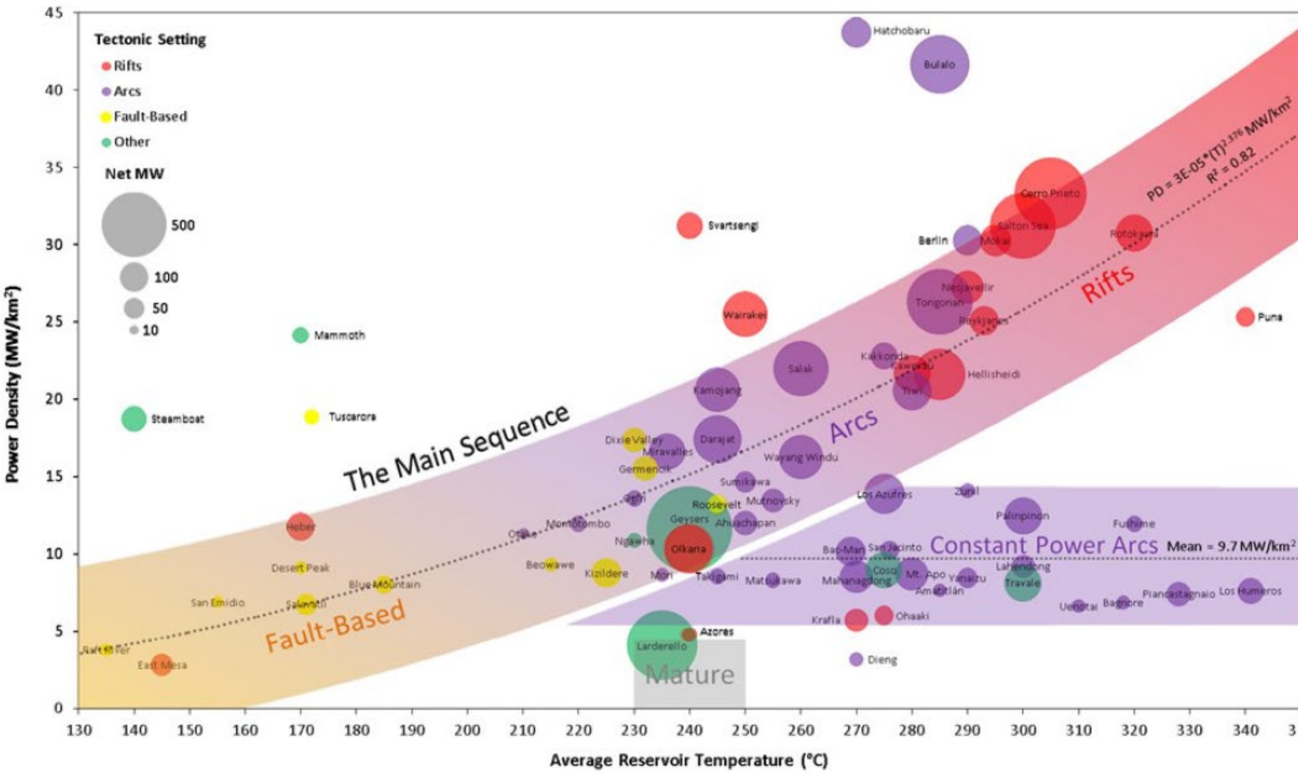


Source: CEC staff

This figure indicates locations where the magnitude of geothermal resource potential is known, as provided by USGS and BLM. Overlayed beneath the points are the known geothermal field boundaries from DOC and BLM lease areas. These areas are used as footprints to delineate surface boundaries of the geothermal reservoirs. The point locations circled in red indicate identified resources (USGS 2008) that are not within a 2-kilometer buffer of a known geothermal field boundary. The spatial footprints of these sources are constructed using the power density approach described below.

To determine an appropriate power density, the CEC staff reviewed temperature data from the USGS 2008 report for these stand-alone geothermal point resources and noted they are relatively low temperature – between 130 °C and 180 °C. The temperatures would therefore be more typical of resources that would have a power density of about 10 MW/km^2 based on the data shown in Wilmarth et al. 2020, reproduced below in Figure C-26. Using this power density, the CEC staff calculated a radius needed to support the estimated resource potential.

Figure C-26: Power Density and Temperature Relationship



Source: Wilmarth et al. 2020

This plot shows the power density relationship with reservoir temperature for a large sample of geothermal power plants. The temperatures of the USGS identified resources that do not intersect within 2km of a known geothermal field indicate a power density of approximately 10 MW/km² is appropriate for this analysis.

Circular footprints with the estimated area were then plotted as part of the resource potential basemap at the point location provided by USGS. This is likely a gross simplification of the area where the resource limits are expected to occur given the variability in geologic conditions that could occur. For screening purposes, they are believed to be adequate for landscape planning envisioned in this assessment. The areas are at least an order of magnitude smaller than the established KGRAs and CalGEM geothermal field boundaries, but they are also typically one order of magnitude less than the resource potential estimated from the established geothermal fields. The results of the size of the constructed geothermal field delineation using the chosen constant power density, 10 MW/km², is shown in Table C-6 below.

