



Bren School of Environmental Science & Management
University of California, Santa Barbara

The Future of Large-Scale Solar Energy in California

A Group Project submitted in partial satisfaction of the requirements for the degree
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The mission of the Bren School of Environmental Science & Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Group Project is required of all students in the Masters of Environmental Science and Management (MESM) Program. It is a three-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

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Abstract

The development of large-scale solar energy (LSSE) in the California desert is of vital importance to the state's renewable energy objectives. LSSE development can help California meet its 33 percent Renewable Portfolio Standard by 2020. Recently, shifts in state and federal policies and in economics have stimulated a boom in solar utility development. The CDCA is the most attractive location for solar development due to high solar insolation; however, the impacts of such development on desert ecosystems are largely unknown. We created six potential future LSSE development scenarios to quantify the range of possible resource impacts and calculated how much energy each scenario would contribute to California's electricity supply by 2020. Next, we incorporated three different LSSE technology portfolios into each development scenario to show how resource impacts vary with technology selection. These scenarios and portfolios help estimate the likely cumulative land and water resource requirements of future LSSE developments in the CDCA. Through spatial analysis we eliminated land in the CDCA unavailable for solar development, and then ranked the suitability of the remaining land as high, medium, or low for solar development. The ranking is based on proximity to infrastructure, sensitive species habitat, and water availability. This spatial analysis indicates the most suitable land for solar development and provides a visual representation of the land required by the likely solar scenarios. Finally, this study provides recommendations for our client regarding the future of LSSE in California and locations where solar development would be most suitable.

Executive Summary

Large-scale solar energy (LSSE) development is experiencing unprecedented growth in California. In 2010 alone, nine large-scale solar energy facilities were approved for construction on public lands. These facilities have the potential to provide 4,000 megawatts of capacity – a tenfold increase in the current solar power capacity. This growth in solar development in California has led to an ongoing debate on the tradeoffs between renewable energy as a means of mitigating climate change, and the resource impacts this development will cause.

This Master's Group Project takes a broad look at what is currently driving LSSE development in California and projects how these drivers will shape the trajectory of future development. The project quantifies LSSE's contribution to California's 2020 electricity generation and the resource impacts that result from this level of contribution. Additionally, this study includes a comprehensive spatial analysis that indicates where LSSE facility siting is most likely to occur with the least impact on water availability and sensitive species habitat.

The **three primary objectives** of our research include:

1. Project LSSE's contribution to California's electricity supply in 2020.
2. Estimate the range of LSSE impacts on land area and water use as a function of technology and existing energy policy.
3. Within the CDCA, to show where development within the CDCA may have the least impact on water resources and sensitive species habitat.

Background

Most of the LSSE development is happening in the southwestern desert regions of California, which are characterized by high insolation levels, arid climate, scarce water resources, an abundance of open space, and a large amount of publicly owned lands. California deserts are also home to sensitive plant and animal species, several unique ecosystems and valued cultural resources. Proposed LSSE plants therefore have the potential to impact a wide range of natural and cultural resources in the California desert regions.

Because LSSE has large impacts on species' habitat, water use and land area, the process of applying for state and federal permits is one of the major challenges facing LSSE developers. Operating within a limited timeframe, developers want to move through the permitting process as quickly as possible in order to remain competitive. This challenge has created new business opportunities for our client, AECOM.

In the last three years, AECOM Environment, based in Camarillo, CA, has worked to guide solar power developers through the complex permitting process required for licensing of LSSE projects in California. AECOM proposed this Bren Group Project because it was seeking insight into the macro-level trends driving solar utility permitting.

Policy Drivers

California law currently mandates that 20 percent of the state's electricity be sourced from renewable sources by 2010, and Governor Schwarzenegger has issued an Executive Order raising this target to 33 percent by 2020 (Schwarzenegger, 2009). In addition, California's Global Warming Solutions Act of 2006 (AB 32) set an economy-wide cap on the state's GHG emissions at 1990 levels by 2020. At the national level, the American Recovery and Reinvestment Act (ARRA) provided a 30 percent cash incentive on investments by solar developers if they begin construction on their project before the end of 2011.

These recent state policies have created a demand for solar energy, while the federal ARRA opportunity has created an attractive way for developers to increase the supply of renewable energy.

Methodology

1. Solar Electricity Demand Scenarios

- Reviewed national, state and local policies and programs to understand the key drivers for growth in the LSSE industry.
- Developed six solar electricity demand scenarios representing LSSE's potential contribution to California's electricity supply in 2020.

2. LSSE Technology Portfolios

- Reviewed solar industry reports and documents to identify current LSSE technology trends.
- Selected six different types of LSSE projects that have been recently permitted. These representatives of each LSSE technology are used in our land and water use calculations.
- Reviewed selected project application documents for technology parameters, including land-use efficiency and water-use requirements.
- Developed three distinct technology portfolios that represent three possible LSSE technology mixes for 2020.

3. Land and Water-Use Impacts of Future Scenarios

- Applied each technology portfolio to each demand scenario to calculate the different projections of energy that LSSE could contribute to California in 2020.
- Estimated the range of land-use and cumulative water-use impacts for the sixteen permutations of future solar electricity demand scenarios.

4. Spatial Analysis

- Conducted using ESRI's *ArcGIS* software and was limited to the 25 million acre California Desert Conservation Area (CDCA).

Solar Development Constraints

- Identified and removed all land areas that are not compatible with LSSE development in the CDCA from the available land for solar development: "hard" constraints.

Siting Criteria

- Identified four criteria to determine the suitability of siting LSSE projects: proximity to roads, proximity to transmission lines, water resources, and sensitive species habitat: "soft" constraints.

Suitability Analysis

- Developed a set of suitability maps with each of the four siting criteria weighted differently.

Key Findings

1. Solar Electricity Demand Scenarios

- Continually changing national, state, and local policies make predicting LSSE future contribution to California's energy mix in 2020 difficult.
- LSSE currently provides 0.27 percent of California's electricity demand – this is the lower bound for 2020.
- California's current RPS calls for 33 percent renewable energy by 2020 – this is the theoretical upper bound for 2020; however, it is highly unlikely that solar can supply all of this.
- Based on current energy policy, availability of funding, competition with out-of-state LSSE developers and technology trends, the most realistic range that we expect LSSE to meet in 2020 is between 3.3 percent and 9 percent of California's electricity demand.

2. LSSE Technology Portfolios

- Our three portfolios are comprised to reflect the following technology mixes:
 - o *Portfolio A* is based on the *currently* operational solar plants in California.
 - o *Portfolio B* is based on projects that are currently operational, approved, and under review in California.
 - o *Portfolio C* assumes a future technology mix where photovoltaics (PV) make up half of the technology mix. This is based on an assumption that PV costs will decrease significantly.
- We anticipate Portfolio B being the most likely future technology portfolio due to its use of less water-intensive “dry-cooled” technologies.

3. Land and Water Use Impacts of Future Scenarios

- Solar facilities’ land-use and water-use requirements vary by nameplate capacity, technology type, and sometimes on-site mitigation requirements.
- Land-use requirements for the different technologies range from 5 to 12 acres/MW.
- Water-use requirements range from 0.5 to 1,190 gallons/MWh for operational water use.
- Land area required is primarily influenced by the solar electricity demand scenario, which dictates how much development will occur, while water use is influenced by the technology portfolio.
- The greatest water savings are in technology portfolio C which favors photovoltaic technologies. The water footprint under each scenario for Portfolio B is only slightly larger than Portfolio C, with a reduced impact on land.
- To supply our projected range of electricity demand in 2020, 3.3 to 9 percent, a range of 38,000 to 100,000 acres and 53,500 and 121,000 cumulative acre-feet will be required using a technology mix similar to Portfolio B.

4. Spatial Analysis

Solar Development Constraints

- “Hard” constraints, where solar development is illegal or physically impossible, include (1) physical obstacles (e.g., water bodies, urban areas, steep slopes); (2) areas that are legally incompatible with development (e.g., national parks, national monuments, state parks, wilderness areas); and (3) areas with conflicting use or permitting obstacles.
- Within the 25 million acre CDCA, about 6.7 million acres of land is considered potentially available for solar development, which is equal to 26 percent of the total CDCA.
- A “Soft” constraint, where LSSE development may be feasible but not suitable, includes land areas that: are beyond 20 miles from transmission lines and major roads, are above adjudicated groundwater basins, and are federally designated critical habitat for endangered species.
- Within the CDCA, 3.9 million acres of land is considered suitable for solar development, which is equal to 15 percent of the total CDCA.

Siting Criteria

Transmission and Roads

- o Proximity to transmission is a higher priority for developers than proximity to roads; however, both affect project cost and the suitability of a solar development site.

Water Resources

- Use of recycled water is favored over groundwater and surface water resources; however, it is not available in abundance due to limited access to Waste Water Treatment Plants in the CDCA.
- Many groundwater basins are not suitable for power plant cooling uses.

Sensitive Species Habitat

- The CDCA is home to 14 threatened or endangered wildlife species and 10 threatened or endangered plant species and predicted distributions of these sensitive species habitat overlap with areas available for solar development.
- Conflicts with sensitive species habitat can cause serious permitting setbacks.

Suitability Analysis

- The available land in the western part of the CDCA typically had low suitability values, while the land in the eastern regions was characterized with medium to high suitability scores.
- Groundwater availability and technology strongly influence the amount of highly suitable land available for solar development.

Conclusions and Recommendation

LSSE can significantly reduce GHG emissions resulting from the generation of electricity by displacing the need for new fossil-fuel powered facilities. As California's population and energy demand grow over the next decade, LSSE will play an important role in helping the state reach its mandated GHG reductions. This report shows that there is enough land available in the CDCA to accommodate the development of LSSE in the amounts we project to be most likely; however, water availability is likely to be an increasingly important constraint on LSSE development. With careful planning, it is possible to site LSSE plants in areas that are more suitable for development. However, development in these "most suitable" places still comes with significant resource impacts and tradeoffs that are likely to be contentious.

With this in mind, we have developed a set of recommendations based on our findings, which we hope will help AECOM and others interested and invested in the future of renewable energy development in California to evaluate the tradeoffs and move forward along the path to a sustainable energy future.

- AECOM should develop capacity within their firm to predict future solar electricity demand and associated resource impacts, as those will indicate the direction of future business opportunities.
- AECOM should anticipate a decrease in the rate of solar thermal permitting activity in 2012 due to a decrease in demand for new renewable energy contracts and the expiration of the ARRA cash grants at the end of 2011.
- AECOM should be prepared to shift their focus from permitting solar thermal plants to large-scale solar PV, particularly if PV prices decrease.
- AECOM should use the LSSE suitability maps produced in this report in combination with other resources when working with developers to identify potential LSSE sites in order to reduce the number of complications during the permitting process.
- Future studies should be conducted in the areas of water resource availability, sensitive species habitat, cumulative ecological impacts, land use compatibility with solar development, and transmission capacity.

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List of Acronyms

AB	Assembly Bill
AFC	Application for Certification
ARRA	American Recovery & Reinvestment Act of 2009
BLM	Bureau of Land Management
BLM SS	Bureau of Land Management Sensitive Species
CARB	California Air Resources Board
CDCA	California Desert Conservation Area
CDFG	California Department of Fish and Game
CEC	California Energy Commission
CESA	California Endangered Species Act
CNPS	California Native Plant Society
CPUC	California Public Utilities Commission
CREZ	Commercial Renewable Energy Zones
CSP	Concentrating Solar Power
CSSC	California Species of Special Concern
DOE	Department of Energy
DOI	Department of Interior
DRECP	Desert Renewable Energy Conservation Plan
DWMAs	Desert Wildlife Management Areas
DWR	Department of Water Resources
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ESA	Federal Endangered Species Act
GBIF	Global Biodiversity Information Facility
GW	Gigawatt
GWh	Gigawatt-hour
HCP	Habitat Conservation Plan
HTF	Heat Transfer Fluid
IOU	Investor-Owned Utility
LSSE	Large-Scale Solar Energy
LTVAs	Long-Term Visitor Areas
MW	Megawatt
MWh	Megawatt-hour
NCCP	Natural Community Conservation Plan
NPDES	National Pollutant Discharge Elimination System
OHV	Off-Highway Vehicles
PV	Photovoltaic
REAT	Renewable Energy Action Team
RETI	Renewable Energy Transmission Initiative
ROI	Region of Interest

ROW	Right of Way
SB	Senate Bill
SDM	Species Distribution Model
SEGS	Solar Energy Generating Systems
SEIA	Solar Energy Information Association
SESA	BLM Solar Energy Study Area
SPEIS	Solar Programmatic Environmental Impact Statement
SWP	State Water Project
SWRCB	State Water Resources Control Board
TES	Thermal Energy Storage
TWh	Terawatt-hour
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
UTM	Universal Transverse Mercator
WSRs	Wild and Scenic Rivers
WWTP	Wastewater treatment plant

1. Introduction

As concern over global climate change resulting from the emissions of greenhouse gases (GHGs) increases, renewable energy technologies provide a solution to reducing carbon emissions from electricity generation (IPCC, 2007). In response to this concern, California has been experiencing an unprecedented boom in large-scale solar energy (LSSE) development in the last three years. From 1990 to 2010, there has been a total of 400 megawatts (MWs) of LSSE facilities operating in California (CEC, 2010b). In 2010, these existing facilities supplied only 0.27 percent of the power needed to fulfill California's annual electricity demand. At the current rate of permitting, California is on track to have 4,000 MWs of new LSSE in operation by 2016 (CPUC, 2011).

Legislation to regulate GHGs and encourage the use of renewable energy technology is becoming increasingly prevalent. The recent surge in the rate of solar energy development in California is driven by state and federal policies attempting to reduce GHG emissions. At the state level, Assembly Bill (AB) 32 and the Renewable Portfolio Standard (RPS) have successfully used policy mechanisms to generate demand for renewable energy in the utility market (CPUC, 2010). Under the RPS, Investor-Owned Utilities (IOUs) are required to procure 33 percent of their electricity from renewable resources by 2020 (Schwarzenegger, 2008). At the federal level, funding from the American Recovery and Reinvestment Act of 2009 (ARRA) has enabled an increase in the supply of renewable energy generation (Goodward & Gonzalez, 2010). This relatively uncoordinated combination of state and federal policies have combined to catalyze the development of solar utilities in California at an exponential rate, leading to conditions which are ripe for rapid growth in the LSSE industry.

The area in which the bulk of the proposed LSSE development is focused is the California Desert Conservation Area (CDCA). This region, which makes up nearly one quarter of the state's land area, is home to a wealth of unique plant and animal species, several distinct ecosystems, and cultural resources with immense value to the people who are connected to the land (Fernandes *et al.*, 2010). The CDCA is also characterized by an arid climate and sparse

water resources (Fernandes *et al.*, 2010). This area is especially favorable for LSSE development because of locally high insolation levels, an abundance of open space, and the availability of publicly owned land (Fernandes *et al.*, 2010).

LSSE is defined for this study as any utility-scale facility that has a cumulative nameplate capacity of 50 MWs or more and operates far from where the produced electricity is consumed. There are multiple types of specific solar technologies that fall under the heading of LSSE. The distinction between the different technologies is important because each type of technology has different resource requirements and impacts. The land-use efficiency (acres/MW cumulative capacity) and the water-use efficiency (acre-feet of water/MWhs produced) vary considerably for different LSSE technologies. The differences in resource efficiency between the various types of solar technologies become increasingly important as LSSE is developed at larger scales.

1.1 Problem Statement

In order to meet the 2020 RPS deadline and take advantage of the federal funding while it is available, renewable energy developers are seeking to move as quickly as possible to get their projects approved and under construction. This process of solar development in the CDCA is complicated by the fact that LSSE projects must pass through a rigorous and potentially expensive permitting and environmental review process before being approved by state and federal regulators. The permitting process is required because LSSE has large and permanent impacts on species habitat, water use, and land area. Because of these impacts, many proposed developments face problems with litigation, financing, siting, and permitting that slow down, or halt, the development process and increase costs significantly.

The client for this Bren Group Project, AECOM, works with LSSE developers to navigate the permitting and licensing process. In 2010, AECOM identified a need for more information on how this rapidly changing industry may impact its business operations, as well as the future of the CDCA, and how California as a whole may achieve its ambitious renewable energy goals. At the core of this Bren Group Project is the understanding that tradeoffs are inherent in the development of any large-scale renewable energy project. To address this need for deeper

understanding of LSSE development in California, this project was proposed by AECOM to quantitatively compare the tradeoffs between the renewable energy gained by LSSE development and the resource impacts of the solar industry's expansion within the CDCA.

1.2 AECOM

AECOM is a large international corporation invested in the mission "to enhance and sustain the world's built, natural, and social environments" (AECOM, 2010). In the last three years, AECOM's Camarillo office has worked to guide solar power developers through the complex permitting process required for licensing LSSE in California. As a result of working closely with solar project applicants and regulatory agencies, AECOM is experienced in the full arc of a project's trajectory: project design and proposal, application, permitting, and mitigation. AECOM proposed this Bren Group Project because it was looking for insight into the macro-level trends driving solar utility permitting.

The primary questions to be answered for AECOM include:

- Given current trends, how much solar development will occur by 2020?
- Which solar technologies are likely to be permitted?
- Where is LSSE development most likely to be permitted quickly?

1.3 Objectives

For the purpose of informing AECOM, the solar industry and the California public, this Bren Group Project will quantify the future development of LSSE in California and the resource impacts that may result. The three primary objectives of our research include:

1. Project LSSE's contribution to California's electricity supply in 2020.
2. Estimate the range of LSSE impacts on land area and water use as a function of technology and existing energy policy.
3. Within the CDCA, show where development may have the least impact on water resources and sensitive species habitat.

To fulfill these objectives, we analyze how shifting energy policy and technology trends will impact the amount of energy that LSSE will contribute to California's electricity supply in

2020. Our results include a set of possible future scenarios for LSSE development, and considering the different types of LSSE technologies most likely to be utilized, we provide an estimate of the land-use and water-use impacts for the different scenarios. Finally, we identify areas within the CDCA that are most suitable for development when prioritizing different criteria critical to solar project siting. These steps allow us to provide to AECOM a set of projections on the expected pace and the extent of LSSE permitting in the next five years of solar utility development.

1.4 Significance

This Bren Group Project has the opportunity to inform AECOM as well as developers, regulators, and the public on the role solar development will play in California over the next decade. By presenting a decadal-scale view of solar energy development, we offer a previously unavailable perspective on solar electricity's potential for meeting California's energy needs. This information will help AECOM anticipate development trends and move its operations strategically through the quickly changing energy marketplace. Understanding the big picture dynamics of regulatory and business arenas is extremely challenging due to the pace at which the solar industry is growing. Our study has the potential to inform the decisions of developers, regulators, and the public concerning solar technology selection, the desirable amount of solar development, the siting of new utilities, and the resource costs that accompany those decisions.

2. Energy Policy

The recent increase in the rate of LSSE development in California is a direct result of changing energy policies. The history of California and U.S. energy policy is critical to understanding the larger picture of current and future LSSE development in California.

2.1 AB 32

In 2006, the California Legislature passed AB 32, the Global Warming Solutions Act, a comprehensive piece of GHG legislation with significant implications for California's energy policy and future (Pfannestiel & Peevey, 2008). Among other provisions, AB 32 set an economy-wide cap on the state's GHG emissions at 1990 levels by 2020. This cap is approximately an 11 percent reduction from current emission levels and a 30 percent drop from business-as-usual projections (Pfannestiel & Peevey, 2008). AB 32 is the founding policy driver behind the push for California's climate change mitigation measures and renewable energy developments.

2.2 The California Renewable Energy Portfolio Standard

California's RPS is among the most ambitious in the United States (CPUC, 2010). Established by Senate Bill (SB) 1078 in 2002, and expanded in 2006 under SB 107, the RPS applies to the state's three investor-owned electric utilities (IOUs), which are regulated by the California Public Utilities Commission (CPUC). The CPUC is charged with both setting the RPS targets and ensuring compliance (CPUC, 2011). In 2002 the RPS required each IOU to procure 17 percent of their retail electricity from renewable sources by 2010, and in 2006 this requirement was increased to 20 percent (CPUC, 2010).

In November 2008, Governor Schwarzenegger signed Executive Order (E.O.) S-14-08, boosting the state's renewable energy target to 33 percent by 2020 (Schwarzenegger, 2008). This rulemaking spurred the first flurry of solar utility permit applications shortly after it was announced (CPUC, 2011). In 2009, the Governor issued E.O. S-21-09, directing the California Air Resources Board (CARB) to adopt regulations to achieve the increased RPS target (Schwarzenegger, 2009). This extended the reach of the standard to apply to public power entities overseen by CARB in addition to the IOUs regulated by the CPUC.

As of January 2011, the IOUs have not met the requirement to procure 20 percent of their electricity from renewable sources (CPUC, 2011). At the end of 2009, the total amount of renewable electricity purchased by the IOUs amounted to 15 percent (CPUC, 2011). Still, the IOUs report that they have signed enough contracts with wind and solar utility developers both

in and out of state to reach their 33 percent renewable electricity goal by 2020. Nearly 40 percent of the generation capacity represented in these contracts is from solar power (CPUC, 2011). However, there is no guarantee that all of the existing contracts will be fulfilled. Financing, siting, and permitting challenges could prevent development for many of these proposed projects. However, the contracts are a strong indication that renewable energy is on track to reach the December 31, 2020 deadline, with solar contributing a sizable proportion of that energy.

2.3 The American Recovery & Reinvestment Act of 2009

The ARRA, which was approved by Congress in February 2009, made many changes to previously existing tax credits for renewable energy by extending and increasing available benefits (Goodward & Gonzalez, 2010). The two most important changes that are directly affecting solar development are the Treasury Cash Grant and the Investment Tax Credit. The Treasury Cash Grant offered a reimbursement for 30 percent of capital expenses to solar developers if they began construction by December 31, 2010 (CPUC, 2010). The announcement of the Treasury Cash Grant was the spark that started the blaze of solar permit applications seen throughout 2009 and early 2010, with developers attempting to make it through the permitting and approval process for development and get licensed by the end of 2010, in less than eighteen months. Previously, eighteen months from proposal to permitting had been remarkably fast to get through the process. The anticipated expiration of the Treasury Cash Grant also saw nine large solar utilities permitted in the four months preceding its expiration (CPUC, 2010). At the end of 2010, the Treasury Cash Grant was extended for one more year (Department of Treasury, 2011) to enable more renewable energy developers to take advantage of this highly popular development incentive. Barring unforeseen developments, this extension is likely to result in an equal or greater number of solar utilities breaking ground in 2011.