Table C-7: Radii of Constructed Geothermal Field Boundaries from USGS 2008 Point Resources Unassociated with an Existing Field

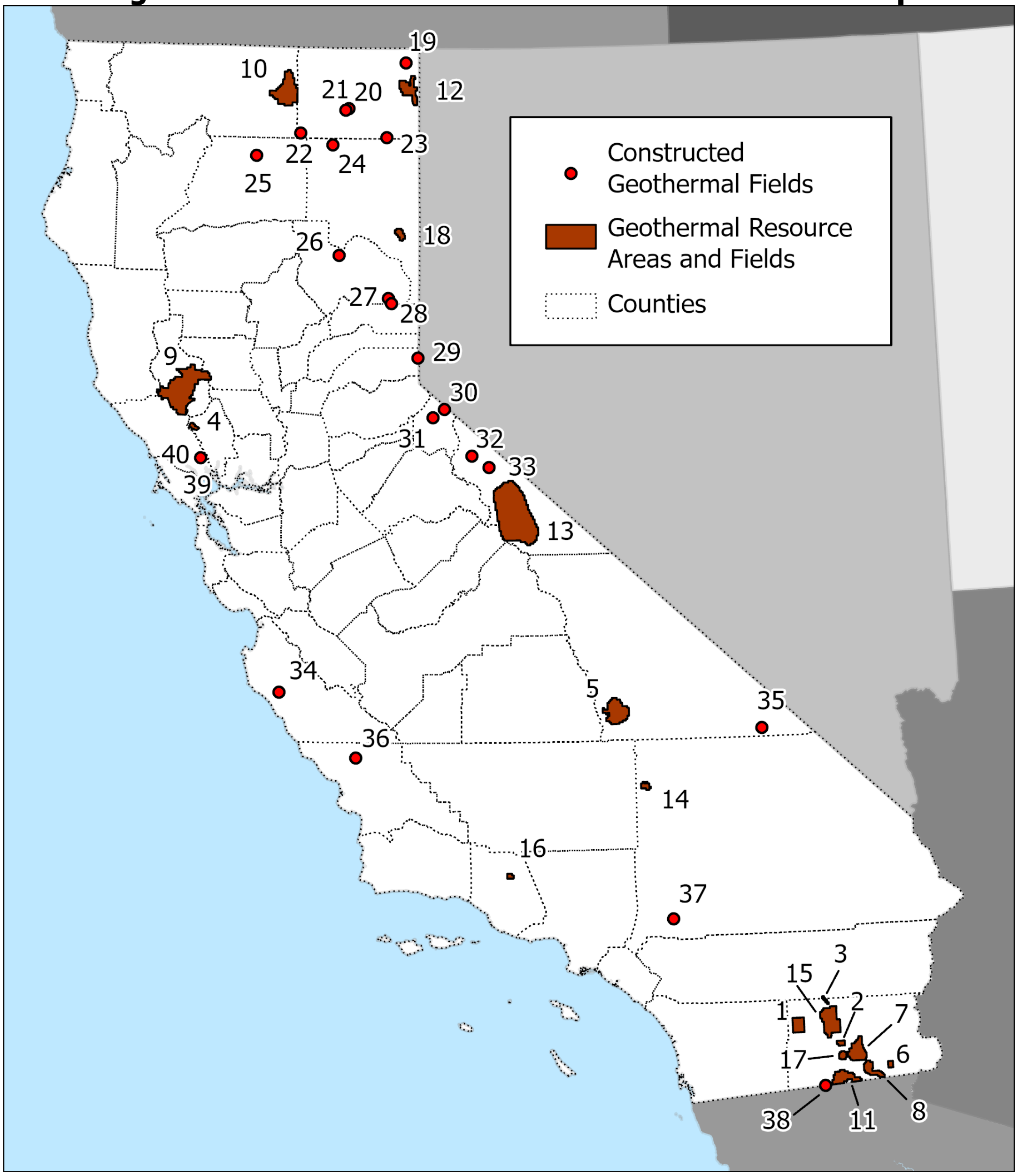
ID	Name	MWe (Mean)	Radius (m)	Min Temp (˚C)	Max Temp (˚C)
19	Fort Bidwell	9.1	538.2	105	130
20	Kelly HS	9.5	549.9	115	130
21	Canby (I'SOT)	9.4	547.0	115	130
22	Little Hot Spring (Fall River)	3.9	352.3	95	110
23	West Valley Reservoir	12.6	633.3	125	135
24	Kellog HS	5.4	414.6	100	115
25	Big Bend HS	4.9	394.9	90	120
26	Indian Valley Hot Springs	3.5	333.8	85	110
27	Marble Hot Well	3.5	333.8	80	120
28	Sierra Valley	3.5	333.8	95	105
29	Brockway Hot Springs	2	252.3	85	95
30	Carson River	15.7	706.9	105	150
31	Grovers HS	2.9	303.8	85	110
32	Fales HS	2.9	303.8	60	115
33	Boyes HS	8.4	517.1	105	135
34	Sonoma Mission Inn	6.3	447.8	105	120
35	Travertine HS	2.8	298.5	70	110
36	Tassajara HS	3	309.0	90	105
37	Tecopa HS	9	535.2	110	130
38	Paso Robles	3.4	329.0	90	110
39	Arrowhead HS	7.1	475.4	110	120
40	Mt. Signal	14.7	684.0	125	145