The Investment Tax Credit is similar to the Treasury Cash Grant, but offers a 30 percent tax break on capital expenses for renewable energy facilities, rather than a cash payment (Goodward & Gonzalez, 2010). The Investment Tax Credit is not as strong an incentive for solar

development as the Treasury Cash Grant, but once the Treasury Cash Grant expires it will take on a larger role, as it will be available until 2016 (Goodward & Gonzalez, 2010). These two federal financial incentives have significantly increased the pace at which developers have submitted permit applications for development. Concurrently, other federal actions are attempting to streamline the permitting process in order to increase the speed of renewable energy development on federal lands. For example, in December of 2010, the BLM released its Solar Draft Programmatic Environmental Impact Statement (SPEIS), outlining best practices for solar development on public lands in six western states (Department of Interior, 2010). This move by the Department of the Interior illustrates that although a cohesive federal policy on renewable energy, such as a climate bill or national RPS, has still not been achieved, that there is considerable momentum behind renewable energy development.

2.4 The Future of Energy Policy & Solar Development

How energy policy will affect solar development in the future is unclear. However, recent events indicate that political support in favor of renewable energy development will continue to remain steady and even increase. In November 2010, California voters rejected Proposition 23, a measure that sought to suspend AB 32. On January 25, President Obama set an ambitious goal for the nation of 80 percent clean electricity by 2035 (Obama, 2011). As one of the steps towards reaching that goal, the Department of Energy (DOE) has been granted 27 million dollars in research and development funding for the “Sunshot” initiative (DOE 2011). This program’s objective is to reduce the installed cost of large scale photovoltaic systems by 75 percent by 2020 (DOE 2011). The current mood at the federal and state level shows that renewable energy development remains politically popular and is likely to continue to receive support and investment in the foreseeable future.

3. Solar Electricity Demand Scenarios

3.1 Projected Energy Use in 2020

For the purpose of our study, we used the *California Energy Demand 2010-2020 Forecast*, which was adopted by the CEC in December of 2009 (referred to as the *CED 2009 Adopted*). This forecast presents electricity and peak demand for the state as a whole, incorporating potential energy efficiency program impacts as well as the impacts of the economic downturn in 2008. The energy consumption and peak forecasts in the *CED 2009 Adopted* are lower than previous forecasts because they add 2007 and 2008 consumption data to the historical series and incorporate a 15 percent increase in electricity rates between 2010 and 2020 (Kavalec & Gorin, 2009).

In the *CED 2009 Adopted*, population is projected to grow at about 1.2 percent annually between 2010 and 2020. This is based on demographic projections made in the California Department of Finance's most recent long-term population forecast (Kavalec & Gorin, 2009). The base economic outlook took into consideration the current recession, but in the longer term, the economy is projected to recover. In terms of conservation and efficiency, the *CED 2009 Adopted* accounts for all conservation that is "reasonably expected to occur" due to implementation of conservation programs or market-driven energy efficiency. The *CED 2009 Adopted* also accounts for programs designed to promote self-generation and future use of electric vehicles (Kavalec & Gorin, 2009).

Based on the *CED 2009 Adopted*, total electricity consumption in California in 2020 is expected to be 316 Terawatt-hours (TWh).

3.2 Large-Scale Solar Energy Contribution to the RPS

California's RPS mandates that 20 percent of California's electricity be met with renewable sources by 2020. Specifically, the RPS "requires retail sellers (defined as IOUs, electric service providers, and community choice aggregators) to increase renewable energy as a percentage of their retail sales to 20 percent by 2010" (CEC, 2010a). This RPS mandate, in combination with ARRA and other financial incentives, is driving the development of solar

utilities. The RPS creates a demand for solar electricity produced by solar developers. We assume that all LSSE generated in the next decade will be purchased by utilities until the 33 percent RPS objective is reached. This assumption is based on the fact that developers are not likely to begin building until a purchase agreement with a utility is signed. Data on purchase agreements are collected and recorded on the CPUC's website.

The *CEC 2009 Adopted* is a list of projected demand forecast forms adopted by the CEC. These forms forecast the anticipated electricity and natural gas production and consumption in California over the next ten years. These forms also detail the assumptions upon which the forecast is based. For the purposes of our study, we used the "Net Energy for Load" forecast, which equals consumption plus losses due to transmission and distribution, minus self-generated electricity. Our LSSE development scenario calculations explore the differing amounts that solar energy could contribute to this forecasted net energy for load.

The goal of these calculations is to show different scenarios representing varying magnitudes of solar energy contribution to California's electricity supply in 2020. These calculations will set the stage for projecting land and water-use footprints under each scenario. In this section, we outline our steps to determine how many MWs of cumulative LSSE capacity is likely to contribute to California's total energy generation.

3.3 Defining the Solar Electricity Demand Scenarios

The lower bound for our scenario development begins with the total amount of electricity that LSSE is currently contributing to California's net energy load. From that boundary, LSSE's contribution to the net energy load increases with each scenario until the upper bound of the 33 percent RPS is reached. Descriptions and assumptions for the six scenarios are listed in Table 1.

Table 1. The six solar electricity demand scenarios and the assumptions that led to the development of each scenario. Each scenario is represented by a percentage equal to the proportion that LSSE will contribute to the overall electricity demand in California in 2020.

Scenarios	Assumptions
0.27%	<ul style="list-style-type: none"> ● Current LSSE contribution to net load. ● No new LSSE is built after 2010 and existing plants continue to operate without interruption.
3.3%	<ul style="list-style-type: none"> ● The nine plants permitted in 2010 will be built and in operation by 2020. ● No additional LSSE will be permitted or built. ● Includes existing LSSE facilities.
9%	<ul style="list-style-type: none"> ● The nine plants permitted in 2010 will be built and in operation by 2020. ● Ten additional plants will be permitted in 2011 due to the extension of the ARRA cash grant, and in operation by 2020. This number is based on the nine plants permitted in 2010. ● From 2012 to 2019 only 5 new plants will be permitted and built. This reduced rate of development is due to the expiration of the ARRA cash grant at the end of 2012 and increasing competition from renewable energy developments in Arizona and Nevada.
15%	<ul style="list-style-type: none"> ● The nine plants permitted in 2010 will be built and in operation by 2020. ● Ten additional plants will be permitted in 2011 due to the extension of the ARRA cash grant, and in operation by 2020. ● Five new plants will be permitted each year from 2012 to 2016. This growth assumes that the ARRA cash grant and tax credits continue to be available until the end of 2016. ● From 2016 to 2019, five more plants will be permitted, based on decreasing IOU demand for new contracts during this time and no competition from out of state renewable developments.
25%	<ul style="list-style-type: none"> ● Additional cash grants and tax incentives are created specifically for LSSE development. ● The permitting process is streamlined. ● There is little legal opposition to extensive LSSE development in the California desert. ● Significant decreases in the cost for LSSE technologies.
33%	<ul style="list-style-type: none"> ● Upper bound of LSSE development. ● IOUs will not purchase more renewable energy than this amount, unless current policy changes to increase the RPS.

Of the six scenarios for potential LSSE contribution to the RPS, the most realistic range that we expect to see in 2020, based on current policy and technology trends, is between 3.3 and nine percent of net load. This range is based entirely on the realities facing solar energy development: availability of federal funding, competition for IOU contracts with out-of-state LSSE energy developers, and current energy policy. Although the remaining scenarios are not as likely as the 3.3 to nine percent range, if significant policy and technological changes occur, they may become more realistic.

The type of LSSE technology used to generate electricity significantly influences the type of resource impacts that occur with development. This is because all LSSE technologies operate differently and have different land use, water use, and other resource impacts.

4. LSSE Technologies

LSSE facilities utilize different types of technology. The two major categories are concentrating solar power (CSP) and solar photovoltaic (PV) systems. Within each of these categories, there are several types of systems which use different methods for harnessing the sun's energy and converting it into electricity. Each technology has different solar-to-electricity conversion efficiency, land-use impacts, and water consumption requirements. The large differences in water-use requirements, in particular, may affect where certain types of LSSE plants may be sited in areas of relative water scarcity.

4.1 Concentrating Solar Power (CSP)

CSP technologies convert solar power into thermal energy which is then used to generate electricity. In a CSP system, mirrors reflect and concentrate solar radiation onto receivers that collect the solar energy and convert it to heat. This thermal energy is then used to generate electricity via a steam turbine or a heat engine that drives a generator (U.S. EPA, 2009). CSP systems operate most efficiently in bright and sunny locations, making southern California an ideal region for their siting. Since the 1980s more than 350 MW of CSP generating

capacity has been operating in California, and in the last three years California has permitted more CSP development than any other state (SEIA, 2010).

A fundamental limitation of solar power technology is its intermittency, as electricity output is reduced on cloudy days and ceases at night. Because CSP systems can generate electricity only when sufficient solar radiation is available, CSP systems are sometimes employed in combination with systems burning natural gas. Additionally, thermal energy storage (TES) can be installed to meet peak load requirements when sunlight is unavailable or inadequate. TES, defined as the capacity of a system to retain thermal energy generated during the day for use when sunlight is unavailable, is therefore a critical component of CSP systems. Today, conventional TES systems have the potential to increase CSP production to 16 hours per day, increasing a plant's capacity factor by more than 50 percent. A plant's capacity factor refers to the ratio of the energy generation system's actual energy output to the output that would have been generated if the system were running at full capacity at all times (Price & Margolis, 2009). The cost-effectiveness of CSP systems generally increases with system size, leading to economies of scale in construction, operation and maintenance costs.

CSP is actually a class of four different solar technologies: Parabolic Trough, linear Fresnel, Power Tower, and Parabolic Dish/Heat Engine. Each of these technologies uses different methods for concentrating solar radiation for heat generation. The first three may be referred to collectively as solar thermal technologies; however, the Parabolic Dish/Heat Engine design is unique in that it does not involve steam generation. Due to its extremely limited commercial application thus far, linear Fresnel is not addressed in this project. An in-depth description of each of these technologies, focusing on system descriptions and commercial applications in California, is provided below.



Figure 1. The Blythe Solar Power project is an example of a Concentrating Solar Thermal (CSP) Parabolic Trough. (Source: CEC)

4.1.1 Parabolic Trough

A parabolic trough system consists of u-shaped (parabolic) reflectors with oil-filled pipes (the receivers) that run along the focal point of the reflectors (Figure 1). The reflectors are tilted toward the sun, focusing the sunlight onto the receiver and heating the heat transfer fluid (HTF) running through it. The heated oil is then used to boil water

to produce super-heated steam which in turn runs a steam turbine, generating electricity (SPEIS, 2011). In California, parabolic trough technology has been in commercial operation since 1985, when the state’s first solar power plant, the Solar Energy Generating Systems (SEGS), came online, and has been a predominant technology in LSSE industry. Currently, the SEGS facility, located in the Mojave Desert in southern California, is the largest parabolic trough facility in the world, with 354 MW installed capacity (SEIA, 2010). A total of six parabolic trough projects in California have recently been approved by the CEC and are expected to come online in the next few years (CEC, 2011).

4.1.2 Power Tower

A single power tower system, also referred to as a central receiver, is comprised of a field of many large, flat reflectors that focus sunlight onto a receiver at the top of a tall central tower (Figure 2). The receiver is filled with HTF – typically pressurized water



Figure 2. An example of power tower technology. This is a 10 MW capacity pilot project in Barstow, CA. (Source: DOE)

or molten salt. As with the other CSP systems, the concentrated sunlight heats the HTF, generating thermal energy to produce steam. One of the remarkable characteristics of the power tower system is that it allows the HTF to be heated to a much higher temperature than parabolic trough and linear Fresnel systems. The higher temperature of the HTF makes the power tower system more efficient at generating electricity than parabolic trough and linear Fresnel systems. The 5 MW Sierra Sun Tower, located in California's Antelope Valley, is the only power tower system currently operating in the U.S. However, a number of power tower projects were approved in 2010. These include the 370 MW Ivanpah Solar Electric Generating System and the 150 MW Rice Solar Energy Project (SEIA, 2010).

4.1.3 Parabolic Dish/Heat Engine

Parabolic dish/engine systems are unique among the CSP technologies in that they do not generate steam. The dish/engine system uses mirrored parabolic dishes – as opposed to troughs – to concentrate sunlight onto a receiver mounted at the focal point of each dish (SPEIS, 2011). Each dish's receiver is integrated with its own high-efficiency combustion engine, which generates electricity by using the heat concentrated by the mirrors (SPEIS, 2010).

Because this technology utilizes the Stirling thermodynamic cycle to produce electricity, it does not generate steam and therefore requires far less water than the other CSP systems (U.S. DOE,

2001). Another advantage of the dish/engine system is that it can operate at higher temperatures, allowing it to achieve higher power conversion efficiency (U.S. DOE, 2001). Additionally, the individual dish/engine unit is relatively small, allowing it to be constructed in individual units that can be accommodated by a less uniformly even landscape than most other solar technologies (Figure 3). However, this



Figure 3. The 750 MW Imperial Valley Solar Energy Project is an example of Parabolic Dish/Heat engine technology. (Source: CEC)

technology's disadvantage is that it is more expensive than the other CSP systems. The only current commercial application of the dish/engine system in the U.S. is the Maricopa Solar Power facility in Arizona, which completed construction in 2010 (SEIA, 2010).

4.1.4 Cooling Systems

California's deserts are among the most desirable areas for LSSE plants because of the high levels of solar radiation they receive throughout the year. However, another defining characteristic of this area is water scarcity. This water scarcity may represent a significant constraint on the development of large-scale CSP projects, which require stable and accessible water sources for their construction and operation. During operation, the primary water requirement for CSP facilities is for system cooling, whereby waste heat is transferred away from the system. This waste heat removal is necessary to continuously convert the solar radiation into thermal energy, which runs a steam turbine. Three different types of cooling systems are currently used in CSPs: dry-cooling, wet-cooling, and hybrid wet-/dry-cooling. Dry-cooling and hybrid wet-/dry-cooling consume less water than wet-cooling systems. Due to increasing concern over water scarcity in California as well as to recent policy changes regarding the use of wet-cooling, solar developers are moving towards using less water-intense system-cooling technologies in order to get projects approved by the CEC. The following subsections describe each cooling system in more depth.

Wet-cooling

The most common wet-cooling method currently in operation is evaporative water recirculating cooling (U.S. DOE, 2001). This method draws cool water through the system, absorbing the waste heat expelled by the heat transfer fluid, releasing the water into a cooling tower where the water is cooled via evaporation before being re-circulated back into the system (Birkinshaw, 2002). The average water consumption for a parabolic trough plant using this evaporative recirculating method is approximately 800 gallons per megawatt-hour generated (Table 2).

Dry-cooling

The dry cooling method is quickly becoming the preferred cooling method for CSP systems in California because of the state's rigorous water conservation standards. In a dry-cooling system, the steam enters an Air-Cooled Condenser, where it is cooled and the excess heat is blown off with the use of fans. This method uses comparatively very little water because the waste heat generated by the power plant is released directly into the atmosphere rather than by evaporative cooling. A wet-cooled parabolic trough system consumes about 5.5 to 8.5 times more water than a dry-cooled system, while a wet-cooled power tower plant consumes about 10 times more water than a dry-cooled plant (Table 2).

Dry-cooling is most efficient when the air surrounding the system is significantly cooler than the hot air being expelled. On hotter days, the heat difference between the system and the surrounding air diminishes, causing the heat exchange efficiency between the system and the surrounding air to decline, reducing the overall efficiency of the system. This reduction in a dry-cooled system's performance due to its sensitivity to the ambient temperature is called "performance penalty."

To provide a concrete idea of the temperature at which the performance penalty is seen, an experiment conducted in Daggett, California demonstrated that the efficiency of a dry-cooled system dropped significantly at the ambient temperature above 100 degrees Fahrenheit (Kelly, 2007). In addition to the performance penalty, dry cooled systems cost more to purchase and operate than do wet-cooled systems; this is referred to as the "cost penalty." Table 2 summarizes the average water consumption for a power tower plant and a parabolic trough plant with different cooling technologies (U.S. DOE, 2001).

Hybrid wet/dry cooling

The hybrid wet-/dry-cooling system's main design objective is to achieve reductions in water consumption while maintaining high electricity generation efficiency. A hybrid system consumes less water for system cooling than does a wet-cooling system, but more water than a dry-cooling system (Table 2). For example, a hybrid-cooled parabolic trough system consumes 100 to 450 gallons per MWh of electricity generated, while a wet-cooled parabolic trough

consumes approximately 800 gallons per MWh of electricity generated. Hybrid systems also have higher electricity generation efficiencies in hot climates than do dry-cooled plants because their electricity generation performance is not reduced on the hottest summer days. A hybrid system typically employs both wet- and dry-cooling components inside the plant and operates the two cooling systems either separately (parallel cooling systems) or jointly. A hybrid cooling system has a dry-cooling system as the primary heat-releasing component, but also incorporates the water-cooled system which absorbs additional waste heat. The water-cooled component is used only on summer days, when it is difficult to maintain a temperature difference between the condenser and the atmosphere which is optimal for achieving high efficiency performance (U.S. DOE, 2001). The hybrid system uses only a small proportion of the water used by the wet-cooling system component, but experiences less of a performance penalty than a dry-cooling system. Additionally, hybrid systems are typically less expensive than dry-cooling systems.

Table 2. Average water consumption for cooling CSP power plants with different cooling systems.

Technology	Cooling Method	Average Water Consumption (Gallons/MWh)	Performance Penalty	Cost Penalty
Power Tower	Wet cooling	500-750		
	Hybrid	90-250	1-3%	5%
	Dry cooling	90	1.3%	
Parabolic Trough	Wet cooling	800		
	Hybrid	100-450	1-4%	8%
	Dry cooling	78	4.5-5%	2.9%
Dish/Engine	Only for mirror washing	20		
Linear Fresnel	Wet cooling	1000		

Performance and Cost Penalties

As noted, dry-cooling systems are subject to both performance and cost penalties. There is a tradeoff in cooling systems between improving water efficiency and reducing electricity generation. In addition to the operating temperature constraint, the electricity generation capacity of a dry-cooled CSP plant is reduced because the dry-cooling system utilizes

fans (which consume electricity) to cool down a condenser. The degree to which performance and cost for dry-cooling and hybrid systems differ from wet-cooling systems depends on several factors, including technology, location, and plant size. For any type cooling system, water requirements vary by CSP technology, mainly due to differences in plant operating temperatures. Therefore, the specific annual water requirements of any individual plant are difficult to predict, as it is subject to external environmental factors.

The exception to CSP technologies' water use for cooling that is important to note is that dish/engine systems consume water only for mirror washing and do not require a cooling system.

4.2 Solar Photovoltaic (PV)

Unlike CSP technologies, PV systems convert sunlight directly into electricity. Inside an active layer of semiconducting material within the PV cells, which are wired together to form modules and arrays, free electrons are stimulated by solar radiation, producing an electric current (U.S. DOE, 2010a). Two general classes of PV cells are used in most of today's commercial PV modules – crystalline silicon PV and thin film PV. These cell types differ in composition and material use, solar-to-electricity conversion efficiency, and manufacturing cost.

Crystalline silicon cells are comprised primarily of silicon which has been refined into either mono- or poly-crystalline silicon. Thin film PV cells, which are a fraction as thick as crystalline silicon cells, may be composed of a variety of materials, including copper-indium-diselenide, copper-indium-gallium-diselenide, or cadmium telluride. Because thin film PV is made of extremely thin layers of semiconductor material, the manufactured film is flexible and less fragile, and can be rolled for ease of transport. In general, the conversion efficiency of crystalline silicon PV is higher than for thin film PV, but crystalline silicon is more expensive.

In 2008, PV projects using crystalline silicon cells accounted for 84 percent of PV production. Like CSP systems, PV systems can generate electricity only during daylight hours, and energy output varies with weather conditions (Price & Margolis, 2008). Also like CSP, PV cells produce maximum electricity on hot, sunny days, which generally coincide with high

electricity demand. However, PV plants generally have lower land-use efficiencies than CSP plants, requiring larger land areas to produce equivalent generating capacity. As of early 2011, three LSSE PV plants are operating in California: FSE Blythe, Sacramento Soleil 2008, and CalRENEW-1 in Mendota. Installed capacities for these facilities are 21 MW, 1.25 MW, and 5 MW, respectively (Solar Energy Industries Association, 2010). A number of additional PV plants are also proposed, under development, or under construction, but have not yet come on line. If all of these plants are to come on line, total installed PV capacity in California will rise to 12 GW (SEIA, 2010). California currently leads the U.S. PV market, accounting for nearly 95 percent of new growth from 2007 to 2008 in national grid-connected PV installation (Price & Morgolis, 2008).

4.3 LSSE Land Requirements

All LSSE technologies have different land-use efficiencies and parameters for where they can be located. This influences the different degrees of site-level impacts of each technology. A brief description of some of the important land requirements and LSSE siting requirements follow.

4.3.1 Land Requirements

LSSE technologies' acreage requirements vary by MW capacity, technology type, and the individual project requirements for on-site mitigation. Land requirements for solar power plants may range from 5 to 12 acres per MW of nameplate capacity, and from about 8 to 12 acres per MW for PV plants (Aspen, 2009). Table 3 provides land-use efficiency ranges for the major solar technologies. Land-use requirements are covered in more detail in the Land-use Calculations section (Section 7.3).

Table 3. Land-use efficiency for different LSSE Technologies.

Solar Technology	Acres per MW capacity
Parabolic Trough	5 – 8
Power Tower	10
Stirling Engine	7 – 9
Photovoltaic: Thin Film	10

4.3.2 Flexibility in Construction and Plant Configuration

Solar technologies also differ in siting restrictions and in flexibility of plant design and layout. The level of flexibility in layout may affect the ease or difficulty of mitigating the plant’s impacts – for example, working around sensitive habitat or dry washes – and therefore affect the ultimate size and shape of disturbed areas. Photovoltaic plants generally allow more flexibility in layout because they have fewer moving components (with the exception of tracking PV) and do not require the pumping of fluids (Bachrach & Lindner, 2010), and can be arranged in irregular patterns. Like PV, Stirling engines can be sited in more irregular patterns because they are not constrained by water-use requirements.

Solar thermal technologies generally require a more contiguous configuration. For example, parabolic trough design requires long, rectangular increments of land and is best suited to ‘block’ construction. Blythe Solar Power Project (BSPP), the largest parabolic trough plant permitted so far, is comprised of four adjacent, identical 250 MW units, each consisting of a solar field and power block. These units each house a steam turbine generator (STG), heat exchangers, an air cooled condenser, an evaporation pond, water system and other equipment. Generally, the piping and moving parts associated with steam generation in solar thermal plants do not allow a high degree of flexibility in construction and configuration (Aspen, 2009).