Source: CEC staff

This table shares the magnitude of the electrical generation potential (MWe) used in this report that is used to determine the constructed radius (meters) needed to create a circular geothermal footprint, assuming a constant power density of 10 MW/km^2. IDs listed correspond to Figure C-27. The minimum and maximum temperatures of the geothermal reservoir are also shown to support the constant power density chosen. The values given in MWe (Mean) and the minimum and maximum temperature are supplied by the USGS 2008 report.

The analysis described above provides a starting point for statewide geothermal resource potential estimates, before any land-use screen has been applied. The magnitude and spatial distribution of the resources are shown below in Figure C-27 and create the geothermal resource potential basemap.

Figure C-27: Geothermal Resource Potential Basemap



Source: CEC staff

The total magnitude and spatial delineation of each geothermal resource is shown in this map. The red circular markers indicate a constructed geothermal field boundary and are not drawn to scale. The numbers labeling each field corresponds to values given in Table C-8.

Table C-8: Corresponding Values for Numbered Labels in Geothermal Resource Potential Basemap

ID	Name	Total MWe	MW in Use
1	Truckhaven	50	
2	Brawley	138	49.9
3	Hot Mineral Spa	3	
4	Calistoga	16.9	
5	Coso Hot Springs	419.2	302.41
6	Dunes	18.5	
7	East Brawley	358.5	
8	East Mesa	202.7	74.9
9	Geysers	1096.1	850
10	Glass Mountain	365.6	
11	Heber	159.6	161.5
12	Lake City - Surprise Valley 1	118.5	
13	Mono - Long Valley	64.8	40
14	Randsburg	6.6	
15	Salton Sea	2209.9	430.83
16	Sespe Hot Springs	10.7	
17	South Brawley	42.3	
18	Wendel - Amedee	19.2	
19	Fort Bidwell	9.1	
20	Kelly HS	9.5	
21	Canby (I'SOT)	9.4	
22	Little Hot Spring (Fall River)	3.9	
23	West Valley Reservoir	12.6	
24	Kellog HS	5.4	
25	Big Bend HS	4.9	
26	Indian Valley Hot Springs	3.5	
27	Marble Hot Well	3.5	
28	Sierra Valley	3.5	
29	Brockway Hot Springs	2	
30	Carson River	15.7	
31	Grovers HS	2.9	
32	Fales HS	2.9	
33	Travertine HS	2.8	
34	Tasajara HS	3	
35	Tecopa HS	9	
36	Paso Robles	3.4	
37	Arrowhead HS	7.1	
38	Mt. Signal	14.7	
39	Boyes HS	8.4	
40	Sonoma Mission Inn	6.3	

Source: CEC staff

The numbered ID labels given in Figure C-27 are listed along with the total MW for each geothermal field and the total MW in operation, which are required to determine the net undeveloped resource potential.

In several areas of California, such as the Geysers and Salton Sea, geothermal energy has already been developed and operated for decades. The total generation potential estimates provided above do not include the geothermal resources already developed. For a representative estimate of new geothermal generation potential for this analysis, the net undeveloped generation is determined before any land-use screens are applied.

To calculate the current geothermal generation capacity that is in operation and no longer available for possible development, CEC's Quarterly Fuel and Energy Report (QFER)[99] was reviewed. This database reports the nameplate capacity of all generators including geothermal power plants that generate 1 MW or greater. Where plants are located within 2-kilometers of a geothermal field, the applicable generation capacity is partitioned and summed to get an estimate of the total capacity that is already in operation at each geothermal field.

In the case of the Geysers, the sum of the nameplate capacities for the Geysers currently exceeds the actual production because of changes in the field over time. In their 2004 article, Lovekin, Sanyal, and Klein provide energy generation data for the Geysers that is used here to estimate actual generation from this resource.[100] For Heber, the QFER data of existing generation slightly exceeds the USGS estimate.[101] Although improvements in efficiency could offer a slight increase in generation from this site, the CEC staff estimates a net 0 MW could come from future development of this geothermal field. Using QFER data and data from Lovekin, Sanyal and Klein's 2004 report, the CEC staff estimates there is a total of 1,910 MW in operation statewide. Therefore, given the total statewide resource generation potential of 5,444 MW, it is estimated the net undeveloped geothermal resource potential is 3,534 MW.

Finally, once the net developable geothermal resource potential has been estimated and a 2D geothermal resource map can be generated showing where the resource exists, the land-use screen can be applied. For this technology, the resource potential from geothermal fields that lie entirely within the protected area layer are excluded. This is shown below in Figure C-28.