4.3.3 Topography and grading requirements

Topography, particularly slope, is a critical factor in siting power plants because it affects where solar plants can be located, the amount of grading and environmental disturbance

required, and project cost. Some technologies allow for greater topographic relief, while others require more grading to achieve nearly level surfaces. Photovoltaic technologies and parabolic troughs require a maximum grade of three percent, preferably less. Solar power tower heliostats and Stirling engine dishes can be constructed on steeper grades, up to five and six percent, respectively (Aspen, 2009). For more information refer to Section 8.4 Solar Development Constraints Map. Additionally, during the construction of any type of LSSE facility all of the vegetation is removed from the construction site as part of the grading process. Some revegetation is possible after construction for photovoltaic plants, but is kept below a certain height. Solar thermal facilities, however, must be cleared of all vegetation due to fire concerns, requiring regular herbicide use (Bachrach & Lindner, 2010). These grading requirements contribute significantly to the land-use impacts of LSSE developments.

4.4 Future Trends in LSSE Technology Cost

4.4.1 PV System Costs

The cost of PV systems has changed substantially in recent years. Figure 4 shows that the installation costs for PV systems have been dropping significantly since 1995. The DOE data indicates that the capital cost of both thin film and crystalline silicon cells is expected to decline

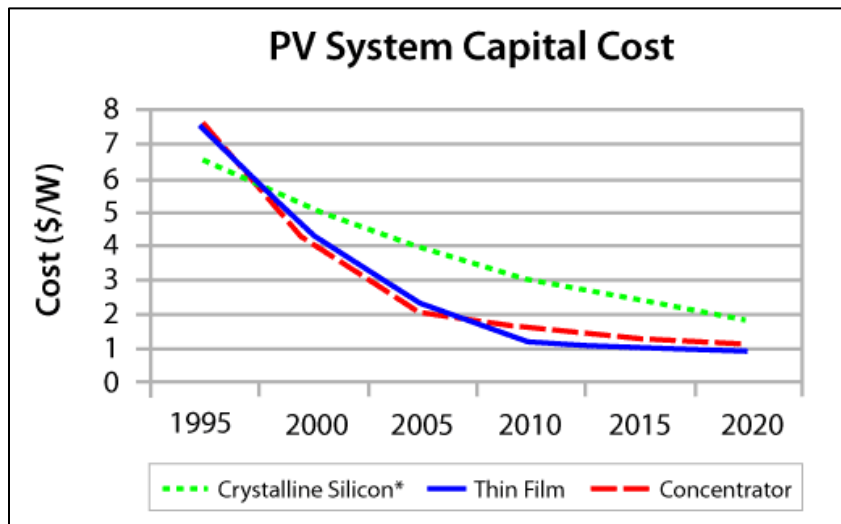


Figure 4. This graph shows the projection of photovoltaic system capital costs through 2020. (Source: DOE)

in the future; however, cost reductions will be slightly more rapid for crystalline silicon than for thin film. This is primarily because the efficiency of crystalline silicon is expected to improve more than for thin film. The extent to which costs will decline in the future is highly

unpredictable, since future cost reductions depend on a number of factors such as growth in solar PV market and financial incentives.

At this time, the costs of installing PV systems exhibit economies of scale, with average installed cost per watt declining as plants become larger (Wiser *et al.*, 2009). According to Wiser *et al.* (2009), the largest systems (over 1000 kW of installed capacity) achieve the lowest average installed cost, at \$7 per watt, while the smallest systems (less than 2 kW of installed capacity) have the largest average installed cost, at \$9.9 per watt. The DOE's recently announced Sunshot initiative will provide 27 million dollars in funding to reduce the installed cost of PV systems to \$1 per watt by 2020 (DOE 2011). If this DOE effort is successful it could significantly change the landscape of LSSE development trends because such large cost reductions are not anticipated for CSP technologies.

4.4.2 Cost of Concentrating Solar Power

CSP technologies are already well established and are therefore unlikely to see a steep decline in price over the next decade. Unlike PV, there are relatively few studies on the long-term cost trends of CSP systems. The PV industry tracks the manufacturing costs of different types of PV cells and reports the data in publicly available documents. However, cost data on CSP plants are not collected or reported in such an organized fashion, primarily because development is just beginning for most of the new LSSE projects in the United States and that cost information remains proprietary. As more of the LSSE CSP plants are constructed and eventually in operation, accurate cost estimates of these technologies may become available.

5. Technology Portfolios

The physical requirements and economic parameters of the different types of LSSE technologies directly influence the permitting and development process. Projects are evaluated on a case-by-case basis by state and federal agencies before they are approved for construction. Much of that approval is contingent upon how the particular LSSE technology impacts land and water resources. Economic considerations play a role in the types of projects

that are proposed, and energy policy also influences what types of projects are approved. We took all these technology considerations into account in analyzing how LSSE may contribute to California’s energy supply, by creating three different technology portfolios.

For our future scenario calculations we created three different technology Portfolios: A, B, and C. These portfolios differ in their relative proportions of each solar technology (Table 4). In order to calculate the land and water-use impacts of each technology portfolio, we use data inputs from six specific LSSE projects that are currently permitted or operating in California. The reported nameplate capacity, capacity factor, land use, and water use reported in the environmental impact statement (EIS) of each specific LSSE plant is used to represent the LSSE technologies comprising the portfolios in our analysis. We assume that future LSSE plants will be built with specifications similar to the ones already approved.

Below is a detailed description of each portfolio and the assumptions that went into creating each one. The three technology portfolios are applied to our solar electricity demand scenarios (Section 3) in order to complete our calculations of the possible future resource impacts.

Table 4. Three potential future LSSE technology mixes: Portfolio A is based on the current technology mix; Portfolio B is based on a future where water becomes more scarce; and Portfolio C is where PV becomes the dominant LSSE technology.

	Wet-Cooled Parabolic Trough	Dry- Cooled Parabolic Trough	Power Tower	Dish Engine	Crystalline Silicon PV	Thin Film PV
Portfolio A: 2010 Operational	90%	0	1%	0	0	9%
Portfolio B: 2010 Permitted	10%	35%	9%	28%	0	18%
Portfolio C: 50% PV	10%	10%	10%	20%	15%	35%

5.1 Portfolio A: 2010 Operational Technology Mix

For Portfolio A, we used California’s currently operational solar plants as the baseline technology mix. We assume the proportion that each technology is currently contributing to the total solar energy production in any given scenario will not change between 2010 and 2020. The current technology mix represented by Portfolio A (Figure 5) consists of wet-cooled parabolic trough (90 percent), power tower (1 percent) and PV thin film (9 percent). These percentages are calculated using data reported by the Solar Energy Industry Association (SEIA) for California solar plants only.

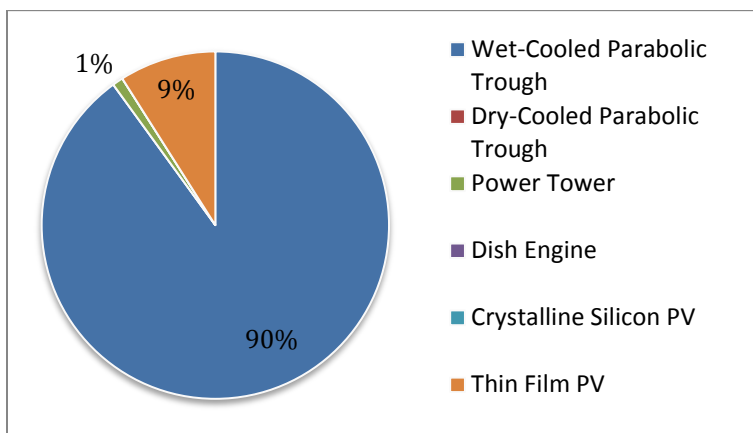


Figure 5. Portfolio A technology mix. This technology mix is based on the current technology mix, which does not include Dry-Cooled parabolic trough, dish engine or crystalline Silicon PV.

5.2 Portfolio B: 2010 Permitted Technology Mix

Technology Portfolio B represents the solar plants that are *currently* operational, approved, and under review for approval in California (Figure 6). Portfolio B consists of: dry-cooled parabolic trough (35 percent), wet-cooled parabolic trough (10 percent), power tower (9 percent), dish/engine (28 percent), and PV thin film (18 percent) (Figure 6). Relative to Portfolio A, the proportion of wet-cooled parabolic trough is reduced, while the proportions of dry-cooled parabolic trough, power tower, dish/engine, and PV thin film are increased in Portfolio B. The last four technologies have higher water-use efficiencies than wet-cooled parabolic trough systems, making Portfolio B significantly less water-intense than Portfolio A.

Portfolio B’s technology mix reflects the current permitting trends that favor thin film PV systems, which use substantially less water than CSP systems, and permitting agencies’ shift

towards requiring or at least strongly encouraging dry-cooling systems for LSSE facilities. The Best Management Practices & Guidance Manual for desert renewable energy projects published by Renewable Energy Action Team (REAT) in December 2010 clearly states that dry-cooled projects are preferable to wet-cooled projects. This shift towards dry-cooled technologies is therefore highly likely to persist in the near future.

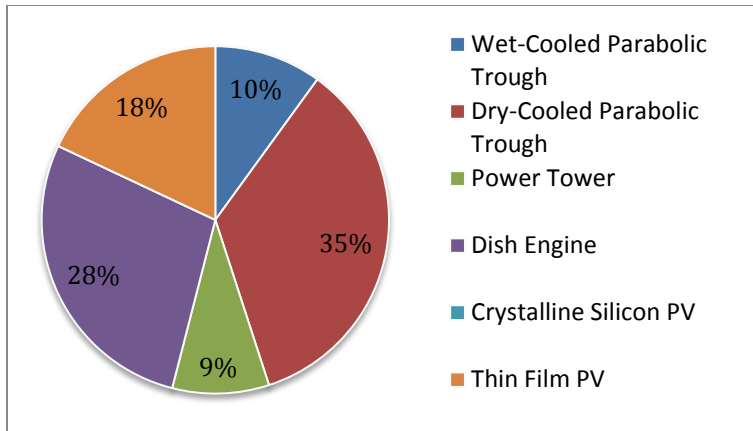


Figure 6. Portfolio B technology mix. This technology mix is based on the technologies that have been permitted in 2010 and reflects the increasing concern over scarce water resources.

5.3 Portfolio C: 50% PV Technology Mix

Portfolio C consists of: dry-cooled parabolic trough (10 percent), wet-cooled parabolic trough (10 percent), power tower (10 percent), dish/engine (20 percent), PV thin film (35 percent), and crystalline-silicone PV (15 percent) (Figure 7). Under this portfolio, we assume that recent trends in PV cost reduction will continue in the future, due mainly to increases in manufacturing capacity and improvements in solar-to-electricity conversion efficiencies. We simultaneously assume that the cost reductions for CSP technologies will be relatively slow because CSP is a more mature class of technologies with less potential for cost reductions. Thus, the combined proportion of thin film and crystalline-silicone PV comprise half of this portfolio. The rest of Portfolio C is constructed to reflect an increase in the permitting of less water-intense CSP technologies, though we assume that the wet-cooled plants that are currently in operation will continue to function.

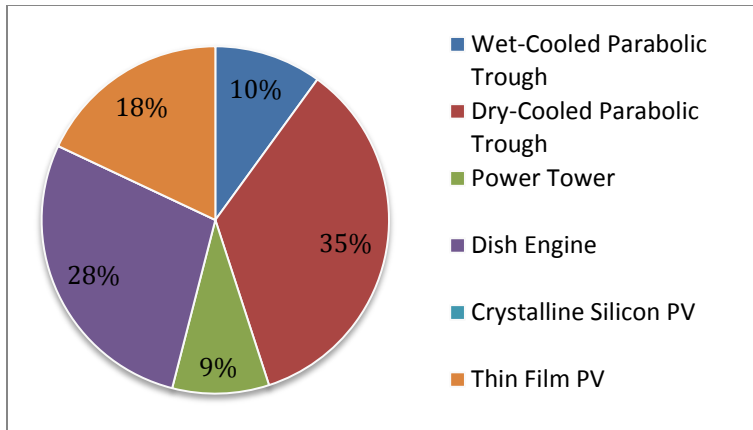


Figure 7. Portfolio C technology mix. This LSSE technology mix represents a future where photovoltaic LSSE technology becomes dominant due to declining costs and water scarcity for cooling systems.

6. Likelihood Analysis of Future Scenarios and Portfolios

The combination of the six scenarios listed in Table 1 and the three technology portfolios described above results in sixteen possible permutations which represent the range of possibilities for the extent and nature of future LSSE development in California. Portfolios B and C are not included in the 0.27 percent scenario because this scenario assumes that only currently existing facilities (represented by Portfolio A only) will contribute to California's electricity supply in 2020, resulting in sixteen permutations rather than eighteen. These combinations allow us to project the range of possible land and water resource impacts from LSSE development. Out of these sixteen different combinations, only a few are likely to be realistic possibilities for 2020. However, any number of these options may become more likely if policy or economic drivers change significantly from the status quo. As discussed previously, the most realistic range of the possible solar demand scenarios for 2020 is between 3.3 and nine percent. Within that range, Portfolio B is the most likely of the portfolios to represent the actual 2020 solar technology mix. This portfolio (Figure 6) is based on what is currently being approved and permitted. Current permitting and cost trends are pointing in the direction of these technologies being dominant during the next decade.

Portfolio C (Figure 7) is also a possible representative of the 2020 solar technology mix if PV costs continue to decline at historic rates and PV becomes more cost-competitive with CSP

technologies. PV technology is still maturing, so costs are expected to continue declining, whereas solar thermal technologies are already well established and are less likely to experience a steep decline in cost.

Portfolio A (Figure 5) is the least likely portfolio to be representative of the 2020 solar technology mix. Technologies that utilize wet-cooling are already being bypassed, reflecting the new BLM Best Management Practices in favor of dry-cooled projects, and this trend is not likely to reverse, given California's water constraints.

The 3.3 to nine percent range of solar electricity demand scenarios, in combination with Portfolio B, is the most likely snapshot of LSSE's electricity contribution to California in 2020. Portfolio C is also a strong possibility if PV costs continue to decline and water resources become increasingly constrained in the coming years.

6.1 Uncertainty in the Analysis

Changes in the status quo which are most likely to produce uncertainty in the feasibility of these scenarios/portfolio combinations include:

1. Changing capacity factors and conversion efficiencies could increase solar energy's contribution to the RPS. If in the next ten years CSP technologies significantly increase their capacity factors, or PV technologies increase their conversion efficiencies, then the most likely scenario represents a higher percentage contribution by solar energy to the RPS.
2. Changing electricity demand will affect the percentage of solar energy's contribution to the RPS. The California energy demand for 2020 is based on a one percent annual growth rate over current demand. If the growth rate fluctuates above or below one percent, this will influence the amount of renewable energy required for the IOUs to fulfill their RPS obligations.
3. Policy changes may alter demand for solar electricity. The 33 percent RPS is based on rule-making rather than a statute, despite multiple legislative attempts to codify the 33 percent standard. There exists a slim possibility of the RPS being reduced back to 20 percent, which is the statutory requirement, as well as the much more remote possibility of the RPS being suspended altogether. Conversely, it is also possible that the RPS percentage may be raised

before 2020. Any change to the RPS will change the feasibility and likelihood of the scenarios outlined in this project.

The utility of the scenario and portfolio combinations is that they allow for a reasonable estimate of the range of cumulative land and water use that will result from varying degrees of solar development. Therefore, if political, economic, or technological trends begin to shift, the resource use estimates may be adjusted accordingly by changing the LSSE percentage contribution to energy demand. Similarly, the technology portfolios may be adjusted to reflect economic and policy changes. Using these combinations of demand scenarios and technology portfolios provides a useful tool, or framework, for understanding the potential range of land and water resource impacts by 2020.

7. Land- and Water-use Calculations

This section of our report addresses our second objective: to provide an estimate of the land-use and water-use impacts under our range of scenarios, taking into consideration the LSSE technologies that are most likely to be utilized. In order to quantify future water and land-use for different solar electricity demand scenarios, we developed the following methodology:

- 1) Define input parameters by selecting representative LSSE projects for each technology.
- 2) Calculate the cumulative capacity required to meet solar electricity demand scenarios.
- 3) Calculate the land area required for each scenario and portfolio combination.
- 4) Calculate the cumulative water usage for each scenario and portfolio combination.

7.1 Define Input Parameters: LSSE Project Selection

Land- and water-use efficiencies depend on the LSSE technology being considered. The average number of operating hours in a year for an LSSE plant is also a function of technology. For this reason, we needed a number of parameters for each technology included in our portfolios. We selected one project either recently approved or currently under review as a

representative for each of the six technologies considered (Table 5). As noted, information from publicly available environmental review documents was used for each of the following parameters: nameplate capacity, capacity factor, land-use efficiency (acres/MW), operational water use (gallons/MWh), and construction water use (total acre-feet) (Table 5).

The six selected projects were chosen based on several criteria, including data availability, project status (projects further along in the permitting process were favored), location (projects within the CDCA were chosen), and installation capacity (we favored plants similar in size to what we believe will be proposed in the future).

Table 5. Solar projects in California selected as representatives of each LSSE technology. (Source: project documents from DOE and CEC)

	Blythe Solar Power Project	Abengoa Mojave Solar Project	Ivanpah Solar	Calico Solar Project	California Valley Solar Ranch	Lucerne Valley Solar Project
Technology type	Parabolic Trough (wet)	Parabolic Trough (dry)	Power Tower	Dish/Engine	PV Crystalline Silicon	PV Thin Film
Location	Blythe, Riverside	San Bernardino	Barstow, San Bernardino	Victorville, San Bernardino	Carrizo Plain	Lucerne Valley, San Bernardino
Nameplate Capacity (MW)	1000	250	370	664	250	45
Capacity Factor	0.26	0.27	0.28	0.25	0.29	0.25
Land Use (acres/MW)	7.0	7.1	9.7	6.9	7.6	9.4
Construction water (acre-feet/MW)	4.1	8.8	2.4	0.4	0.24	0.4
Operational Water (gallons/MWh)	86	1190	36	5	5	0.33
Status	Approved	Approved	Approved	Approved	Under review	Approved

We used the project selection methodology because the parameter values reported by industry associations and research institutions are averages from lab estimates and do not accurately project the capacity and land and water-use efficiencies of projects that are being proposed and developed. We reasoned that projects being developed, permitted and built represent the best available information, and that parameters from these projects better

reflect technologies that are likely to be used in the future. Although many of these facilities have not yet begun construction, the project parameters are likely more realistic than those from older projects.

No data on capacity factor are available for the two PV facilities used in this analysis, so an average regional capacity factor reported in the DOE’s Solar Technologies Market Report was used instead (Price & Margolis, 2008). Because the California Valley Solar Ranch project uses a single-axis tracking system, we took the average of the Los Angeles and Phoenix capacity factors for single-axis tracking systems (Figure 8). We could not determine which tracking system Lucerne Valley Solar Project intends to use, so we used a value of 25 percent for this project, based on the assumption that it will utilize either the fixed-tilt or a-axis tracking module most common in recently proposed PV projects.

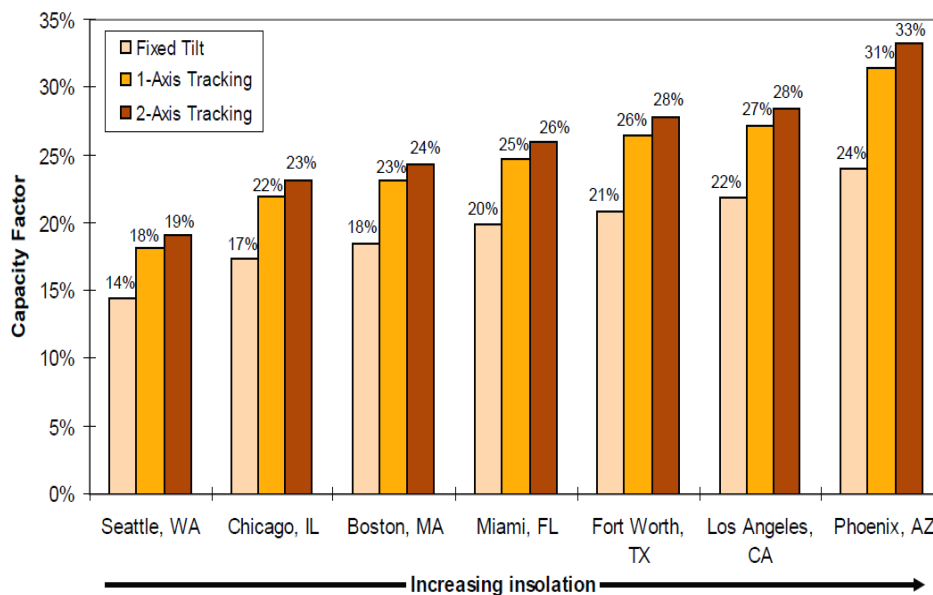


Figure 8. Capacity factor of photovoltaic systems with different tracking systems and across different locations. In general, with more insolation and 2-Axis Tracking, capacity factor is greater. (Source: NREL)

7.2 Cumulative Capacity Calculations

Each solar electricity demand scenario will require a certain amount of cumulative capacity – the sum total of the nameplate capacities of all installed LSSE plants. We calculated the cumulative capacity required for each of the scenario and portfolio combinations included in our study using the following methodology:

1. Calculate LSSE generation in 2020 for each scenario

In order to calculate the solar energy generation required for each scenario, we multiplied the CEC's 2020 forecasted energy demand by the percentage of solar energy contribution associated with the six different solar electricity demand scenarios (Section 3). For example, if LSSE were to provide 33 percent of California's energy in 2020, LSSE would generate 108 Terawatt-hours (TWh) annually (327 TWh multiplied by 0.33).

2. Calculate LSSE generation in 2020 by technology for each scenario

After determining the solar electricity demand for 2020, we calculated the amount of LSSE generation required by each technology to meet this demand. Each technology portfolio is comprised of a different proportion of LSSE technologies. We multiplied the solar electricity demand by the proportion of each technology for Portfolios A, B and C. In the case of the 0.27 percent scenario, we assumed that no new LSSE development would occur; therefore only Portfolio A – the current technology mix – was applied to this scenario for a total of 16 scenario and portfolio combinations. The LSSE generation by technology was subsequently converted from TWh to MWh.

3. Calculate the average number of operating hours in a year using capacity factor

As noted in Section 4, solar power plants typically report a capacity factor associated with a particular technology. The capacity factor is equivalent to the proportion – zero to one – of the year that the plant is operational. We define a plant to be “operational” when it is actively generating electricity. Capacity factor varies by technology, location, and season, as it is dependent on the amount of solar radiation an area receives, the technology's efficiency at capturing that power, the electricity generation efficiency, and a system's ability to store energy. The capacity factors that each of our representative LSSE plants reported were based on a pre-selected location. If a project should move to a new location, it is possible that the capacity factor would change. To calculate the number of operating hours in a year for each technology, we multiplied the capacity factor by the total number of hours in a year ($365.25 * 24 = 8,766$ hours).

4. Convert energy generation into cumulative power capacity

To convert the LSSE generation required by each of the technologies to cumulative power capacity needed, we used the standard method used by the solar development industry: divide energy generation by number of operational hours in a year. Specifically, we divided the LSSE generation (MWh) for each of the scenario and portfolio combinations by the number of hours in a year each solar technology is operational, to get the cumulative capacity required from LSSE facilities of each technology. The cumulative capacities required by each technology were summed for each portfolio and scenario combination.

7.2.1 Results

Our results show 16 different possibilities for the cumulative capacity required to meet the 2020 solar electricity demand scenarios under the different technology portfolios (Table 6). If solar energy were to contribute 33 percent to California's electricity with the current technology mix (Portfolio A), close to 46,000 MW of installed cumulative capacity would be required. Under our most likely scenario, if solar were to contribute only 9 percent to California's 2020 electricity with technology Portfolio B, we would need 13,464 MW of cumulative capacity.

Table 6. The megawatts of cumulative capacity needed to meet each solar electricity demand scenario for each technology portfolio.

Scenario	Portfolio	Cumulative capacity needed (MW)	Average MW capacity needed
33%	A	45911	47229
	B	49369	
	C	46408	
25%	A	34781	36123
	B	37401	
	C	36186	
15%	A	20869	21674
	B	22441	
	C	21712	
9%	A	12521	13004
	B	13464	
	C	13027	
3.3%	A	4591	4768
	B	4937	
	C	4777	
0.27%	A	376	

7.2.2 Discussion

While these calculations are informative, it is important to be aware of their underlying assumptions and simplifications, as well as the limitations of the data. The first simplification we used was to perform all calculations based on an annual timescale. This means that we looked at the TWh generated over an entire year. While this is an easy number to work with, it is important to understand that solar electricity generation varies throughout the year according to the angle of the sun, the number of daylight hours and the number of cloudy days.

To be more accurate, we could look at electricity generation by month; however, developers typically report metrics for plants on an annual basis. Likewise, the CEC forecasts are reported annually as well. For these reasons, we chose to conduct our analysis of future scenarios on an annual basis.

Another data limitation relates to the reported capacity factor for each plant used as a technology representative. When a plant is built, it is usually monitored closely to determine the number of hours per year that it is actually producing electricity. From this monitoring, we can generate a capacity factor that is averaged over the year. However, for plants that have not yet been built, the capacity factor must be predicted. Only once the plant is operational, is its capacity factor more accurately assessed.

7.3 Land-Use Calculations

7.3.1 Solar Power Tradeoffs: Land vs. GHG mitigation

Though solar power plants use a renewable, carbon-free source of power to generate electricity, a disadvantage to both CSP and PV technologies is the large land areas required. The BLM's "fast-track" solar facility applications – those approved by the end of 2010 and thus eligible for ARRA funds – will each cover hundreds, or more commonly, thousands of acres. The 1,000-MW BSPP, for instance, will cover over 7,000 acres. In contrast, the 1,124 MW La Paloma Generating Power Plant Project, a natural gas-fired, combined cycle power plant which started construction in Kern County in 2000, covers only about 23 acres (CEC, 1999). Because much of the land targeted for solar development in the California desert is relatively undisturbed and may provide habitat for sensitive species, the large land footprint of solar power development is a significant tradeoff to GHG mitigation.

7.3.2 Methodology

As inputs to the land-use calculations, we used parameters from our selected representative LSSE projects. The total land-use and disturbance for each project are reported in the associated environmental review documents. These land area values include the area needed for the project's infrastructure and the total permanently disturbed land area. As

noted, the land area disturbed per MW differs across technologies, as do grading requirements and flexibility in plant configuration.

Although there are a number of ways to assess a solar facility's spatial footprint, we chose one method for our calculations. Our method, as demonstrated here using the proposed BSPP, is an example of how solar technologies' land-use requirements are calculated for the analysis. While this facility's right of way (ROW) grant is for approximately 9,400 acres, its construction and operation will 'disturb' only about 7,025 acres, of which 5,950 will eventually be covered by solar fields. Here, we use the 'disturbance' figure of 7,025 acres, which includes most of the infrastructure and permanently disturbed land – but not the total ROW – to calculate acreage requirements.

To calculate the total amount of land required for each scenario and technology portfolio combination, we multiplied the cumulative capacity of each technology (MW) by the land-use efficiency of the specific project chosen as a technology representative. For example, under the nine percent scenario, and using technology Portfolio A, the cumulative nameplate capacity of all wet-cooled parabolic trough plants will be 11,187 MW. This estimate is based on the specifications from the Abengoa Mojave Solar Project, our representative wet-cooled parabolic trough plant, with a reported land-use requirement of 7.1 acres/MW of capacity. Therefore, the total land area requirement for CSP parabolic trough plants under the nine percent scenario is 78,980 acres. We repeated this step for the other two types of technologies in Portfolio A to get the total acreage required for each. Then we summed the three technologies' land-use requirements to get the final amount of land use for the nine percent scenario under Portfolio A. We repeated this process for each technology in each portfolio for every scenario, resulting in 16 potential future land-use footprints. This methodology is outlined in the flow chart below (Figure 9).

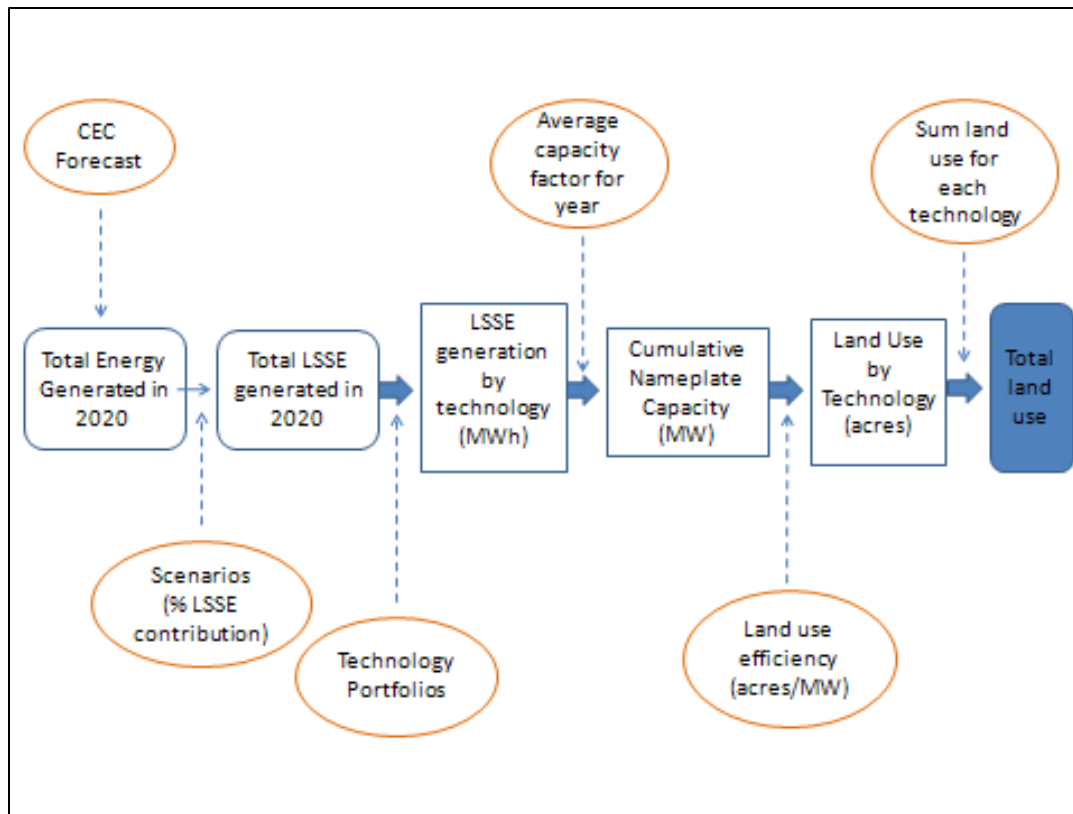


Figure 9. Cumulative capacity and land-use calculation flow chart. The flow chart demonstrates the methodology for calculating the total land use under each solar electricity demand scenario for each technology portfolio.

7.3.3 Results

Our calculations show that both the scenario and the technology portfolio chosen affect the amount of land area required by LSSE plants. If LSSE on its own were to generate enough electricity to fulfill the RPS, then the amount of land area required would be over 300,000 acres with the current technology mix (Portfolio A) and over 350,000 acres under both the dry-cooled technology mix (Portfolio B) and the PV-heavy mix (Portfolio C). However, if LSSE were to expand only enough to provide 3.3 percent of California’s electricity, the land requirements would be less than 50,000 acres for each technology portfolio (Figure 10).

With the current technology portfolio, the land area required is less than with Portfolio B and C. Portfolio C, which is characterized by rapid growth in PV, shows the largest land area impact under all solar electricity demand scenarios. This is due to the fact that in Portfolio C both CSP power tower and PV – which require more land per MW capacity than other

technologies – increase their relative contribution. The Ivanpah CSP power tower plant has the highest reported land-use requirement of all the technologies included in our study (9.7 acres/MW) and Chevron Lucerne photovoltaic plant has the second highest reported land-use requirement, at 9.4 acres per MW.

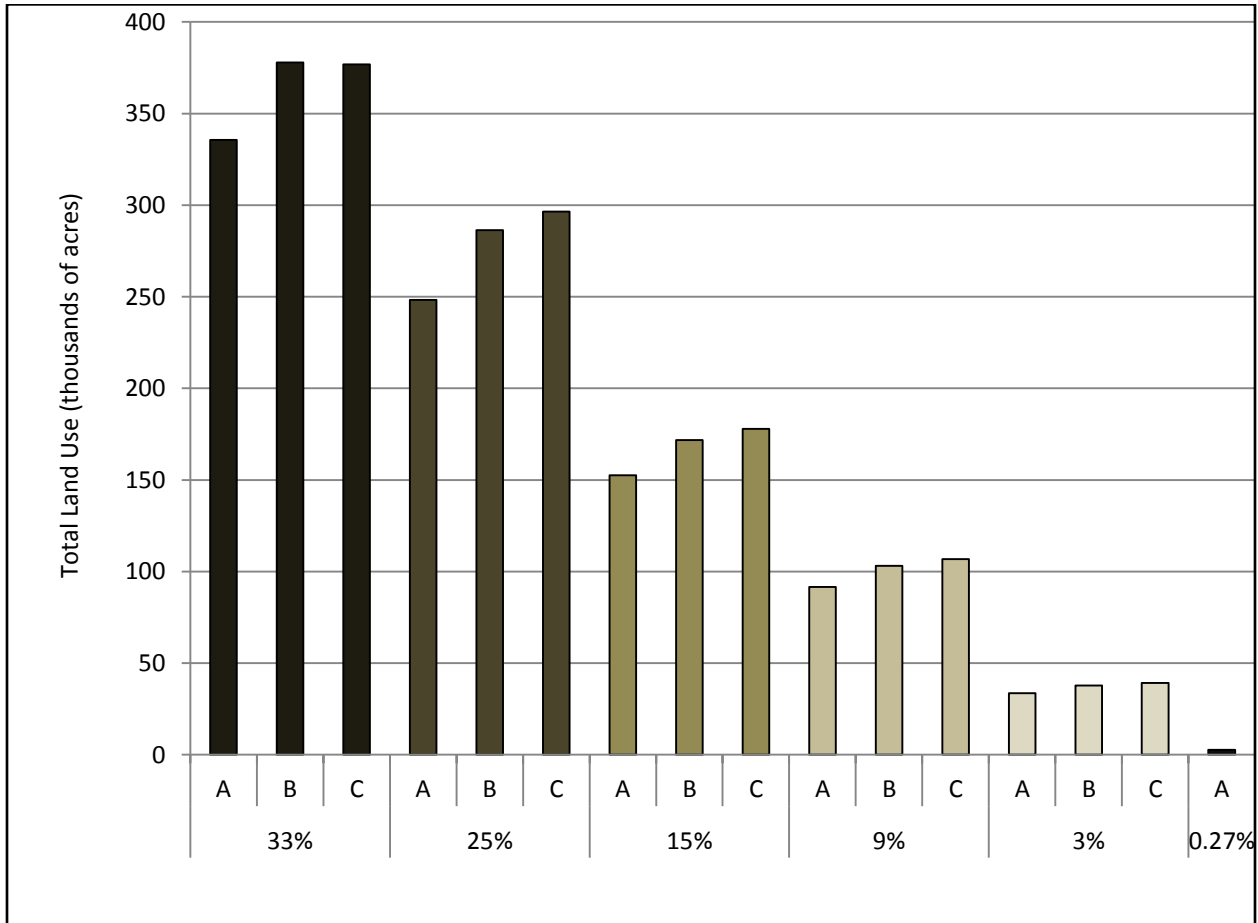


Figure 10. Land-use requirements for each of the sixteen scenario and portfolio combinations

7.3.4 Discussion

Our preliminary calculations show that to supply our projected range of electricity demand in 2020, 3.3 to nine percent, a range of 38,000 to 100,000 acres would be required for LSSE development. A key finding of this analysis is that while the technology portfolio does affect the total land area required for a given solar demand scenario by up to +/-14 %, the primary factor influencing land area requirements is the extent of solar energy’s total contribution to the RPS. In other words, the scenario, not the technology portfolio, is the main driver LSSE land-use impacts.

The impact on the California desert and the species that inhabit it is, as of yet, uncertain. Many of the areas that are ideal for LSSE development are also habitat for sensitive species. Any endangered species habitat that is “taken” requires authorization and a habitat management plan under both the ESA and the CESA. As more land is developed, the mitigation lands needed to offset the development of species habitat are becoming more limited (See Appendix D). Additionally, there may be potential issues associated with “resource-loading,” whereby sensitive species are physically relocated to areas identified as their habitat, crowding the individuals of the species that already inhabit the area. This issue has been a problem especially with projects that involve the taking of desert tortoise habitat. As LSSE projects continue to be developed in the desert, it is likely that habitat mitigation land will become a limiting factor unless the current policies protecting endangered and sensitive species change. Appendix D addresses mitigation requirements for LSSE projects.

Section 8.5.4 of this report analyzes critical species’ habitat distributions in the CDCA and identifies areas for solar development that may minimize impacts on sensitive habitat and reduce the need for mitigation.

7.4 Water-use Calculation

7.4.1 Solar Power Tradeoffs: Water vs. GHG Mitigation

The availability of water resources is an important considerations in the siting of solar plants in the CDCA (Section 4.1.4), which generally has scarce water resources. Historically, California deserts had vast groundwater reserves, but pumping in the last fifty years for both municipal and agricultural needs has depleted many groundwater basins (CA DFG, 2010). Accurate and up to date information on the status of the groundwater reservoirs in the CDCA is currently lacking. The lack of information on water resources makes it difficult to predict if there will be enough water available in the CDCA to support extensive LSSE development during the next decade.

The types of LSSE technologies chosen to supply California’s electricity demand will be determined by several factors, including the availability of water for construction and operation throughout the life of the LSSE plant. Some LSSE technologies require vastly different volumes

of water than others (Figure 11), but the use is always consumptive. The consumptive nature of this water use creates concerns about long-term environmental impacts, conflicting uses, and uncertainty about whether there is sufficient water supply to meet the cumulative demand. Because much of the land targeted for LSSE development is in water-scarce regions of California, the cumulative, consumptive water requirements of LSSE development is another tradeoff for reducing GHG emissions.

7.4.2 Methodology

The methodology for the water-use calculation is very similar to the land-use calculation described previously. As inputs to the water-use calculations, we used parameters from our selected representative LSSE projects. The total water use required for both the construction and annual operations of each project are reported in the associated environmental review documents. Figure 11 illustrates the difference between technologies in the water volume required to produce one MWh during plant operation.

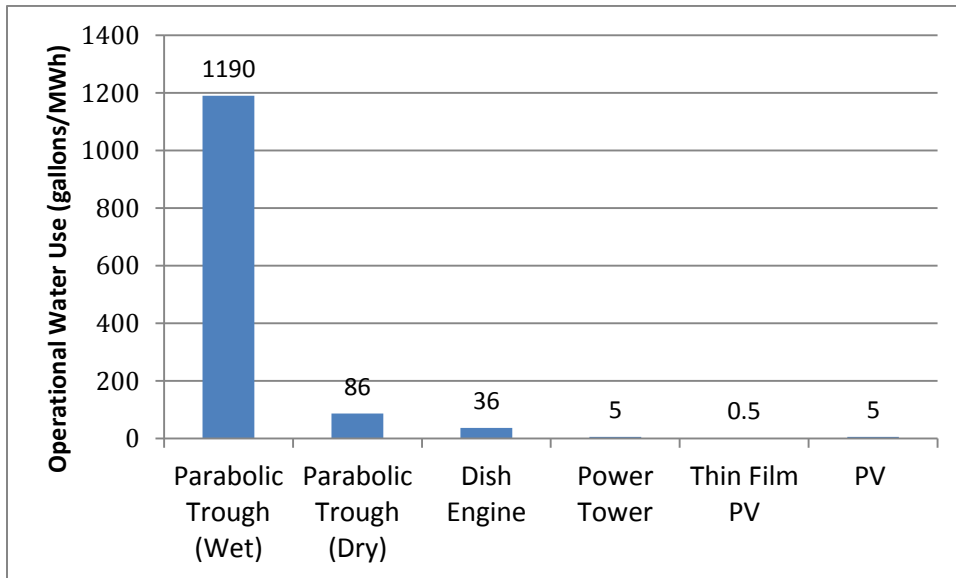


Figure 11. Operational water use in gallons/MWh for six classes of LSSE technology. Parabolic trough technologies that use wet-cooling systems are significantly more water intensive than any other LSSE technology.

To assess each solar facility's water footprint, we chose the following method. The final EIS from each LSSE project supplied our initial water-use numbers for construction and annual operation in acre-feet per year (AFY). Construction water use is a one-time use, so we simply

took that number and held on to it for last part of the calculation. For the operational water use, we converted the total operational water numbers for each technology to gallons per year. This is because PV systems use too little water to do the calculations in acre-feet. Next, we calculated the number of megawatt hours the plant will produce based on its capacity factor and nameplate capacity. The number of gallons per year was then divided by the MWh per year to give us a final number for operational water use in gallons per MWh per year. The first steps of the methodology are illustrated in Figure 12. The equation is shown below:

$$AFY * 325,851 \text{ Gallons} = \text{Gal year}^{-1} \div \text{MWh operating year}^{-1} = \text{Gallons/MWh/year}$$

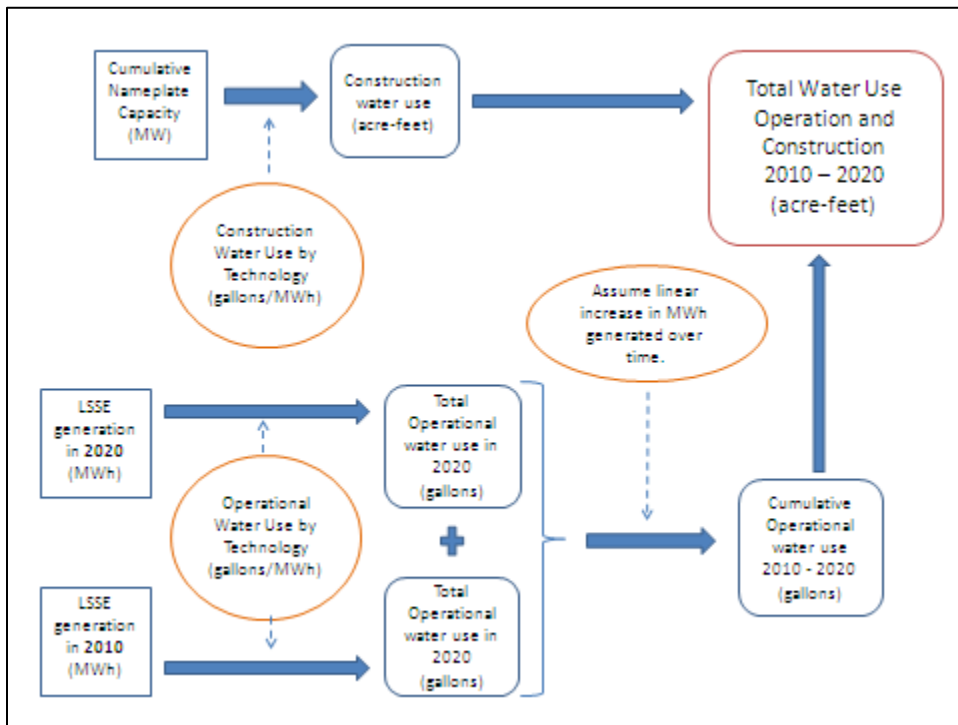


Figure 12. Water-use calculations flow chart. This flow chart shows the inputs (orange circles) and the process whereby we calculated the cumulative water use for each scenario/portfolio in 2020.

The next step is to calculate the cumulative operational water use. The timeline we considered for solar development is from 2010 to 2020. To identify the entire water footprint of each LSSE scenario, we need to calculate the operational water use over this ten year development period. Since our scenario calculations inform us of what the cumulative megawatt capacity will be by 2020, we assume a linear growth (considering construction time and date that projects come on line) of the LSSE developments in the period from 2010 to 2020. By integrating the rate of water consumption from 2010 to 2020 we are able to calculate the

cumulative operational water use in 2020 for each technology. This number is then added to the construction water use to get the final water use for each technology within each portfolio within each scenario. Finally, we graphically represent the different technology portfolios and their water use under each development scenario to see how their water-use impacts vary.

7.4.3 Results

Figure 13 shows the cumulative water impact from all years of operational use and construction use under each development scenario. This graph shows the differences between the total land impacts and the total water impacts. It is important to note that the lines for land impacts and water impacts do not follow the same trend.