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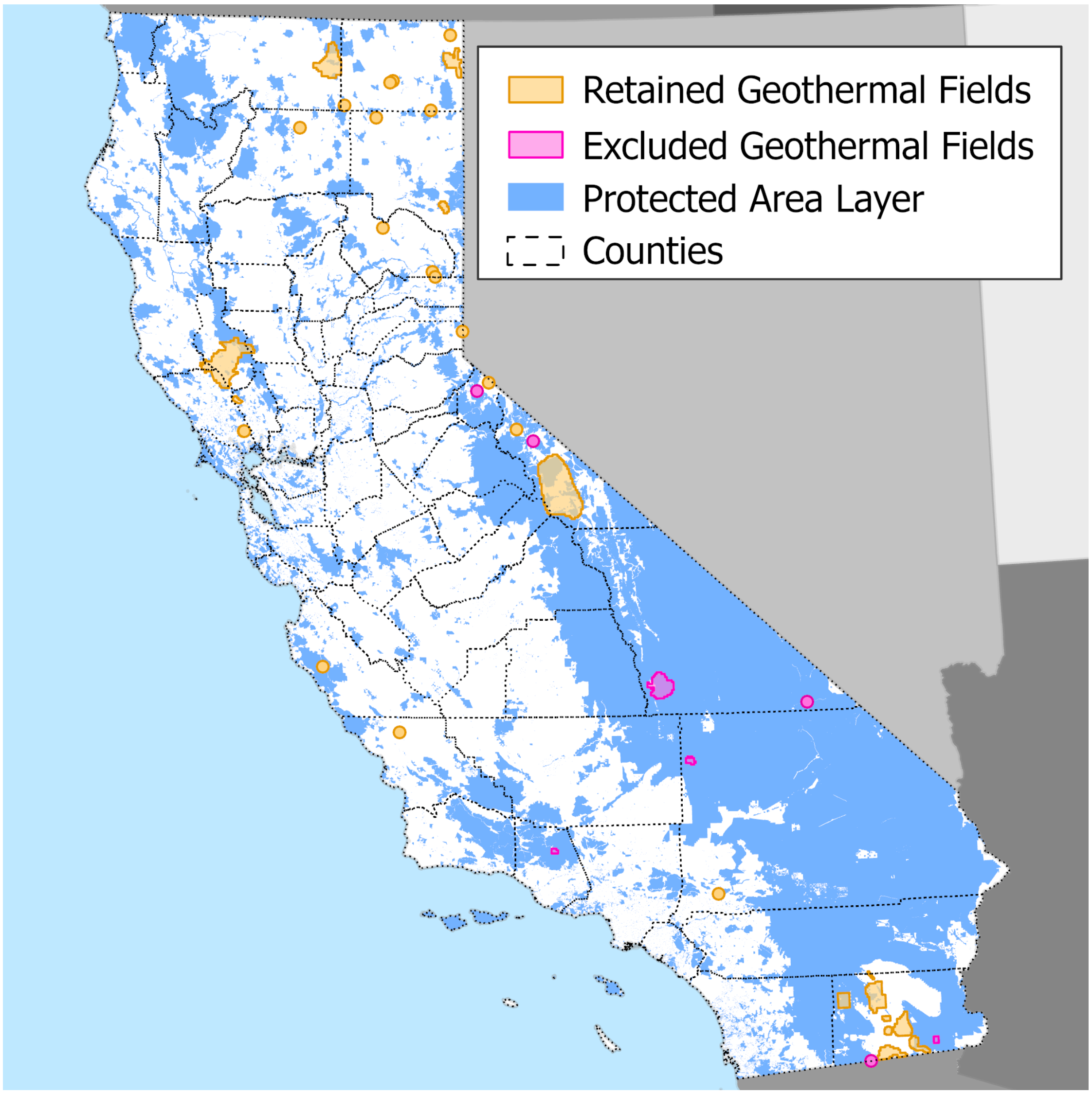
99 See *Quarterly Fuel and Energy Report (QFER) Data Tables,* available at https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/quarterly-fuel-and-energy-report-qfer-data

100 Lovekin, James W., Subir K. Sanyal, Christopher W. Klein. 2004. "New Geothermal Site Identification and Qualification." California Energy Commission: Public Interest Energy Research Program.

101 See Quarterly Fuel and Energy Report (QFER) Data Tables, available at https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/quarterly-fuel-and-energy-report-qfer-data

Areas that lie only partially in the protected areas have not been reduced or excluded because of the flexibility in developing steam fields and the relatively small footprint of geothermal power plants that may still provide opportunity for development. Among the larger geothermal fields, the protected area layer screen removes Coso Hot Springs, Sespe Hot Springs, and Dunes, and in total reduces the resource potential by a net of 182 MW.