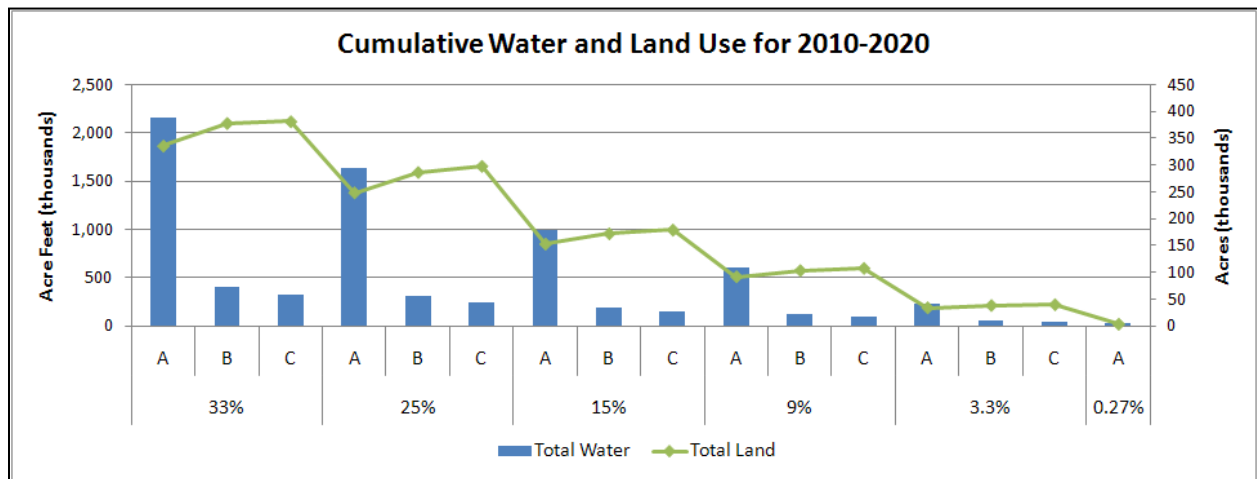


Figure 13. Total water use including construction and all years of operation from the time plants come online until 2020. The green line above shows the land-use requirement as a comparison.

Figure 14 shows the cumulative water use between 2010 to 2020 from operational water use. The development scenarios and the technology portfolios under these scenarios reflect our project’s prediction of the most likely range of LSSE development in the future.

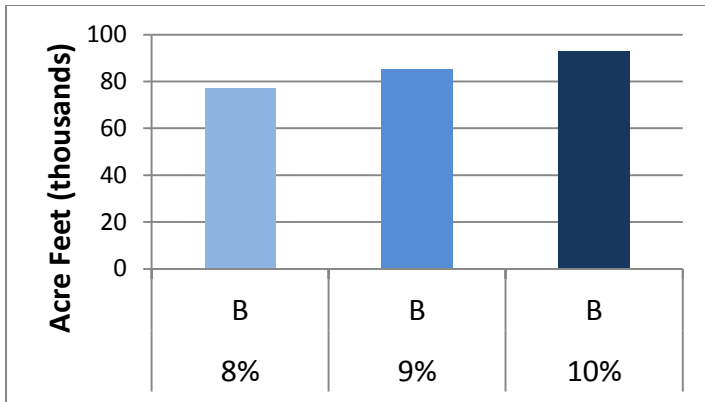


Figure 14. Cumulative water use for Portfolio B when LSSE contributes 8, 9 and 10 percent to California's 2020 electricity demand.

Figure 15 shows our theoretical upper bounds of water use from LSSE development. Portfolio A with 33 percent shows LSSE supplying electricity for the entire RPS using a technology mix dominated by mostly wet-cooled parabolic trough facilities. Portfolio B with 25 percent solar of the RPS shows the possibility of solar playing a large role in renewable energy, with an emphasis on dry-cooled technology.

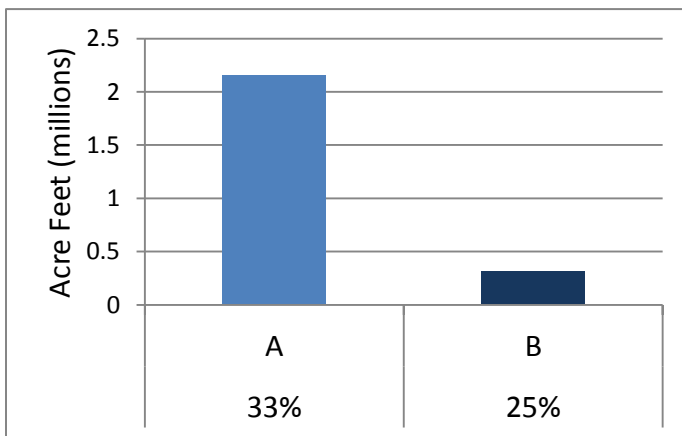


Figure 15. Cumulative water use for the theoretical upper bounds of water use from LSSE development.

7.4.4 Discussion

Our preliminary calculations show that to supply our projected range of electricity demand in 2020, 3.3 to nine percent using technology Portfolio B, a range of 53,500 to 121,000 acre-feet of water would be required for LSSE development. A key finding of this analysis is that unlike the land-use calculation, where the technology portfolio does not significantly affect

the total land area, we find that the effect is the opposite for water use. The technology portfolio, rather than the solar electricity demand scenario, significantly affects the amount of cumulative water required in 2020. In this part of the analysis, the type of LSSE technology utilized is the main driver of LSSE water-use impacts.

The availability of water in the future and the impact of its consumptive use on the California desert and the species that inhabit it are uncertain. California desert groundwater basins have a large storage capacity, though their current volumes are unknown. This lack of data is complicated by the potential for clustered siting trends for LSSE plants near transmission lines, roads, and other existing infrastructure. This fact may limit the amount of water available for LSSE development and in turn sway development in favor of the technologies that use water most efficiently.

8. Spatial Analysis

8.1 Introduction

The purpose of the spatial analysis component of this project is to determine whether the suitable land area in the CDCA is adequate to accommodate our estimates for LSSE's expected contribution to the RPS, given a set of environmental, legal, and physical constraints on solar development. Because permitting challenges are driven primarily by location, this spatial analysis further assesses the relative environmental suitability and permitting feasibility of the land area available for solar development after these constraints are taken into account. The primary objective of this analysis is to show where development may have the least impact on water resources and sensitive species habitat, while also minimizing the costs of connecting to existing transmission lines and roads. Our goal is not to perform a site-level suitability analysis, as the data we used are not sufficiently precise for such decisions, but to provide a macro-scale view of potential future solar development patterns.

The spatial analysis was conducted in *ArcGIS* and consists of three components:

1. Constraints Map: Identify all land uses that are not compatible with LSSE development and determine the land area that is available for LSSE development in the CDCA.
2. Siting Criteria: Determine the suitability of the remaining land available for LSSE development based on four criteria: (1) proximity to roads, (2) proximity to existing transmission lines, (3) water availability and (4) sensitive species habitat.
3. Combined Suitability Analysis: Aggregate the four siting criteria to determine the most suitable land area for LSSE development.

8.2 General Methodology

By applying a series of constraints – eliminating land that is illegal, physically unavailable, or unfavorable for solar development – we narrowed down the available area to meet basic permitting criteria. However, the remaining land is still characterized by varying degrees of solar development suitability. Developers typically classify land suitability based on land cost and permitting feasibility, while regulatory agencies, interest groups, and other stakeholders may classify land as “suitable” for solar development based on species habitat and other environmental parameters. Therefore, because AECOM must consider a variety of stakeholders’ interests during the permitting process for LSSE plants, we chose to incorporate several criteria into our suitability analysis. We created five different suitability layers in GIS, with each raster cell given a value according to suitability. These raster layer suitability values are based on (1) distance to transmission, (2) distance to roads, (3) groundwater availability, (4) distance to wastewater treatment plants, and (5) sensitive species habitat. Using these suitability criteria we were able to determine regions in the California desert that will be most suitable and therefore most likely for permitting LSSE development, and provide visual representation of possible future land development scenarios.

8.3 Study Area

As noted previously, we used the CDCA, a 25.9 million-acre designation in southern California established by the Federal Land Policy and Management Act of 1976, as the region of

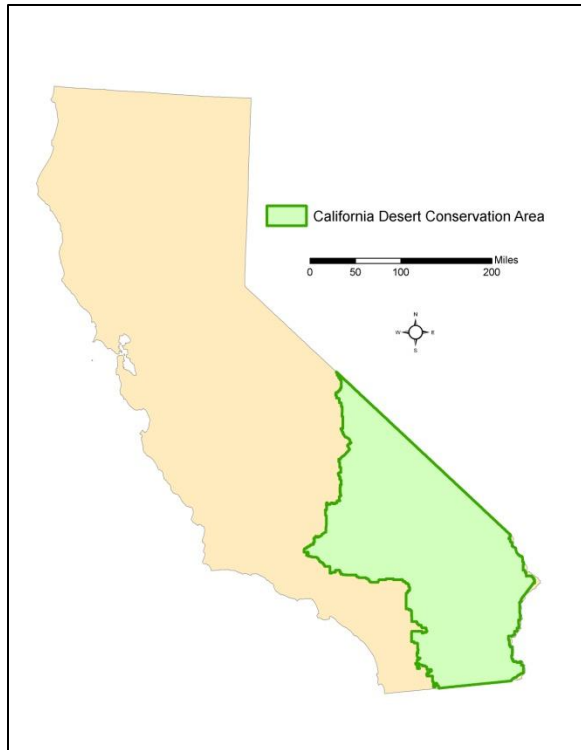


Figure 16. The California Desert Conservation Area (CDCA) is our region of interest for the spatial analysis section.

interest (ROI) to bind our constraints map and limit the extent of our spatial analyses (Figure 16). The CDCA was chosen as the ROI because it contains a large proportion of California’s existing, approved, and proposed LSSE developments. Forty-four out of 45 proposed solar facilities listed on the BLM website are located within the CDCA. The CDCA is generally targeted for solar development because of its abundance of undeveloped, federally-owned, and relatively flat land, as well as high year-round levels of solar insolation. These features make solar development both physically possible and more economically viable than in areas that are more populated and/or costly to build on. The CDCA is therefore a region where

solar development impacts are likely (Fernandes *et al.*, 2010).

The CDCA, which covers roughly a quarter of California, also represents the ecological bounds of southern California’s desert region (Fernandes *et al.*, 2010). Although there are many solar developments outside of the CDCA under consideration, we believe that limiting our analysis to this area allows for a comprehensive examination of future solar development scenarios in California. The CDCA includes much of the California Desert District (CDD), the unit of BLM that manages California’s desert ecosystem (Fernandes *et al.*, 2010). The coastal portions of the CDD were excluded from the ROI due to high population density, lower solar insolation levels and a perceived difficulty of solar permitting.

8.4 Solar Development Constraints Map

The first phase of our spatial analyses was to develop a ‘constraints layer’ to eliminate from our ROI land on which solar power cannot be legally or feasibly developed. These exclusions are the initial ‘hard’ constraints. A set of criteria-specific ‘soft’ constraints is defined in later sections. The hard constraints layer includes (1) physical obstacles (e.g., water bodies, populated areas, steep slopes); (2) areas that are legally incompatible with development (e.g., national parks, national monuments, state parks, wilderness areas); and (3) areas we determined are unlikely to be developed for solar power because of conflicting use or permitting obstacles. The remaining land is considered potentially available for solar development.

8.4.1 Data Sources

The GIS data used to create the constraints map included publicly available GIS layers downloaded from both the California State BLM GIS webpage (<http://www.blm.gov/ca/gis/>) and the RETI Documents webpage (<http://www.energy.ca.gov/reti/documents/index.html>). RETI is a statewide effort for identifying transmission projects necessary for achieving California’s renewable energy goals and facilitating the designation of transmission corridors and permitting (CEC, 2010d). RETI is a collaborative effort run by California entities involved with renewable energy policy and electricity infrastructure, including CPUC, CEC, California Independent System Operator (California ISO), and publicly-owned utilities, to identify the areas that can be developed most cost-effectively and with minimal environmental disruption. Many of the GIS layers included were available from both sources; when this occurred we chose the most complete and/or most recent version.

GIS data obtained from RETI included a ‘blackout’ layer showing slope of greater than five percent, water bodies (including lakes, playas, marshes and other classes of water body), lands managed by the National Park Service (NPS) (national parks and monuments), urban areas (with buffer), California State Parks, airports, military lands (DOD installations), and Areas of Critical Environmental Concern (ACECs). GIS data obtained from the BLM were populated

places (includes rural populated areas but not large urban centers), Wilderness Areas and Wilderness Study Areas (WSAs), renewable energy ROWs, and active BLM mines.

Solar insolation data were downloaded from the National Renewable Energy Laboratory's (NREL) GIS data archive, available at http://www.nrel.gov/gis/data_analysis.html, but as noted, were ultimately not used in the spatial analysis. All GIS data were collected during the month of October 2010, and do not reflect subsequent changes. With the exception of the RETI slope layer, all GIS data were downloaded as shapefiles. For a description of the data quality assessment and the process used to generate the constraints layer in GIS, see Appendix B.

8.4.2 Methodology: Hard Constraints

The fourteen GIS layers listed below are used to create the solar development hard constraints map.

- Water bodies – This layer includes lakes, reservoirs, playas, marshes and other water body classifications. Some of these water body types are physically impossible to build on (e.g., lakes and reservoirs). Others, such as playas or marsh areas, may be technically feasible to build on, but are unlikely to be permitted and are undesirable for development from an environmental standpoint. Although GIS data on rivers were available in the form of line shapefiles, these data could not be used to create exclusion areas due to the raster cell size used in our analyses (100 meters).
- Urban areas – This includes large cities and surrounding buffers.
- Populated areas – This includes populated rural areas and cities and towns which are smaller than are included in the urban areas layer.
- National Parks and National Monuments – These lands owned and managed by the NPS and are legally incompatible with energy development.
- State Parks – These lands are managed by the California Department of Parks and Recreation and are legally incompatible with commercial development by statute, regulation, administrative designation, or a Park's General Plan.

- Wilderness Areas (WAs) and Wilderness Study Areas (WSAs) – These lands are managed by various federal agencies including the BLM, USFWS and USFS. Energy development is legally prohibited in these areas (Fernandes *et al.*, 2010).
- Wind energy ROWS – Preliminary wind energy ROW applications (106) to the BLM were excluded under the assumption that these areas would be developed for wind energy rather than solar energy.
- DOD installations – This includes areas owned and managed by the DOD. These lands may be open to energy development only if the energy produced is also consumed on DOD lands. However, this is not typical of renewable energy facilities in the ROI and do not count towards the state’s Renewable Portfolio Standard. We therefore counted military lands as legally incompatible with solar development.
- Active BLM mines – Active mines are pre-existing infrastructure and land uses that make solar development physically impossible.
- Airports – These are pre-existing infrastructure and not available for development. Areas close to airports also face a number of unique permitting challenges (Bachrach & Lindner, 2010); however, only the airport facilities themselves were excluded from consideration.
- Areas of Critical Environmental Concern (ACECs) – ACECs are administrative designations by the BLM highlighting lands determined to require special management attention in order to protect important environmental, historic, cultural or scenic values (BLM, 2011). Though ACEC designation does not strictly preclude some degree of disturbance, ACEC status conflicts significantly with energy development (Fernandes *et al.*, 2010). The many permitting and regulatory obstacles likely to be faced in developing solar facilities in these areas led us to exclude them from availability.
- Slope – Lands with a slope of greater than five percent grade were included in the exclusion layer. As a factor in solar plant siting, slope differs from the land uses and designations described above because although it affects siting feasibility, it is not a simple yes/no determinant. Different solar technologies have different siting requirements, including those for slope and grading. Parabolic trough and most photovoltaic plants can be constructed on land with a slope of up to about three percent, whereas solar power tower

facilities can accommodate up to five percent slope, Stirling engine plants up to six percent, and linear Fresnel plants up to just one percent (Fernandes *et al.*, 2010; Aspen, 2009).

Grading may bring land into the necessary slope range; however, the more grading required for site preparation, the more expensive a project becomes. Sites with lower grade slopes are therefore highly preferable, but there is not necessarily a clear threshold between areas with slopes of low enough grade to build on and those that are simply too steep. Because slope is both an important physical and economic factor in siting decisions and feasibility, we chose five percent as a cut-off that would be realistic while not being too strict.

Data Not Included in the Constraints Map

Solar insolation

Solar insolation levels were also assessed as a possible basis for exclusion; however, GIS insolation data is not used in this analysis to eliminate land from consideration. High solar insolation is an important prerequisite for siting a solar power plant. When assessing potential sites, project applicants apply thresholds for exclusion to a set of criteria. One such criterion is solar insolation; for CSP plants, a site must receive a minimum of 7.0 kWh/m²/day of solar radiation to be suitable (Solar Millennium LLC, 2009). More accurate, site-level assessments of solar insolation are made after a number of potential sites are screened. In order to apply our exclusion criteria conservatively, we decided to use a threshold of 6.5 kWh/m²/day – the minimum value used in the development of the SPEIS and identification of proposed solar energy zones (SEZs) (SPEIS, 2010). However, the 10 km annual average direct normal solar resource data obtained from NREL indicate there is enough solar radiation in the entire ROI, so no exclusions are made based on insolation levels.

Cultural and archeological resources

While cultural and geo-archeological resources are relevant to siting and to permitting feasibility, including such information would be prohibitively time-consuming and hindered by the lack of publicly available, highly accurate GIS data for our ROI. One proxy for cultural significance would be to use the perimeter of dry lake beds – data which are available –

because prehistoric water bodies tend to have high occurrence of artifacts (Ortiz, 2010). However, solar developments have been proposed for the interior of such dry lake beds, so there is some uncertainty as to whether these areas should be excluded from future consideration. The CEC has recently begun to require developers to prepare wide-area (usually 25 sq. mile) geo-archaeology studies and soil maps to identify those areas in and around their proposed sites where they should be focusing their archeological assessments (Ortiz, 2010). Like solar insolation, geo-archaeological resources are studied in greater detail after site possibilities have been narrowed down. We do not exclude tribal areas, because while there may be issues associated with siting solar plants in these areas, tribes may embrace such initiatives from an economic standpoint.

Low-conflict land designations and sensitive habitat

Other data not included in the constraints map are low-conflict land-use designations, sensitive habitat and special management or conservation areas. We do not treat sensitive species habitat as a hard constraint because it is used in a later criteria analysis which optimizes siting based on avoidance of sensitive habitat. We also do not exclude areas designated for uses with a relatively low level of conflict with solar energy development, such as Off-Highway Vehicle (OHV) Use Areas. Additionally, we do not consider Wild and Scenic Rivers (WSRs) because there are no WSR designations in our ROI as of October, 2010. Data on national trails, Long Term Visitor Areas (LTVAs) and Desert Wildlife Management Areas (DWMAs) are unavailable and therefore are not included as hard constraints. We also do not consider areas of cultural or historic importance, or tribal lands, as hard constraints because these areas, in some circumstances, may be available for LSSE development.

Agricultural Land

High value agricultural land is also an exclusion criteria used by developers in their site selection process. However, due to the scope of our analysis, we do not have the data to eliminate land based on agricultural status.

8.4.3 Results: Land Available for Solar Development

After excluding the hard constraints listed above, the remaining area totals 6.75 million acres (ma), or about 26 percent of the CDCA (Figure 17). This available land is more than enough to satisfy the entire 33 percent RPS with solar energy.

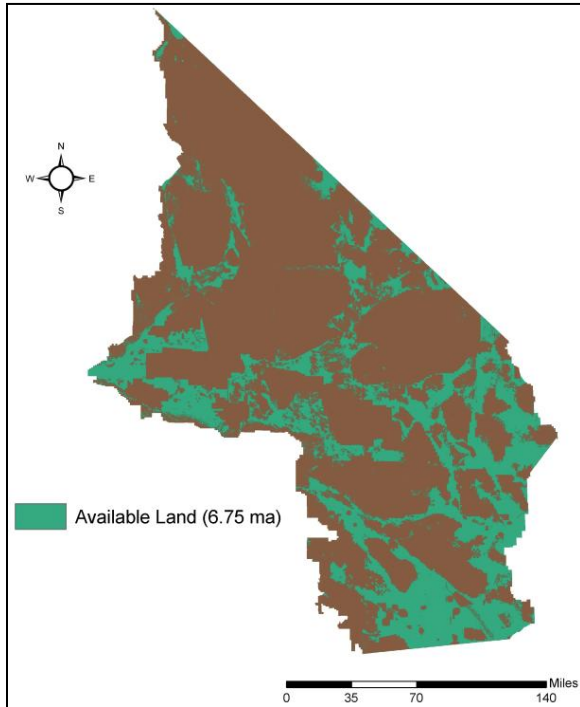


Figure 17. Within the CDCA, the turquoise represents the area available for solar development after applying hard constraints.

8.5 Siting Criteria

In this component of our analysis, we eliminate an additional set of constraints which relate to solar development siting criteria, and then perform suitability analyses on the remaining area based on these criteria. There are numerous factors which affect the viability of a solar project; however, based on communication with our client, AECOM, and information obtained from the CEC, we identified proximity to transmission, proximity to roads, water availability, and the avoidance of sensitive species habitat as the most important solar development siting criteria. For most solar siting criteria, there is rarely a hard cutoff beyond which a solar project is infeasible. The physical, technical and financial feasibility of a solar project depends on numerous factors, each of which could tip the balance towards or away

from economic or permitting feasibility. First we identify a set of ‘soft’ constraints for each of these four siting criteria and eliminate additional area based on these constraints, and then we rank the remaining area by suitability according to proximity to transmission and roads, water availability, and the avoidance of sensitive species habitat.

8.5.1 Transmission

Renewable energy development is limited by both distance to and the capacity of the existing transmission infrastructure. As LSSE development grows to meet California’s RPS, additional transmission infrastructure will be needed. Currently, many of California’s transmission lines are close to their maximum capacity and will be able to accommodate only the electricity generated by one or two more new solar facilities (U.S. DOE, 2010). Therefore, this need for additional capacity is driving new transmission line development, such as the Tehachapi Renewable Transmission project in California (Southern California Edison, 2010), which will transmit renewable energy through eastern Kern County and San Bernardino County (Southern California Edison, 2010).

In our analysis we did not make a distinction between the lines that have capacity for several new plants versus the ones that are close to reaching full capacity, because often new lines are built alongside existing lines to expand capacity in high transmission areas. Although transmission line capacity will be an important constraint to future solar development, capacity issues are beyond the scope of this project. Here, we focus on distance to transmission lines as a siting criteria and basis for additional land exclusions.

When considering potential sites for LSSE development, developers prioritize areas that are close to existing transmission lines in order to reduce project costs, avoid permitting obstacles, and reduce environmental impacts. The further a solar project is sited from transmission lines, the more expensive construction, materials, and maintenance costs become (U.S. DOE, 2010; Head, 2011). Additionally, as transmission connectivity lines span across land owned by multiple parties, more parties will have to grant land-use approval; this makes land acquisition and the permitting process increasingly complex and expensive (Birenbaum, pers. comm., 2011).

Aside from construction costs, solar developers must also consider the environmental impacts created by solar site connectivity to transmission. As solar sites are permitted further from transmission lines, more species habitat and hydrogeological resources are impacted (U.S. DOE, 2010).

To minimize both the costs and the environmental impacts created by a solar facility, developers typically prefer to site facilities within 10 miles of the nearest transmission line; in fact 10 of the last 13 solar projects to be permitted in California fall within 10 miles of the nearest transmission (CEC, 2010). However, many prospective solar developers have applied for ROWs up to 20 miles from existing transmission lines, with the furthest ROW application at a distance of 23 miles (CEC, 2010; Fernandes *et al.*, 2010). Because this facility is an outlier and because no projects have yet been approved at that distance, we chose to set the cutoff for distance to transmission at 20 miles. Considering the barriers to permitting that arise from building further from transmission, 20 miles is a realistic cutoff that balances infrastructure cost, multiple landowner permitting obstacles, environmental impacts, and development growth.

Data Source

It is the CEC's policy not to release digital transmission data to the public for both security and confidentiality reasons. Therefore we were unable to obtain complete and accurate GIS data that depicts the location of all of the transmission lines within our ROI. However, we were able to use publicly available GIS data downloaded from the California State BLM GIS webpage (<http://www.blm.gov/ca/gis/>), which is not complete but was able to give us a coarse-grained look at transmission coverage and availability within the CDCA (BLM, 2011). We assessed the accuracy of the available transmission data by comparing it to NAIP orthophotos and found that the BLM transmission data was within 10 meters of the transmission lines in the photos. See Appendix B for further details on the data source and GIS modeling procedures.

Methodology

We used *ArcGIS* mapping to calculate the distance to transmission and excluded any previously available land that was further than 20 miles from existing transmission lines. See Appendix B for a detailed description of the *ArcGIS* modeling procedures.

Results

After excluding the area beyond the 20 mile cutoff, in addition to the initial hard constraints, 6.27 million acres, or about 24 percent of the CDCA, remained available for solar development (Figure 18). A relatively small amount of land is further than 20 miles from transmission lines, indicating that much of the land initially available after application of the hard constraints was already within 20 miles of existing transmission infrastructure.

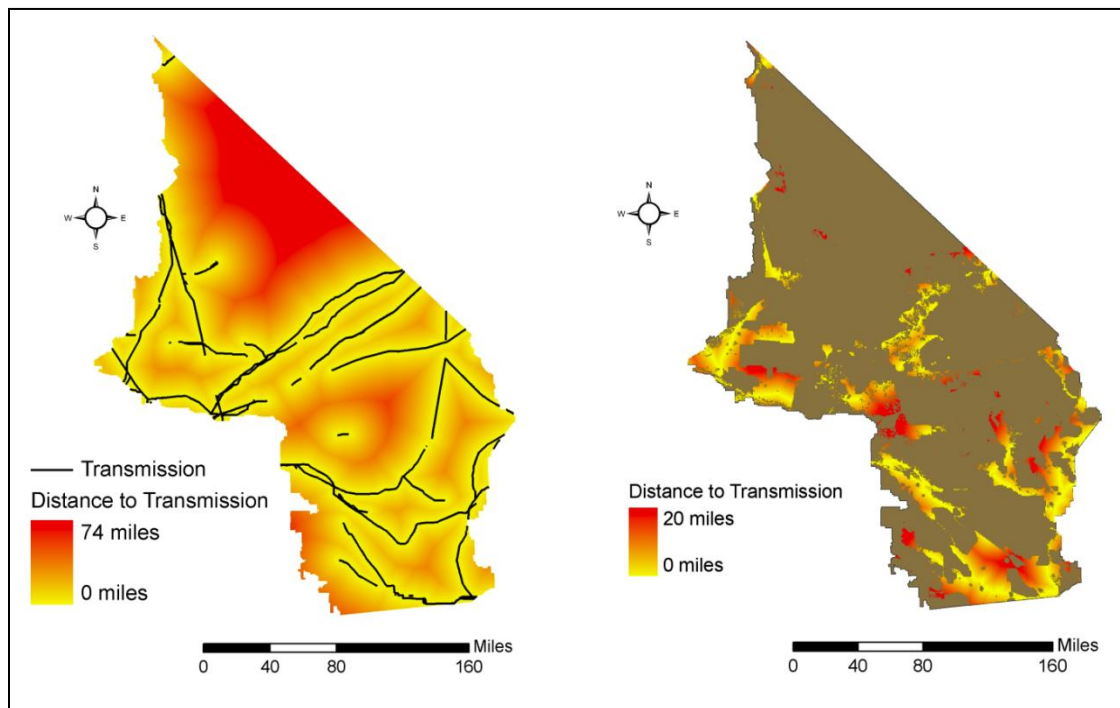


Figure 18. Distance to transmission lines before and after removing solar development constraints. The map on the right shows distance to transmission lines up to 20 miles, after hard constraints are eliminated.

8.5.2 Roads

Another site selection criterion used by solar developers is “reasonable” proximity to large paved roads or highways. Site suitability improves with proximity to roads due to

increased site access during construction and operation, and reduced environmental disruption. Construction and project costs are lower if a site is near major roads because travel time for construction workers is reduced and materials can be delivered more efficiently (Ignizio, 2010). Areas near major roads are also more likely to have experienced prior disturbance and not be pristine habitat, so new developments near major roads are less likely to result in serious ecological impacts than developments in more isolated areas. Additionally, sites that are near other development with high traffic volume are likely to be permitted faster and at lower cost than pristine sites far from other development.

The 13 fast-tracked solar facilities to be permitted recently in California are all situated within 10 miles – the distance threshold preferred by solar developers – of the nearest major road (CEC, 2010). However, many solar facilities have been proposed beyond 10 miles, with the furthest ROW application submitted for a site which is 23 miles from the nearest major road (CEC, 2010). In general, distance to roads is treated as less important for site suitability than the other criteria analyzed here: proximity to transmission infrastructure, water availability, and avoidance of sensitive species and habitat.

Data Source

We obtained our GIS major roads data map from the Cal-Atlas Geospatial Clearinghouse (<http://atlas.ca.gov/download.html#/casil/transportation>). We downloaded the Major Roads Tiger data, which includes highways and major roads, streets, and boulevards.

Methodology

We assume that solar facilities may be permitted well beyond 10 miles from major roads. However, to limit the available land to the most realistic sites, we set the maximum possible distance to major roads at 20 miles, eliminating all land beyond this threshold from consideration. This is a liberal estimate of the maximum permitting distance, but while transmission can be cost-prohibitive, road construction does not have the same financial impact on a project. Using the same procedures as in the transmission GIS model, we eliminated from the hard constraints layer the land that is further than 20 miles from the nearest major road. In the CDCA, access to roads is less of a constraint than access to

transmission lines; therefore less land was eliminated by roads than the transmission constraints. See Appendix B for further details on the *ArcGIS* modeling procedures.

Results

When all areas beyond 20 miles of a major road were eliminated, 6.69 million acres of suitable land remained for development, or slightly less than 26 percent of the CDCA (Figure 19).

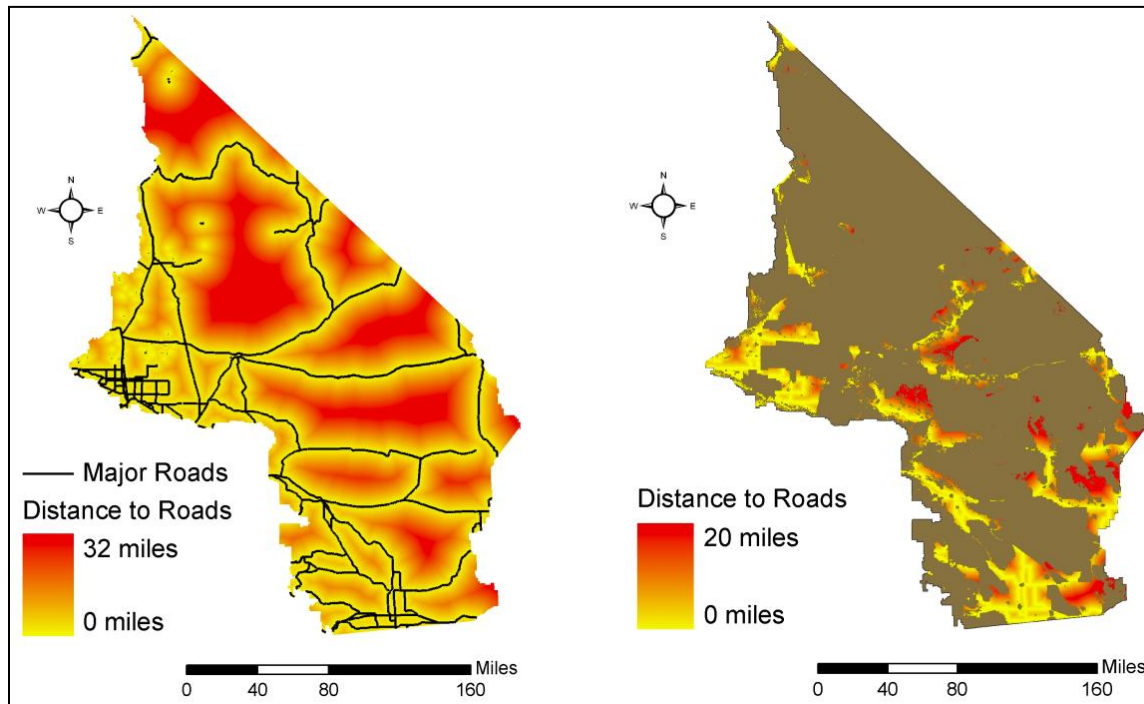


Figure 19. Distance to major roads before and after removing solar development constraints. The map on the right shows distance to roads up to 20 miles, after hard constraints are eliminated.

8.5.3 Water Availability

Water required for the construction and operation of solar power plants, particularly to meet the cooling needs of solar thermal facilities, is a highly contentious issue in California and a significant environmental constraint for solar development. The CDCA includes land in two Department of Water Resources (DWR) Hydrologic Regions, the Colorado River Region and part of the South Lahontan Region, both of which have few natural streams or standing water bodies, the largest of which is the Salton Sea, a saline lake approximately 50 feet deep. Despite the scarce water resources in the region, solar development will require significant quantities of

water for thermal cooling, and some water is required for PV panel or mirror washing. Therefore, water resources must be considered when developing an LSSE project. There are three main factors related to water resources that must be considered when determining the site suitability for solar development in the CDCA: quantity of available water, quality of available water and distance to available water.

Quantity of Available Water

In California, and particularly within the CDCA, the quantity of available water for solar power plants is very limited. Potential water sources include groundwater (the most common option), treated wastewater, water imported from elsewhere, particularly the State Water Project (SWP), and irrigation return flows. Surface water, with the exception of the Colorado River, tends to be intermittent and severely limited as a potential source. The Colorado River is not a viable water source even for those facilities located nearby, as the River's water is already allocated among Colorado River Basin users and generally unavailable for further allocation (DWR, 2009).

Groundwater: Solar facilities often rely on groundwater pumped from on-site wells. Groundwater is a scarce and valuable resource in this area, and its use is not a realistic option in many groundwater basins. In both the Colorado River Region and the South Lahontan Region, groundwater supplies a significant and growing portion of water demanded by previously established land uses such as agriculture and urban. The South Lahontan Region relies more heavily on groundwater, supplying about 65 percent of its urban, agricultural and environmental water demands from local aquifers (DWR, 2009b). In the Colorado River Region, a significant and growing portion of water demand is met through groundwater, with groundwater supplying 7.5 – 14 percent of the region's water demand. Storage capacity is estimated for 40 of the CDCA's 142 groundwater basins, totaling 175 million acre-feet (DWR, 2009a). However, some of this water is too saline or has Total Dissolved Solids (TDS) levels too high to be used untreated.

Several of the CDCA's major groundwater basins are being pumped faster than they can be replenished, a condition known as "overdrafting." Five of these overdrafted basins have been adjudicated, meaning that specific pumping allocations have been assigned to control overdrafting. These basins are managed under various court decisions and agreements. Further groundwater extraction for power plant use in such basins is highly improbable. Often solar developers are required by regulatory agencies to conduct extensive groundwater modeling to show that there is sufficient water, a process that can become prohibitively expensive in the permitting process.

Treated Wastewater: In 1975, the State Water Resources Control Board (SWRCB) issued Resolution No. 75-58, the "Water Quality Control Policy on the Use and Disposal of Inland Waters used for Power Plant Cooling" (U.S. EPA, 2010). In addition to creating consistent statewide water quality principles and guidance for discharge requirements for power plants, this state policy encourages the use of treated wastewater for cooling. Policy 75-58 listed the following order of preference for cooling water sources: "1) wastewater being discharged to the ocean; 2) ocean water; 3) brackish water or irrigation return flows; 4) inland waste waters of low total dissolved solids (TDS); and 5) other inland waters" (U.S. EPA, 2010). The first two options are clearly not applicable to the CDCA. However, the fourth option has been adopted by regulatory agencies; wastewater treatment plants (WWTPs) are encouraged as a water source for solar thermal facilities, but the use of recycled water for power plant cooling is limited by access to WWTPs and the level of water quality. Because photovoltaic plants have no cooling requirements, this policy is relevant only to solar thermal facilities.

Water Availability and Current Land Use: Land-use patterns across these two regions are critically important to the feasibility of siting solar power plants that depend on scarce water resources. Land-use patterns in the Colorado River Hydrologic Region are dominated by irrigated agriculture - particularly in the Imperial, Palo Verde, Bard and Coachella Valleys (DWR, 2009a). Urban land use, representing the other major water demand in this region, is

concentrated near the western border of the CDCA, in the Coachella Valley, and along Highway 111 and Interstate 10.

Quality of Available Water

Water quality – particularly TDS content – is an important determinant of whether a particular site or basin can supply a solar power plant’s needs. TDS content of less than 3000 mg/l is optimal, while greater than 5000 mg/l TDS is generally considered infeasible (Flack, 2010). Many basins within the CDCA have groundwater with TDS content that is too high for power plant use. Although groundwater can be treated to sufficient quality, such a requirement would add considerable cost to a project’s budget and may make it economically infeasible. Groundwater in the north of the South Lahontan Region, where it is recharged by snowmelt and runoff from the Sierras, tends to be of higher quality, whereas in lower elevations in the south, groundwater is more likely to be degraded. Water quality varies significantly by basin. Tertiary treatment of wastewater is required for recycled wastewater to be used for solar thermal power plant cooling.

Distance to Available Water Sources

Distance to potential water sources is another important constraint on solar plant siting, as the infrastructure necessary to bring water to the facility becomes prohibitively expensive over longer distances. As mentioned earlier, WWTPs are encouraged as a water source by regulatory agencies; however, there are tradeoffs between using recycled wastewater and the cost of importing it from a distance. In the CDCA there are relatively few WWTPs due to its sparse population and even fewer that provide recycled water that meets LSSE water quality requirements.

Groundwater Basin Suitability

Data Source

Reliable groundwater data, including estimated aquifer storage capacity and groundwater in storage, recharge, withdrawals and water quality, are of limited availability in

the CDCA. The data on groundwater in storage used in this analysis are of limited quantity and quality and are often not current. Data on water quantity and quality is often several decades old and based on data from a limited number of wells. Estimates of withdrawals and recharge are missing for most of the groundwater basins in the CDCA. The basins with the best available groundwater data tend to be those that have been contested and subsequently adjudicated.

Due to the scarcity of recent, comprehensive data, we relied on a 1979 DWR reconnaissance study entitled Sources of Power Plant Cooling Water in the Desert Area of Southern California in order to assess the relative suitability of the remaining area available for

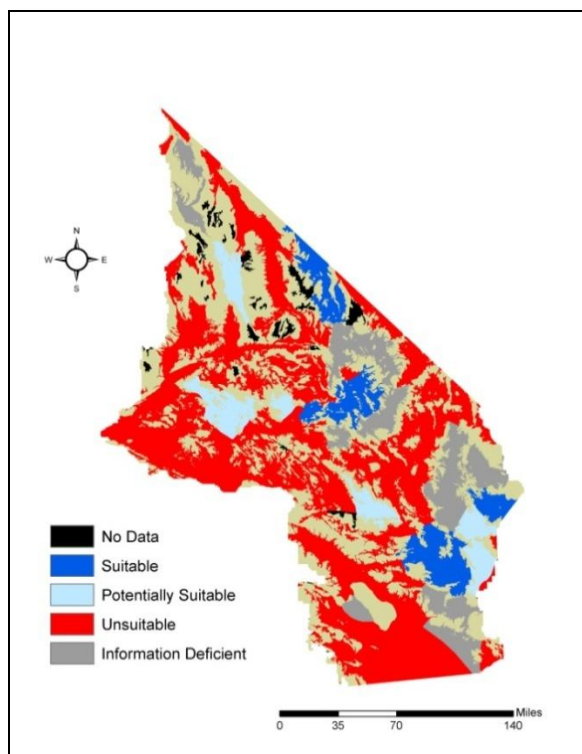


Figure 20. DWR assessment of groundwater basin suitability for power plant development in the CDCA.

solar development (DWR, 1979). This study, performed by the U.S. Geological Survey, evaluated groundwater basin suitability for steam-generating power plant development according to four criteria: estimate volume of water in storage, well yield, water quality and basin development. This report identified five groundwater basins as suitable, six basins as suitable with qualifications, 83 basins as unsuitable, and 13 for which insufficient data were available to make such a determination (Figure 20). No data was available for an additional 34 basins, mostly in the northern

portion of the CDCA. It should be noted that the DWR's suitability assessment focused on a hypothetical 1,000 MW fossil fuel power plant

with considerably higher water requirements than even today's wet-cooled solar thermal power plants. However, this assessment is the most recent comprehensive data source we were able to find, and still relevant to an analysis of groundwater availability and suitability for solar power plants. The 1979 DWR report was downloaded from openlibrary.org (DWR, 1979). In order to incorporate each groundwater basin's power plant suitability status into the spatial

analysis, data from the 1979 report was used in concert with GIS data obtained from the DWR Bulletin 118 website

(http://www.water.ca.gov/groundwater/bulletin118/gwbasin_maps_descriptions.cfm). See Appendix B for additional information on the processing of this data.

Methodology

Groundwater basins were ranked according to their suitability for hosting solar thermal power plants. Following the DWR classification of basins, we classified those basins determined by DWR to be suitable as “high suitability” areas, and those basins determined potentially suitable by DWR as “medium suitability” areas. We grouped DWR’s unsuitable basins, those basins with insufficient data to make a suitability determination, and those basins for which no information was given, as “low suitability” areas for solar thermal development. Although PV plants require water for panel washing and other uses, their water needs are considerably less than those of solar thermal plants, and basin status is assumed to be less of a siting constraint for these technologies. One important point is that, because our groundwater suitability assessment deals with a different technology having much lower water requirements than conventional 1970s power plants, we can not necessarily dismiss DWR’s “unsuitable” classifications as infeasible for either photovoltaic or solar thermal development. Rather, we stress that these are *relative*, not *absolute* rankings of suitability, and that these basins can therefore be viewed simply as more or less likely to be suitable for solar development.

Results

Of the 3.5 million acres remaining available after the elimination of all constraints, about 20 percent is classified as “suitable” or “potentially suitable,” while the rest of the remaining available area is “unsuitable,” “data inadequate,” or not listed (Figure 20). The 3.5 million acre figure is much lower than the 3.9 million acre figure given previously because many areas in the CDCA do not have underlying groundwater basins and therefore cannot be included.

Wastewater Treatment Plants

As the rate of groundwater recharge has diminished and the rate of groundwater pumping has increased in the CDCA, tertiary wastewater treatment plants (WWTPs) have become a preferred source of water for LSSE plants (Garner, 2010). However, most of the large National Pollutant Discharge Elimination System (NPDES)-permitted facilities are concentrated in the small cities surrounding the Salton Sea, so only three of the last 13 solar facilities approved have proposed to source their water from WWTPs (CEC, 2010). The Beacon solar project considered three potential water sources: a WWTP 12 miles away in California City, a WWTP 40 miles away in Rosamond, or on-site groundwater wells (Douglas, 2010). The CEC's final decision stated that groundwater will be used for the plant's construction, but will be phased out over five years as pipelines are built to transfer recycled water from California City (Douglas, 2010). Piping water from California City is more realistic than building pipelines to transfer water 40 miles from Rosamond. However, as groundwater resources diminish, developers might be left with little option but to pipe recycled water longer distances to break ground on their project (Flack, 2011).

A solar facility that proposes to use recycled water rather than groundwater must source its water from a WWTP that meets certain water quality and availability standards (Flack, 2011). Principally, the recycled water provided to the solar facility must meet the Title 22 tertiary water treatment standards (Flack, 2011). If a WWTP has already contracted most of its recycled water supply to other users, or if it is a significant contributor to an Urban Water Management Plan, then it may not have enough available water to supply a solar plant. Another water availability issue that has blocked the use of recycled water for solar facilities is the argument that a better use for recycled water is groundwater recharge through discharge to infiltration ponds in overdrafted basins (Flack, 2011). This has been a contentious issue particularly in adjudicated basins where legal battles over WWTPs' water resources have blocked solar facilities from obtaining recycled water. For example, the city of Lancaster's WWTP has faced this type of litigation. Despite contributing significantly to an Urban Water Management Plan, the Lancaster WWTP still has excess water to contract out; however, it has

not yet done so because of arguments that the treated water should be allocated to groundwater recharge (Flack, 2011).

Although recycled water from WWTPs is the preferred water source for solar facilities, there are many who will argue against contracting more water out for power plant cooling. Water resources in the CDCA are stretched thin and whether solar developers look to groundwater basins or to WWTPs, they are bound to face some permitting challenges and/or water-use mitigation requirements. However, if there is a WWTP within reasonable distance of a proposed solar facility, it will be the preferred as a water source over groundwater.

Methodology and Data Source

Although groundwater is the primary water source for most LSSE plants, there are some areas where groundwater is not available for use or is of poor quality. Therefore, rather than eliminate land that does not have access to groundwater, we developed the WWTP layer to support the groundwater basins map. The two maps go hand-in-hand, so when a raster cell in the ROI fell within 20 miles of a WWTP, the WWTP was the preferred water source over the nearest groundwater basin. All of the remaining cells outside of the 20-mile buffer were ranked based on the DWR's groundwater basin suitability assessment, as described in the Appendix B. Therefore, when building the WWTP layer, we found it important to include in our study the largest wastewater treatment plants in the CDCA. These wastewater treatment facilities are all NPDES federally permitted plants under the Clean Water Act. We obtained a list of all of the NPDES wastewater treatment plants and narrowed the list to facilities that are not privately owned and operated (e.g. we did not include wastewater treatment plants on geothermal facility sites). Once we had a list of the 12 treatment plants that could potentially supply water to a solar facility, we identified the coordinates of each plant in Google Earth and imported them into GIS as point data. The 12 plants are concentrated to the northwest and to the southeast of the Salton Sea, and when checked against orthophotographs, they appeared in the identical location as the WWTPs in the photos.