Figure C-28: Protected Area Layer Screen Applied to Geothermal Resource Potential

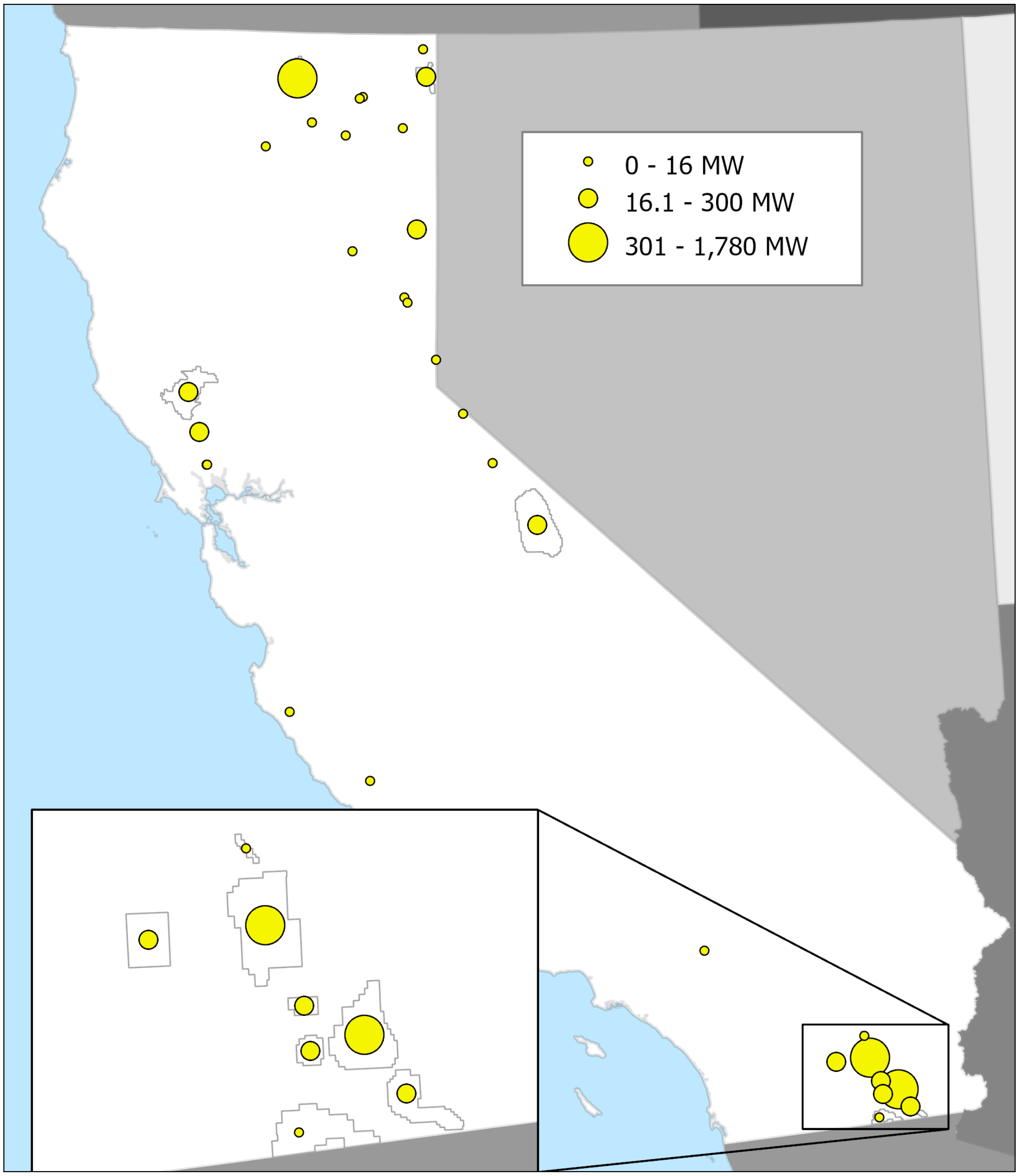


Source: CEC staff

This figure shows the spatial footprints of the geothermal fields that make up the statewide resource potential estimate. The footprints are overlayed onto the protected area layer and partitioned by color by the protected area layer exclusion. Note, the constructed geothermal fields are not drawn to scale.

Removing the geothermal resource areas and fields that are entirely within the protected area layer provides the final component needed to estimate the geothermal resource potential to use in statewide electric system planning. The total geothermal resource potential is 3,354 MW, and its distribution throughout the state is depicted by Figure C-29.

Figure C-29: Net Undeveloped Geothermal Resource Potential



Source: CEC Staff

This figure depicts the final distribution of resource potential after applying the land-use screen appropriate for geothermal and adjusting for the capacity that is already in production.

A summary table of all the components used in the geothermal resource potential estimate is given in Table C-9 below. The numbers in the ID column corresponds to the geothermal fields shown in the map of Figure C-27. This table shows the total resource potential in MW (Total MWe) available in those geothermal fields, the current electrical power generation in operation, the geothermal resource areas that are removed by the protected area layer exclusion (a value of 1 indicates an exclusion), and the net undeveloped electrical power generation potential in MW (the difference between the "Total MWe" and the "MW in Use" columns).

Table C-9: Final Results for Net Undeveloped Geothermal Resource Potential

ID	Name	Total MWe	MW in Operation	Protected Area Exclusion	Net Undeveloped MWe
1	Truckhaven	50		0	50
2	Brawley	138	49.9	0	88.1
3	Hot Mineral Spa	3		0	3
4	Calistoga	16.9		0	16.9
5	Coso Hot Springs	419.2	302.41	1	116.79
6	Dunes	18.5		1	18.5
7	East Brawley	358.5		0	358.5
8	East Mesa	202.7	74.9	0	127.8
9	Geysers	1096.1	850	0	246.1
10	Glass Mountain	365.6		0	365.6
11	Heber	159.6	161.5	0	0
12	Lake City - Surprise Valley 1	118.5		0	118.5
13	Mono - Long Valley	64.8	40	0	24.8
14	Randsburg	6.6		1	6.6
15	Salton Sea	2209.9	430.83	0	1779.07
16	Sespe Hot Springs	10.7		1	10.7
17	South Brawley	42.3		0	42.3
18	Wendel - Amedee	19.2		0	19.2
19	Fort Bidwell	9.1		0	9.1
20	Kelly HS	9.5		0	9.5
21	Canby (I'SOT)	9.4		0	9.4
22	Little Hot Spring (Fall River)	3.9		0	3.9
23	West Valley Reservoir	12.6		0	12.6
24	Kellog HS	5.4		0	5.4
25	Big Bend HS	4.9		0	4.9
26	Indian Valley Hot Springs	3.5		0	3.5
27	Marble Hot Well	3.5		0	3.5
28	Sierra Valley	3.5		0	3.5
29	Brockway Hot Springs	2		0	2
30	Carson River	15.7		0	15.7
31	Grovers HS	2.9		1	2.9
32	Fales HS	2.9		0	2.9
33	Travertine HS	2.8		1	2.8
34	Tasajara HS	3		0	3
35	Tecopa HS	9		1	9
36	Paso Robles	3.4		0	3.4
37	Arrowhead HS	7.1		0	7.1
38	Mt. Signal	14.7		1	14.7
39	Boyes HS	8.4		0	8.4
40	Sonoma Mission Inn	6.3		0	6.3

Source: CEC staff

For every geothermal field with enough information known about its electric generation potential, the total estimated capacity, the capacity currently in operation, the net undeveloped resource potential, and whether the field is excluded by the protected area layer is given in this table. The numbers in the ID column correspond to the geothermal fields shown in Figure C-27.

APPENDIX D:
Model Input and Data Thresholds

Table D-1: Datasets used in the Protected Area Layer

Dataset	Example Designations	Citation or hyperlink
PAD-US (CBI Edition)	National Parks, GAP Status 1 and 2, State Parks, Open Spaces, Natural Areas	2016. "PAD-US (CBI Edition) Version 2.1b, California." Conservation Biology Institute. https://databasin.org/datasets/64538491f43e42ba83e26b849f2cad28.
Conservation Easements		2022. "California Conservation Easement Database (CCED), 2022a." www.CALands.org.
Inventoried Roadless Areas		"Inventoried Roadless Areas." US Forest Service. https://www.fs.usda.gov/detail/roadless/2001roadlessrule/maps/?cid=stelprdb5382437.
BLM National Landscape Conservation System	Wilderness Areas, Wilderness Study Areas, National Monuments, National Conservation Lands, Conservation Lands of the California Desert, Scenic Rivers	https://gbp-blm-egis.hub.arcgis.com/datasets/BLM-EGIS::blm-ca-wilderness-areas https://gbp-blm-egis.hub.arcgis.com/datasets/BLM-EGIS::blm-ca-wilderness-study-areas https://gbp-blm-egis.hub.arcgis.com/datasets/BLM-EGIS::blm-ca-national-monuments-nca-forest-reserves-other-poly/
Greater Sage Grouse Habitat Conservation Areas (BLM)		2015. "Nevada and Northeastern California Greater Sage-Grouse Approved Resource Management

		Plan Amendment." US Department of the Interior Bureau of Land Management Nevada State Office. https://eplanning.blm.gov/public_projects/lup/103343/143707/176908/NVCA_Approved_RMP_Amendment.pdf
Other BLM Protected Areas	Areas of Critical Environmental Concern (ACECs), Recreation Areas (SRMA, ERMA, OHV Designated Areas), including Vinagre Wash Special Recreation Management Area, National Scenic Areas, including Alabama Hills National Scenic Area	https://gbp-blm-egis.hub.arcgis.com/datasets/BLM-EGIS::blm-ca-off-highway-vehicle-designations https://gbp-blm-egis.hub.arcgis.com/datasets/BLM-EGIS::blm-ca-areas-of-critical-environmental-concern https://gbp-blm-egis.hub.arcgis.com/datasets/BLM-EGIS::blm-az-area-of-critical-environmental-concern-polygon [Big Marias ACEC and Beale Slough Riparian and Cultural ACEC] BLM, personal communication, November 2, 2022.
Mono Basin NFSA		https://pcta.maps.arcgis.com/home/item.html?id=cf1495f8e09940989995c06f9e290f6b#overview
Terrestrial 30x30 Conserved Areas	Gap Status 1 and 2	2021. "30x30 Conserved Areas, Terrestrial." CA Nature. https://www.californianature.ca.gov/datasets/CAnature::30x30-conserved-areas-terrestrial/.