Although the WWTP plants serve only a small portion of the CDCA, they all lie within our constraints layer and have the potential to offset the water that would otherwise be demanded

from groundwater basins. As more solar projects are built in the desert and recycled water is in greater demand due to over-allocated groundwater resources, developers may be more willing to pipe recycled water to their plants at greater distances. Therefore, we created a 20-mile buffer around each of the WWTP points and ranked each cell with a value that corresponded to distance (ex. 1 mile = 1, 2 mile = 2, etc.). Reclassifying the data implies that there is a linear relationship between cost and the distance of the pipeline. Our assumption is that as the pipeline gets longer the project will become more expensive and more difficult to permit, making further sites steadily less suitable for development. The Imperial Valley Solar plant is 10 miles from its source WWTP, which is the furthest a fast-tracked solar facility is permitted from its water source (James *et al.*, 2010). We assumed that as solar development continues, site suitability for each new solar plant will diminish and recycled water will have to be piped from longer distances until it is no longer cost-effective to build the piping infrastructure. Therefore, we chose 20 miles as the cutoff because, although it is not the most desirable piping distance, it can be accommodated if necessary (Figure 21).

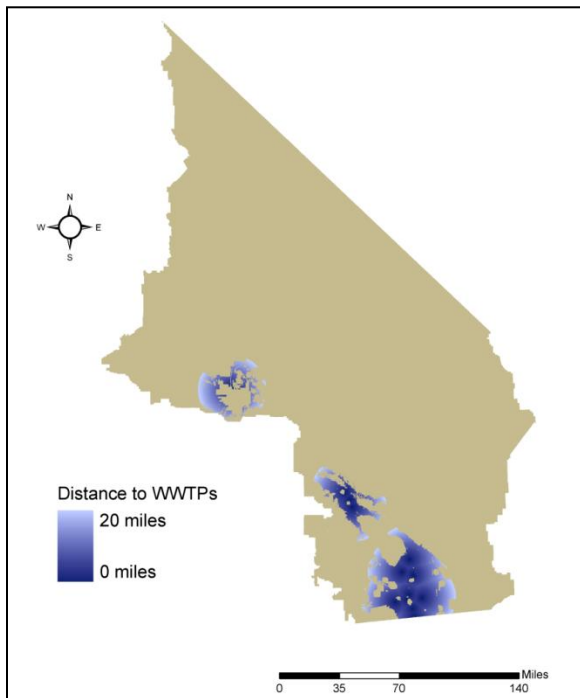


Figure 21. Distance to the 12 NPDES permitted Wastewater Treatment Plants in the CDCA.

8.5.4 Sensitive species habitat

The land area required for solar development often overlaps with sensitive species habitat and natural communities, many of which are protected through federal or state policies. The tradeoff between solar energy and species habitat in the desert has been a contentious subject and many environmental groups have opposed certain solar developments due to the adverse ecological impacts. Here, we describe the ecology of the CDCA, provide one method for assessing species habitat and provide recommendations for solar development siting that could potentially avoid conflicts with sensitive species.

Species and Natural Communities

The CDCA supports hundreds of species, some of which are described, some of which are not, and some of which have yet to be discovered. Many of these species are endemic to the region or live in isolated communities, dependent on special habitat features, such as wetlands, desert washes, small woodland communities, unique soil types, and active sand dunes (Spencer *et al.*, 2010). In the CDCA, there are 69 wilderness areas, 22 wilderness study areas (WSAs), 14 threatened or endangered wildlife species, 10 threatened or endangered plant species and 85 areas of critical environmental concern (BLM, 2006).

The endemic species, natural communities and ecological processes unique to California's deserts are severely stressed by human-induced land-use changes (Spencer *et al.*, 2010; Webb, Heaton, & Brooks, 2009). Additional stress from direct and indirect effects of energy developments, such as habitat conversion and fragmentation could lead to further ecological degradation and increase the likelihood of species extinctions (Spencer *et al.*, 2010).

Federal and state environmental policies have been put in place in an attempt to protect and conserve these unique species, communities and ecosystems. The Natural Communities Conservation Plan (NCCP) Act of 2003 (Senate Bill No. 107) aims to "sustain and restore those species and their habitat... that are necessary to maintain the continued viability of those biological communities impacted by human changes to the landscape." In response to the NCCP policy requirement "to conserve, protect, restore, and enhance natural communities," Governor Schwarzenegger mandated the development of a NCCP for the

Mojave and Colorado Deserts. In order to implement this plan a group of representatives from the USFWS, California DFG, BLM, and CEC formed the Renewable Energy Action Team (REAT) and developed the California Desert Renewable Energy Conservation Plan (DRECP).

This governor-ordered conservation plan aims to provide binding, long-term endangered species permit assurances and facilitate the review and approval process for renewable energy projects. The plan also aims to serve as the basis for one or more habitat conservation plans (HCPs) under the Federal Endangered Species Act (ESA). In the DRECP Planning Agreement report, species of “planning interest” to solar developers were identified. Species were selected based on conservation status, occurrence in the planning area, likelihood of being affected by plan actions, and sufficiency of knowledge to determine plan effects (REAT, 2010; Spencer *et al.*, 2010). Since the publication of the DRECP Planning report, a group of independent science advisors have published a review of REAT’s work on conservation-aspects of the DRECP. For the purpose of this study, we used species from the DRECP planning report list and incorporated suggestions from the independent science advisors to assess the suitability of solar development in the California deserts.

Methodology

Our overall methodology was to quantify the suitability of habitat for sensitive species in the CDCA in order to prioritize the avoidance of the most sensitive areas. This criteria analysis included two steps. First we excluded specially designated habitat and conservation areas. Secondly, we projected habitat suitability for species of special planning concern using a species distribution modeling approach. The species distribution models were informed by species presence and absence data as well as environmental indicators for our ROI. Overall, we sought to convey both ecological sensitivity and permitting difficulty due to the presence or potential presence of sensitive species or habitat.

Sensitive Habitat Exclusions

Critical habitat for 17 federally-listed endangered or threatened plant and animal species occurring in the CDCA were excluded from the initial available area for solar development. Also excluded for this analysis were Flat-tailed Horned Lizard Management Area,

Mohave Ground Squirrel Conservation Area, and Mojave Fringe Toed Lizard Habitat. Although not strictly illegal on these lands, solar development conflicts significantly with their designated use. An ESA provision allows disturbance on up to a cumulative total of 1 percent of the acreage of a critical habitat unit (CHU), and take permits may be issued under some circumstances; however, permitting a solar plant in such an area would be challenging (Bachrach, 2011). These areas were also excluded because they represent habitat that is established as particularly important for the species. After adding these exclusions to the hard constraints identified in the previous section, the total area of available land calculated during the initial constraints analysis dropped from 6.75 million acres to 5.28 million acres, or from about 26 percent to 20 percent of the CDCA. This figure is likely a more realistic representation of the available land.

Species Distribution Modeling

The DRECP science advisors recommend “judicious” use of species distribution models (SDMs) to represent or predict species distributions (Spencer *et al.*, 2010). In our study we modeled the distribution of 35 species in our ROI that have federal or state protections. We then weighted each of these species based on federal and state ranking systems. All weighted species distribution maps were summed into one map that shows where species habitat is either common or highly weighted according to our methodology.

Species

The species we chose to include in our study were amphibians, birds, mammals, reptiles, plants and one insect included in the DRECP planning report by REAT (REAT, 2010). Exhibit B of this planning report provides a “preliminary list of species of planning interest.” We used this list of species as our initial starting point. However, the DRECP is a bigger area than the CDCA and therefore includes more species. We removed species from the list that are not found in our study area.

Species survey data and environmental variables are incorporated to produce a correlative model that predicts where a species is likely to be found. In this study, we used observational data from the Global Biodiversity Information Facility (GBIF) website, which is

presence-only data (accessed online at <http://www.gbif.org/>). Data were limited on many species and we removed species from the list that did not have 20 or more data points. In the end, we included 35 species in our study, which are listed in Appendix C.

Since the publication of the DRECP Planning Agreement, a group of independent science advisors (Spencer *et al.*, 2010) has provided recommendations on how to improve the list of “covered species” by including subspecies designations and excluding species that do not fall within the DRECP area (Spencer *et al.*, 2010).

Ranking systems

To assess the importance of each species from a solar development perspective, we utilized existing federal and state ranking systems: the ESA, the California Endangered Species Act (CESA), designation as a BLM Sensitive Species (BLM SS), and designation as a California Species of Special Concern (CSSC) to develop a numerical ranking system. The limitations of using these ranking systems are that there is some overlap in listings, and that the BLM SS and CSSC status are available only for animal and not plant species.

Federal Endangered Species Act (ESA): The ESA of 1973 is the primary federal statute dedicated to wildlife protection. Its purpose is to “protect and recover imperiled species” and their associated habitat. For terrestrial species (both plants and animals), the ESA is administered by the U.S. Fish and Wildlife Service (FWS). Under the ESA, a species may be listed as “endangered,” meaning that it is “in danger of extinction throughout all or a significant portion of its range,” or “threatened”, meaning that it “is likely to become endangered within the foreseeable future.” A “candidate” species is one that is under review by the ESA for possible designation. The species we examined in this study were listed as one of the following: federally listed as endangered, federally listed as threatened, candidate for federal listing, no federal status, and delisted, meaning the species was previously listed (U.S. FWS, 2009).

California Endangered Species Act (CESA): The California Endangered Species Act (CESA), administered by the California Department of Fish and Game (CDFG), is generally analogous to

the ESA, and many species are listed under both the ESA and CESA. Under CESA, a species listed as “endangered” is defined as “in serious danger of becoming extinct throughout all, or a significant portion of its range.” This designation is limited to species and subspecies native to California (California Environmental Resource Agency, 2005). A “threatened species” is a species that “although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future” (LegalTips.org, 2007). A species is designated as “Rare” when “although not presently threatened with extinction, it is in such small numbers throughout its range that it may become endangered if its present environment worsens” (Justia.com, 2010). A “candidate” species is one that is under review under CESA for possible designation. The species we used in our study are categorized into one of the following: state listed as endangered, state listed as threatened, state listed as rare, and no state status.

BLM Sensitive Species (BLM SS): BLM State Directors have the authority to designate BLM Sensitive Species status for those animals present on BLM public lands “for which BLM has the capability to significantly affect the conservation status of the species through management” (BLM, 2010). The BLM may list a species on the BLM SS list if the species “becomes in danger of rapidly dwindling to extinction” (BLM, 2010). The BLM’s objective is to maintain or improve these populations through rehabilitation measures and through partnerships with other agencies and private land owners (California Environmental Resource Agency, 2005).

California Species of Special Concern (CA SSC): A Species of Special Concern is defined as a “species, subspecies, or distinct population of an animal native to California that currently satisfies one or more of the following criteria: is extirpated from California, is federally- but not State-listed as threatened or endangered, is experiencing, or formerly experienced, serious declines that, if continued, could qualify it for State threatened or endangered status; or has naturally small populations with high susceptibility to risk that could lead it to qualify for State threatened or endangered status (CDFG, 2008).

Weighting System

We developed a weighting scheme for each of the ranking systems. For the ESA and the CESA, we assumed a linear progression from one rank to the next. For example, under the CESA, endangered status was given a weight of four, followed by threatened with a weight of three and rare with a weight of two. Table 7 displays the weights that were applied to each of the ranking systems. We chose a simple linear weighting system based on the assumption that as a species moves up in ranking, its significance increases in a linear fashion. We decided that species listed as endangered under the CESA and the ESA were equally significant, therefore we attributed the same weight. Likewise, we assumed that species listed as rare under the CESA and as candidate under the ESA were of equivalent significance to those species designated as CSSC and BLM SS, and all were given a weight of two. Only species that have been delisted were given a weight of one. Any species not listed under ESA, CESA, CSSC or BLM SS were not given a weight; however, all species listed by the Independent Science Advisors (Spencer *et al.*, 2010) were designated on at least one of these ranking systems.

Table 7. Weighting scheme for different species ranking systems.

Ranking System	Rank	Weight
CESA	Rare	2
CESA	Threatened	3
CESA	Endangered	4
ESA	Delisted	1
ESA	Candidate	2
ESA	Threatened	3
ESA	Endangered	4
CSSC	yes	2
BLM SS	yes	2

In order to weight an individual species, we assigned the highest weight from all ranking systems to each species. For example, the desert tortoise, which is listed under both the CESA and the ESA – both of which are assigned a weight of four – was assigned a weight of four because that is the most valuable ranking according to our system.

Maximum Entropy

We used the program Maximum Entropy , or Maxent (Phillips, Anderson, & Sphapire, 2006) to model all species included in our study because Maxent is based on an algorithm that is appropriate for presence-only data and because this program is well-documented in peer-reviewed literature (Elith & Leathwick, 2009).

We incorporated 12 environmental factors that were used by Nussear (2009) in a USGS study that modeled habitat suitability for the desert tortoise (*Gopherus agassizi*). For the purpose of our study, we assumed these environmental influences are equally good predictors of habitat suitability for other species. These 12 environmental variables were divided into four categories of influence: landscape, climate, biotic and soils. Landscape environmental variables included surface roughness, slope, aspect and elevation. Climate variables were winter precipitation, summer precipitation and variance of precipitation. Biotic variables included annual plant potential and perennial plant cover, and soil variables included soil depth, rockiness and bulk density. These variables were chosen specifically for the desert tortoise.

We conducted Maxent SDMs at the scale of 1 km sized pixels because the environmental variables were available at this size. However, we recognize that pixel size may affect model results and that the scale at which the SDM is conducted depends on the species of interest. In the future we recommend defining the scale based on the species being modeled.

In the evaluation of the SDM results for each species, we did not conduct a statistical analysis; however, this should be done for future SDMs. Specifically, we suggest re-running models multiple times with different environmental layers and at different scales and comparing the results. Due to the fact that we used presence-only data, we conducted the

SDMs with Maxent; however, it is possible that an alternative algorithm may return a more representative result, depending on the survey data available for a species.

For each of the 35 species that we modeled, Maxent produced two output maps, one which displayed a continuous gradient of a species' probability of occurrence and one which provided a discrete suitable/unsuitable habitat map. We used discrete maps because they were more easily incorporated with the other criteria analyses conducted in our study region.

The discrete map was created by Maxent by defining a threshold value above which a piece of land was designated as suitable habitat and below which land was designated as unsuitable habitat. The threshold value was that value at which sensitivity was equal to specificity; in other words, where the chances of a "false positive" species occurrence (sensitivity) were equal to the chances of a "false negative" species occurrence (specificity). In the future, we recommend allowing for more sensitivity in the model (i.e. allowing for more false positives and reducing the number of false negatives) by manually setting a lower threshold.

After creating 35 species habitat suitability models, we used our weighting system described earlier to weight each of the individual species maps. For example, if a species were considered Endangered on the ESA and designated as a sensitive species under the BLM, then it was given a rank of four for the ESA endangered ranking, the highest rank-weight given to this species (ESA Endangered = 4; and BLM SS = 2). The entire habitat deemed suitable by the Maxent discrete map was given a value of four. After we reclassified all of the species distribution maps with this weighting scheme, we overlaid these maps and summed the layers to produce a map that shows a gradient from low habitat suitability for species with a low weight to high habitat suitability for species with a high weight. The summed and weighted species distribution map provided an indication of where suitable habitat was clustered in our study area.

Results

Our Maximum Entropy results show the land where each of our 35 species are likely to be found. We have binary species distribution maps for each of these 35 species. Figure 22 shows two of these species distribution maps as examples.

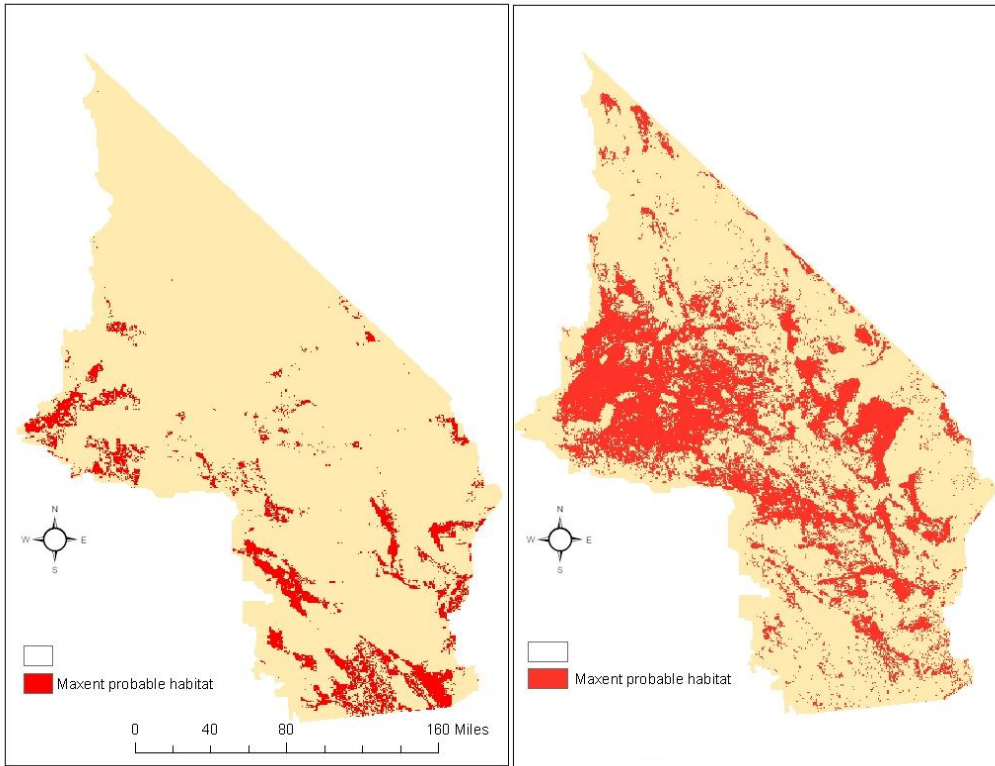


Figure 22. MaxEnt species distribution model output of the probable habitat distribution for the Kangaroo Rat (*Dipodomys merriami*) (left) and Desert Tortoise (*Gopherus agassizii*) (right) in the CDCA. The red areas show regions that MaxEnt predicts the species may occur.

After weighting all the species according to their ranking, we summed each weighted species map with ArcGIS programming to get a summed and weighted species distribution map for each of our 35 species (Figure 23).

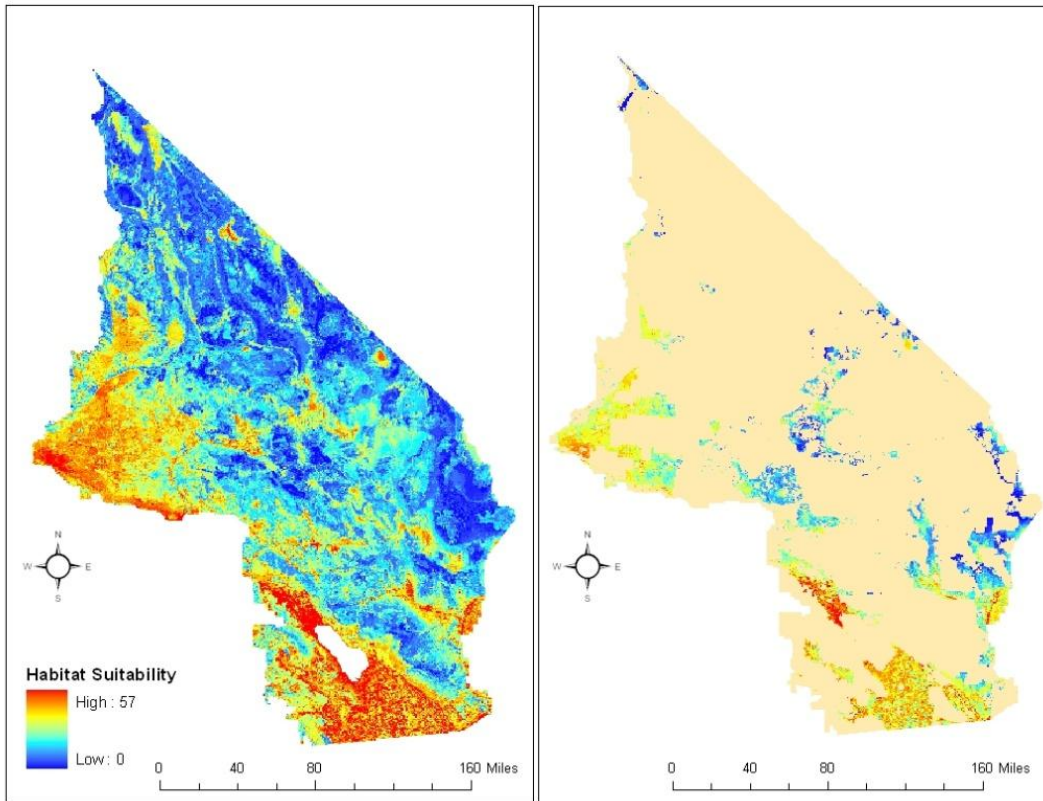


Figure 23. Summed weighted habitat suitability layers for 35 species present in the CDCA. The red areas indicate a high degree of species sensitivity and habitat for multiple species. The darker red the area, the less suitable it is considered for LSSE development, while dark blue areas are the most suitable for sensitive habitat avoidance. The map on the left shows the weighted suitability layer for the entire CDCA, while the map on the right shows the weighted suitability for the available land only.

Discussion

Limitations and recommendations for the future: While species distribution modeling is recommended by Independent Science Advisors in the identification of suitable habitat, there are many factors that must be considered in conducting species distribution models. For future analyses of species distribution in the desert, we defer to the recommendations provided in the Independent Science Advisors report (Spencer *et al.*, 2010). Specifically, our study is limited in the following ways:

1. Environmental variables: We used the same environmental variables for each species. The environmental variables were chosen specifically for the desert tortoise. While these environmental variables may correlate with other species

occurrence data, we recommend choosing specific environmental factors to match the species being modeled.

2. Scale of modeling units: We used the same scale to model all species (1 km) based on the environmental variable data we incorporated into the model. However, some species may require use of smaller scale modeling units.
3. Summation of SDM outputs: For the purpose of our study, we hoped to give developers a general idea of where species habitats are concentrated in the landscape that is available for LSSE development. For this reason, we used the crude approach of summing up all SDM model outputs. In the future, we recommend choosing species based on an approach suggested by the science advisors (Spencer *et al.*, 2010) and completing comprehensive SDMs for a handful of strategically chosen species. These individual habitat suitability maps can then be used to individually assess whether a LSSE project will affect the habitat of that species. There are many approaches to identifying and choosing species strategically and these are addressed in the science advisor's report (Spencer *et al.*, 2010).
4. Sensitivity Analysis: Conducting a sensitivity analysis on the species distribution maps would allow us to determine which of the environmental factors most strongly affect the SDM map outputs.