CPAD	Open Spaces and Parks under city or county level	2022. "California Protected Areas Database (CPAD), 2022b". https://www.calands.org/cpad/.
USFS Special Interest Management Areas	Research Natural Areas, Recreation Areas, National Recreational Trail, Experimental Forest, Scenic Area	https://data-usfs.hub.arcgis.com/datasets/usfs::special-interest-management-areas-feature-layer/about
Proposed Protected Area	Molok Luyuk Extension (Berryessa Mtn National Monument Expansion)	CalWild, personal communication, January 19, 2023.

Source: CEC staff

Table D-2: Query Definition for Components of Protected Areas

Dataset	SQL Query
PAD-US (CBI Edition)	p_des_tp IN ('Wild, Scenic and Recreation River', 'Area of Critical Environmental Concern', 'Ecological Reserve', 'National Conservation Area', 'National Historic Site', 'National Historical Park', 'National Monument', 'National Park General Public Land', 'National Preserve', 'National Recreation Area', 'National Scenic Area', 'National Seashore', 'Wilderness Study Area', 'Wilderness Area', 'Wildlife Management Area', 'State Wildlife Management Area', 'State Park', 'State Recreation Area', 'State Nature Preserve/Reserve', 'State Natural Area', 'State Ecological Reserve', 'State Cultural/Historic Area', 'State Beach', 'Special Management Area', 'National Wildlife Refuge', 'Natural Area', 'Nature Preserve', 'Research Natural Area') Or s_des_tp IN ('Natioanal Monument', 'National Monument', 'National Park General Public Land', 'National Preserve', 'National Recreation Area', 'National Scenic Area', 'National Seashore', 'National Conservation Area', 'Area of Critical Environmental Concern', 'National Wildlife Refuge', 'State Park', 'State Wildlife Area', 'State Wildlife Management Area', 'State Wildlife Refuge', 'State Ecological Reserve', 'Wild, Scenic and Recreation River', 'Wilderness Area', 'Wildlife Management Area') Or t_des_tp IN ('National Monument', 'National Park General Public Land', 'National Recreation Area', 'Area of Critical Environmental Concern', 'National Conservation Area', 'State Wildlife Management Area', 'Wild, Scenic and Recreation River', 'Wildlife Management Area') Or p_loc_ds IN ('Ecological Reserve', 'Research and Educational Land') Or gap_sts IN ('1', '2') Or own_type = 'Private Conservation Land' Or (own_type = 'Local Land' And (p_des_tp LIKE '%"Open Space"%' Or p_des_tp LIKE '%Park%' Or p_des_tp LIKE '%Recreation Area%' Or p_des_tp LIKE '%Natural Area%')) Or (p_des_tp = 'Other State Land' And (p_loc_ds IN ('State Vehicular Recreation Area', 'BLM Resource Management Area', 'Resource Management Area') And gap_sts <> '2'))
CPAD	AGNCY_LEV IN ('City', 'County') And ACCESS_TYP = 'Open Access' And (UNIT_NAME LIKE '%Park%' OR UNIT_NAME LIKE '%Open Space%' OR UNIT_NAME LIKE '%park%' OR

	UNIT_NAME LIKE '%Recreation Area%' OR UNIT_NAME LIKE '%Natural Area%' OR GAP2_acres > 0 OR GAP1_acres >0)
Greater Sage-Grouse Habitat Conservation Areas (BLM)	For Solar Technology: BLM_Managm IN ('PHMA', 'GHMA', 'OHMA') For Wind Technology: BLM_Managm = 'PHMA'

Source: CEC staff

Table D-3: Biological Planning Priorities Input Datasets

Dataset Name	**Source**	**Usage**
Terrestrial Biodiversity	2018. "Terrestrial Biodiversity Summary." California Department of Fish and Wildlife. https://wildlife.ca.gov/Data/Analysis/Ace#523731770-species-biodiversity	Rank 5 in Core and SB 100 Terrestrial Climate Resilience Study Screens
Terrestrial Connectivity	2018. "Terrestrial Connectivity." California Department of Fish and Wildlife. https://wildlife.ca.gov/Data/Analysis/Ace#523731772-connectivity	Ranks 4 and 5 in Core and SB 100 Terrestrial Climate Resilience Study Screens
Terrestrial Irreplaceability	2018. "Terrestrial Irreplaceability." California Department of Fish and Wildlife. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=150816&inline	Ranks 4 and 5 in Core and SB 100 Terrestrial Climate Resilience Study Screens
Critical habitat	[1] 2015. "FWS HQ ES Critical Habitat." US Fish and Wildlife Service. https://hub.arcgis.com/datasets/fws::fws-hq-es-critical-habitat. [2] 2013. "USFWS Proposed Critical Habitat Map." https://www.bistatesagegrouse.com/general/page/maps-gis GIS Data: BSSG_ALL_UNITS_PCH_FINAL.shp	Core and SB 100 Terrestrial Climate Resilience Study Screens

Wetlands	2022. "Habitat and Land Cover (FVEG Derived)." CA Nature. https://www.californianature.ca.gov/maps/habitat-and-land-cover-fveg-derived	Wetlands Category of Habitat and Land Cover in Core and SB 100 Terrestrial Climate Resilience Study Screens

Source: CEC staff

Table D-4: Cropland Index Input Data

Dataset Name	Source	Usage
Gridded Soil Survey Geographic (gSSURGO) Database	Soil Survey Staff. 2020. "The Gridded Soil Survey Geographic (gSSURGO) Database for California." United States Department of Agriculture, Natural Resources Conservation Service. https://gdg.sc.egov.usda.gov/	Provides CA Revised Storie Index, Electrical Conductivity, and Sodium Adsorption Ratio for the CEC Cropland Index Model for Core and SB 100 Terrestrial Climate Resilience Screens for solar resource potential
California Important Farmland	2022. "2018 California Important Farmland." Farmland Mapping and Monitoring Program." California Department of Conservation. https://www.conservation.ca.gov/dlrp/fmmp	Prime Farmland, Unique Farmland, Farmland of Statewide Importance, and those designation's footprint are used in the CEC Cropland Index Model for Core and SB 100 Terrestrial Climate Resilience Screens for solar resource potential.
California Statewide Crop Mapping (2019)	2022. "2019 California Statewide Crop Mapping." California Department of Water Resources. https://data.cnra.ca.gov/dataset/statewide-crop-mapping	The footprint is used as part of the mask for the CEC Cropland Index Model for Core and SB 100 Terrestrial Climate Resilience Screens for solar resource potential.

Source: CEC staff

Table D-5: Additional Input Datasets for Screens

Dataset Name	Source	Usage
Terrestrial Landscape Intactness	Degagne, R., J. Brice, M. Gough, T. Sheehan, and J. Strittholt. 2016. "Terrestrial Landscape Intactness 1 kilometer, California." Conservation Biology	Core and SB 100 Terrestrial Climate Resilience Study Land-Use Screens

	Institute.https://databasin.org/datasets/e3ee00e8d94a4de58082fdbc91248a65/	
Terrestrial Climate Change Resilience	2018. "Terrestrial Climate Change Resilience." California Department of Fish and Wildlife. https://wildlife.ca.gov/Data/Analysis/Ace#523731773-climate-resilience	SB 100 Terrestrial Climate Resilience Study Land-Use Screen
BLM Existing Project Footprints	BLM, personal communication, January 31, 2023.	case_disp_txt = "AUTHORIZED" is used in the Core and SB 100 Climate Resilience Study Land-Use Screens
DRECP development focus areas (DFAs), variance process lands (VPLs) and general public lands (GPLs)	[1] 2016. "BLM LUPA Renewable Energy Designations." Conservation Biology Institute. From DataBasin.org: https://databasin.org/datasets/c61b0e256e494fc5b6958d6c3999a19a/. [2] 2016. "BLM LUPA General Public Lands." Conservation Biology Institute. From DataBasin.org: https://databasin.org/datasets/1cb6eabad6bf48b5b8e24f45b33ff028/.	VPL and GPLs were added as technical resource potential in the resource potential basemap. DFAs were partitioned by technology type. For Solar technology, subset query Technology IN ('Solar and Geothermal', 'All Technologies') were allowed in the resource potential basemap, while Technology = 'Geothermal' was excluded. For Wind technology, subset query Technology IN ('All Technologies') was allowed in the resource potential basemap, while Technology IN ('Geothermal', 'Solar and Geothermal') was excluded.

Source: CEC staff

Table D-6: Geothermal Resource Assessment

Source	**Usage**
Williams, Colin F., Marshall J. Reed, Robert H. Mariner, Jacob DeAngelo, and S. Peter Galanis, Jr. 2008. "Assessment of Moderate- and High-Temperature Geothermal Resources of the United States." U.S. Geological Survey Fact Sheet. 2008-3082. https://pubs.usgs.gov/fs/2008/3082/.	Provided generating capacity estimates for all geothermal fields except for Truckhaven. Subset of data used: State='CA'

GIS Data: *Geothermal Systems* https://certmapper.cr.usgs.gov/server/rest/services/geothermal/westus_favoribility_systems/MapServer/0	
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 KGRAs
CalGEM Field Administrative Boundaries GIS Data: https://gis.conservation.ca.gov/portal/home/item.html?id=07b08eaaee0842caa8fc258cbdc7d319#overview	Provided spatial footprint of geothermal fields not listed as a KGRA. Subset of data used: FIELD_CODE IN ('G1-‘,’G2-‘,’G3-‘)

Source: CEC staff