8.6 Combined Suitability Analysis

The purpose of the combined suitability analysis is to identify and quantify the highest suitability areas according to all the criteria discussed above, and compare this acreage to the land area required for our most likely solar development scenario for 2020. Not only will this analysis allow us to evaluate the environmental suitability and feasibility of our most likely LSSE scenario, but it can also serve as a rough guideline for developers on where environmental and permitting challenges are least likely to arise. Due to the fact that solar development involves diverse stakeholders with varying interests and values, criteria are often not valued equally among all interested parties. For example, environmental groups will most likely value the

conservation of endangered species habitat over other criteria. Additionally, not all technologies affect resources equally; water use, especially, varies by technology and may be a concern for some developers, but not for others. For this reason, it is critical that suitability analyses of this type be transparent in how each criterion is weighted. In this analysis, we made a concerted effort to take into consideration the varied interests of stakeholders and the varying resource uses of different LSSE technologies.

8.6.1 Methodology

At this point in our spatial analysis, the areas which are legally and physically unavailable for development (identified as hard constraints) have been eliminated from our study area. The areas identified as unfavorable according to each criterion (the soft constraints) have been removed from consideration as well. The remaining available land area was ranked according to its suitability for each individual criterion: proximity to transmission lines, proximity to roads, water availability, and sensitive species habitat. In this section, we reclassified each criterion into three categories of high, medium and low suitability, and combined the categorized criteria maps in *ArcGIS* in order to identify those areas most suitable for solar development according to all four criteria. We compared several weighting schemes to prioritize different criteria, allow for additional water sources, and consider a potential shift to water-efficient solar technologies.

Criteria Weighting

We performed two separate sets of suitability analyses using the same methodology, one using the constraints map that includes all hard and soft constraints, and one using the constraints map that includes all hard constraints and all soft constraints *except for water*. The base area for the first analysis takes into account distance to roads and transmission lines, water availability, and sensitive species habitat criteria, and represents the 3.9 million acres previously identified as available for solar development. This constraints map is referred to here as “All Constraints.” The area for the second set of analyses included the land area available after eliminating the same constraints *with the exception* of those soft constraints

related to water availability. In effect, we add back into consideration those groundwater basins previously eliminated based on their high TDS content and adjudicated status. This area is significantly larger than the *All Constraints* map, at approximately 4.9 million acres, and is referred to here as “No Water Constraints.”

We conducted our suitability analysis in this manner due to the fact that water-efficient technologies will likely be favored in the future (see Portfolio C). The purpose of this distinction is to illustrate the possible differences in appropriate siting based on technology differences. Water is much less of a constraint for low water-use technologies – particularly photovoltaics – and alternative sources such as trucking in water to the site may be economically feasible for facilities with very low water requirements, whereas they are not for most solar thermal plants. The *No Water Constraints* map does not incorporate suitability ranking based on water availability, but only on proximity to roads and transmission lines and sensitive habitat scoring.

We produced a series of suitability maps by varying the importance given to each criterion using a range of weighting schemes. These weighting schemes were selected to show how the prioritization of different criteria may change spatial extent and quantity of land designated as highly suitable area for solar development. For the *All Constraints* map, we use three different weighting schemes: (1) Equal Weighting, which weights roads, transmission, water and species as equally important; (2) Species Emphasis; and (3) Water Emphasis. Additionally, for each of these weighting schemes, we perform the suitability analysis for two alternative water source scenarios – one that includes WWTPs as a possible water source in addition to groundwater, and one that includes groundwater but excludes WWTPs from consideration. For the *No Water Constraints* map, we use just two weighting schemes: (1) Equal Weighting; and (2) Species Emphasis. See Table 7 for the full list of weighting schemes used.

The weighting schemes used in this analysis reflect the relative importance of each criterion to siting solar projects based on expert advice, project cost and observation of permitting obstacles. In most of the weighting schemes, with the exception of equal weighting, transmission and roads are given significantly lower importance than species and water. This decision is based on most developers’ judgments that, within a reasonable distance

to transmission lines and roads (identified here as 20 miles), distance is less important than water availability and sensitive habitat avoidance. Additionally, proximity to roads is assigned less weight than proximity to transmission, as transmission infrastructure is generally viewed as more of a cost constraint. The equal weighting schemes therefore do not accurately portray what we believe the actual siting priorities are, but are included primarily to demonstrate the relative influence of water and species on suitability.

Criteria Reclassification

The following ranking methods are used for both constraints maps. For each criterion, the available area is categorized as follows: 3 = high suitability; 2 = medium suitability; and 1 = low suitability. Distance to roads, distance to WWTPs, and sensitive habitat were subsequently reclassified in a similar manner. However, because of the ordinal rankings of the groundwater basins, these were reclassified differently (see Section 8.5.3). Table 8 summarizes the reclassification scheme used for each of the criteria.

Table 8. Reclassification scheme used to convert criteria suitability rankings into a common scale: 3 = High Suitability, 2 = Medium Suitability, 1 = Low Suitability Scale.

Reclassification of Criteria-specific Suitability Score to a Common Suitability Scale		
Suitability Criteria	Criteria-specific Suitability Values	Standard Suitability Value
Proximity to Transmission, Roads, & Wastewater Treatment Plants	0 – 6.67 miles	3
	6.67 – 13.33 miles	2
	13.33 – 20 miles	1
Groundwater Basin Status	DWR “Suitable Basins”	3
	DWR “Potentially Suitable Basins”	2
	DWR “Unsuitable Basins,” basins with inadequate data, and Basins with no data (1979)	1
Sensitive Species Habitat score	0 – 19	3
	19 – 38	2
	38 – 57	1

Combined Suitability Ranking

Next, the reclassified suitability maps for each criterion were combined in *ArcGIS* to show which areas are most suitable for solar development when considering all four criteria concurrently.

Summation

The weighting schemes described in Table 9 were applied using the Weighted Sum tool in *ArcGIS*. With this tool, the weighted criteria values for each cell are summed together to produce a single suitability value. Because the resulting values are not integers, they must be rounded to the nearest integer to produce three discrete categories representing high, medium, and low suitability. This process is described in more detail in Appendix B. Table 9 summarizes the high suitability acreages under each weighting scheme, as well as their size relative to the available area within the CDCA. Using these overall suitability rankings, we identified the highest suitability areas for solar development by prioritizing different criteria and varying water constraints.

8.6.2 Results and Discussion

The amount of available land area ranked as “highly suitable” varies significantly with the weighting scheme, ranging from about 350,000 acres to 1.3 million acres (Table 9). However, the spatial patterns remained fairly consistent across weighting schemes (Appendix A contains more maps showing suitability under different weighting schemes).

Table 9. Land acreages ranked as 'Highly Suitable' under each weighting scheme for the 'All Constraints' map and 'No Water Constraints' map.

	Water Criteria Map	Weighting Scheme					High Suitability Acres	Percent Available Land	Percent CDCA
			Water	Species	Trans	Roads			
All Constraints	Ground-water only, No WWTP	Equal Weighting	0.25	0.25	0.25	0.25	346,237	9%	1%
		Species Emphasis	0.25	0.5	0.15	0.1	418,695	11%	2%
		Water Emphasis	0.5	0.25	0.15	0.1	374,206	10%	1%
	Ground-water & WWTP	Equal Weighting	0.25	0.25	0.25	0.25	495,968	13%	2%
		Species Emphasis	0.25	0.5	0.15	0.1	424,861	11%	2%
		Water Emphasis	0.5	0.25	0.15	0.1	663,455	17%	3%
Without Water Constraints	No Water	Equal Weighting	0	0.34	0.33	0.33	1,315,880	27%	5%
		Species Emphasis	0	0.5	0.3	0.2	486,083	10%	2%

The western portion of the CDCA is generally characterized as having low suitability for solar development, with high suitability areas concentrated more in the east. This pattern is intensified when both species and water are weighted most heavily. These spatial patterns are not unexpected, given the patterns seen in groundwater basin status and sensitive habitat established previously.

Equally weighting all criteria relaxed the intensity of this spatial pattern, likely because there is a higher density of transmissions and roads in the more urbanized western region, and therefore higher suitability according to these criteria (Figure 24). Because we gave roads and transmission low weights in most of the suitability maps, the location of roads and transmission didn't influence the suitability scoring enough to tip the balance in favor of the western CDCA. When we weighted sensitive species habitat more heavily, as opposed to equal weighting, large areas in the eastern and southern CDCA move from medium suitability to low suitability. Similar spatial patterns were seen when we emphasized groundwater availability.

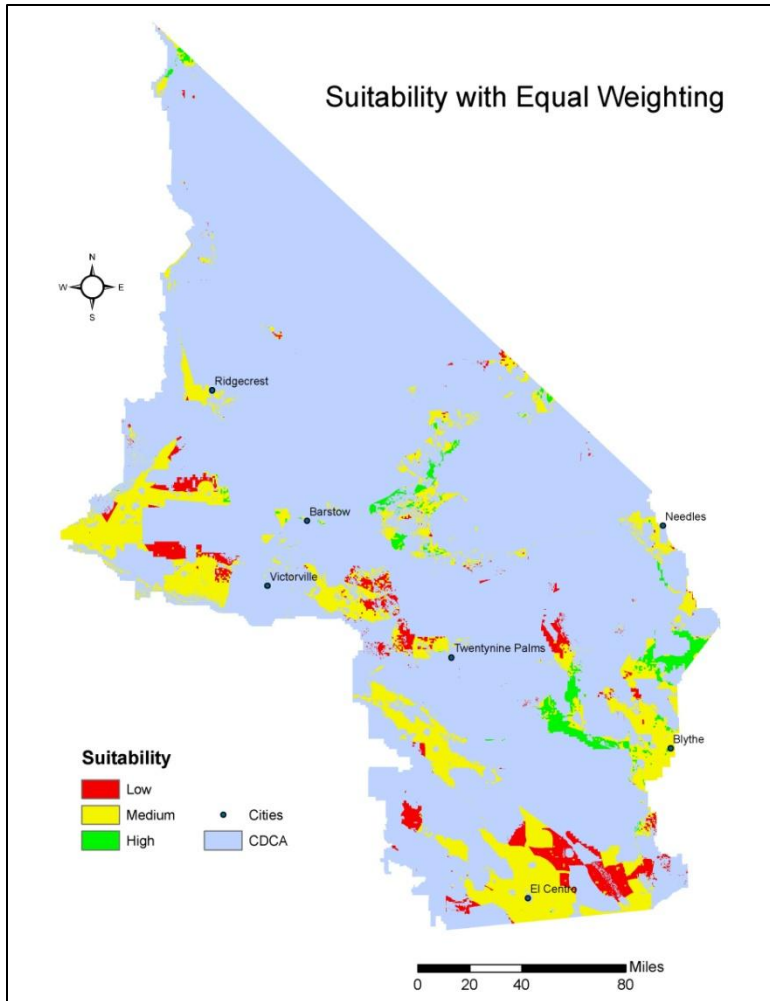


Figure 24. Solar development suitability ranking with equal weight (0.25) given to each criterion: distance to roads, distance to transmission, groundwater availability, and sensitive habitat avoidance.

When only groundwater was included as a possible water source, high suitability area accounted for roughly nine percent (under equal weighting) to 11 percent (species emphasis) of the total land area available, depending on the relative weights of the criteria. When groundwater was the only water source, and water availability was prioritized, about 10 percent of the available land area, or 374,205 acres, was classified as highly suitable.

When we included the 12 WWTPs, which are clustered in the southwestern portion of the CDCA near the vicinity of the Salton Sea, as possible water sources, this area increases in suitability, particularly when we assigned water availability highest priority. (See figures in Appendix A). When we included WWTPs, we observed greater variation in the total acreage of land ranked as highly suitable across different weighting schemes, with high suitability area

varying from about 11 to 17 percent of the available land. This is unsurprising, as including WWTP increases the number of potential water sources, and land previously deemed unsuitable due to lack of groundwater resources becomes more suitable. Including WWTPs and prioritizing water availability resulted in 17 percent ranked as highly suitable. However, when we switched the prioritization to sensitive habitat, only 11 percent of available land was ranked as highly suitable, an increase from 10 percent highly suitable land when groundwater was the only available water source.

When water was removed as a constraint from the suitability analysis and given a weight of zero, the transmission and road scorings exerted significantly greater influence over the spatial pattern of suitability, as can be seen in Figure 25. The east-west pattern of high-low suitability present in most of the previous maps was greatly reduced when roads and transmission are weighted equally with species. The exclusion of water also resulted in much greater variability in the total acreages categorized as highly suitable in each weighting scheme (Figure 26).

Our results show that approximately one million additional acres are available when water availability is excluded as a constraint, signifying that more highly suitable land is available for low water-use technologies. Likewise, sensitive habitat weighting can affect the amount of highly suitable land. When equal weights are applied to transmission, roads and species, approximately 27 percent of available land, or 1.3 million acres, is ranked as highly suitable. When sensitive species avoidance is weighted most heavily, only 10 percent – less than half that area – is classified as highly suitable. Clearly, emphasizing the importance of species avoidance has a large effect on the available area, particularly with fewer criteria considered.

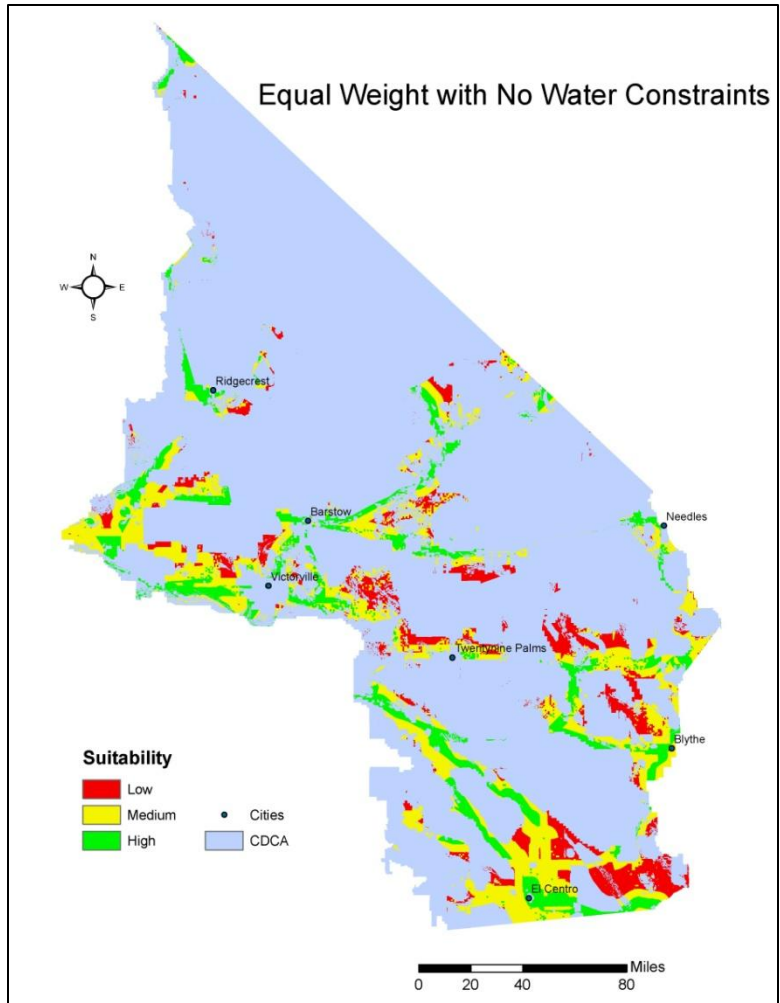


Figure 25. Solar development suitability ranking with equal weight (0.33) given to each criterion: distance to roads, distance to transmission, and sensitive habitat avoidance (no water constraints included and water availability is weighted at zero).

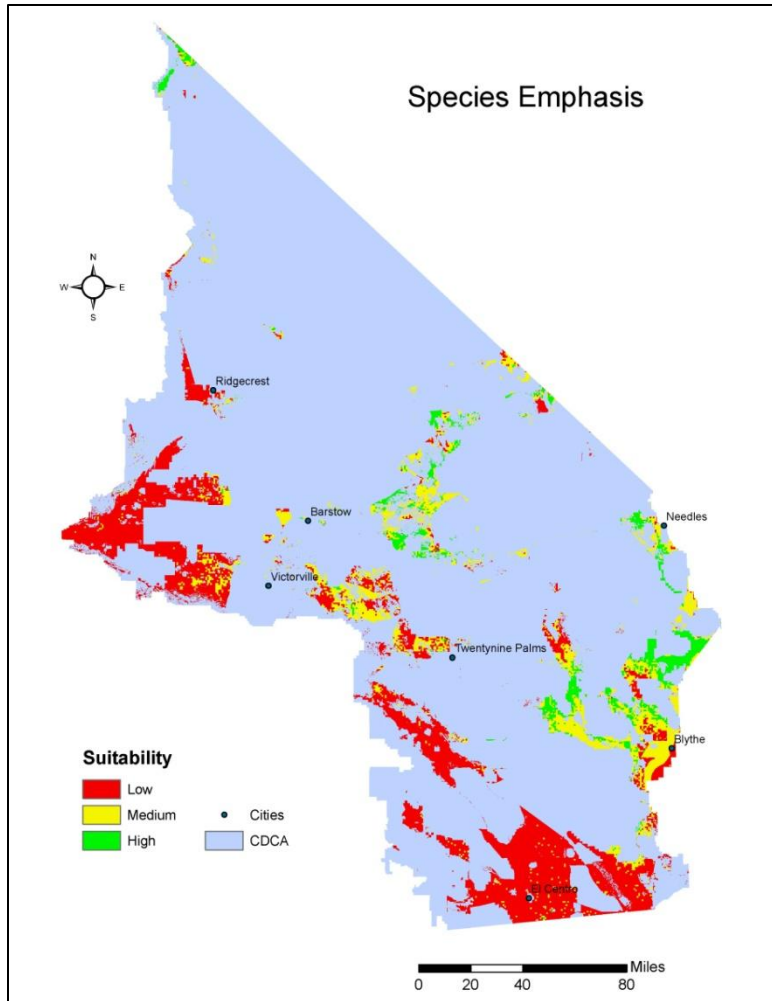


Figure 26. Solar development suitability ranking with sensitive habitat weighted at 0.50. Groundwater availability is weighted at 0.25, transmission at 0.15, and roads at 0.1.

Table 10 shows that the total land requirements under the most likely solar RPS contribution scenarios for all three technology portfolios can be physically accommodated by the highly suitable zones identified in our spatial analysis. Species and water will always be contentious factors when siting solar plants. However, there are common patterns across most of the suitability maps generated in this analysis. Across most of the weighting schemes the high suitability areas were clustered near the center of the CDCA (southeast of Fort Irwin) and especially near the eastern border of the CDCA in the vicinity of Blythe. These patterns reflect, to varying degrees, the spatial patterns shown in the individual criteria analyses for water and species habitat. Interestingly, there appears to be the most variation across weighting schemes within the low and medium suitability categories, whereas high suitability areas stay quite

consistent. Current solar ROW applications are predominantly within or near high suitability areas (Figure 2, Appendix A). However several ROW applications are outside of areas we identified as available; further investigation is required to determine the reasons for this.

Table 10. Percentage of 'high suitability' land required to meet the land area requirements of the 3.3% and 9% solar development scenarios for Portfolios A, B, and C.

		Land Area Required by Scenario Within Each Portfolio					
		Portfolio A		Portfolio B		Portfolio C	
		3.3%	9%	3.3%	9%	3.3%	9%
Scenario		33,562	91,531	37,790	103,064	39,146	106,760
Acres Required							
Weighting Scheme		Percentage of High Suitability Land Required					
No WWTP	Equal Weighting	10%	26%	11%	30%	11%	31%
	Species Emphasis	8%	22%	9%	25%	9%	25%
	Water Emphasis	9%	24%	10%	28%	10%	29%
With WWTP	Equal Weighting	7%	18%	8%	21%	8%	22%
	Species Emphasis	8%	22%	9%	24%	9%	25%
	Water Emphasis	5%	14%	6%	16%	6%	16%
No Water	Equal Weighting	3%	7%	3%	8%	3%	8%
	Species Emphasis	7%	19%	8%	21%	8%	22%

We expect the high suitability areas to present fewer permitting challenges and require less additional infrastructure than the low and medium suitability areas. It is important to note that the results of this analysis do not dictate that solar plants cannot or will not be permitted elsewhere or that any high suitability area can be permitted or is necessarily appropriate for solar development. The suitability rankings developed here should be viewed as relative indicators of permitting ease, rather than absolute designations of appropriateness. Furthermore, although we selected some of the most important criteria for solar siting, there

are many additional criteria that are relevant to the environmental review and permitting process that are beyond the scope of this project to assess.

Possible next steps to add additional depth to the spatial analysis would be to extend it, using our established framework, by accounting for additional constraints and incorporating more criteria. Additional siting considerations that would add depth to this analysis include the avoidance of high-value agricultural land and the prioritization of disturbed and degraded agricultural land, avoidance of areas with a high density of cultural and archeological resources, and considerations of the relative suitability of public vs. private lands. The maps generated in this analysis represent a macro-scale assessment of solar development suitability in the CDCA and should be used as a guide to target further investigation into site suitability, rather than as a siting prescription.

9. Recommendations for AECOM

At this time, the most important driver of LSSE development in California is the state's RPS. If we have correctly assumed that the IOUs and public power entities will stop signing power purchase agreements with developers once they reach the required 33 percent threshold, then LSSE development rates will slow significantly due to decreasing market demand. We do not know exactly when the 33 percent threshold will be reached, but suspect it will be reached before 2015 due to the CPUC's reports on the number of power purchase agreements currently signed for renewable energy.

In the 2010 Q4 RPS Report, the CPUC wrote that "collectively, the IOUs have more renewable electricity under contract than needed to meet a 33 percent RPS target in 2020. However, not all of this electricity is anticipated to come online due to contract failure" (CPUC 2010c). Electric service providers and community choice aggregators must also sign enough contracts to fulfill their RPS obligations, and some of those contracts will fail as well. Therefore, AECOM should regularly monitor the overall status of the progress towards the RPS in order to anticipate changing demand for new LSSE projects. This simple act will keep the macro-level

view of industry drivers in mind and allow AECOM to maneuver strategically in upcoming months.

In June of 2010 the CPUC issued a Scoping Memo that outlines different procurement scenarios for the generation mixes that the IOUs may potentially use to meet their long term procurement plans (CPUC, 2010b). The Scoping Memo was eventually refined and translated into an Excel-based RPS Scenario Calculator introduced by the CPUC in January, 2011. The tool is similar to the scenario calculations and analysis undertaken for this Group Project and is intended to help the IOUs strategically plan their renewable portfolio compositions (CPUC, 2011b).

The information of primary interest to AECOM is that the estimates for the CPUC's RPS Calculator are very similar to the results from our own analysis for the future amount of solar thermal development in California. Although the CPUC's estimates do fall within our 3.3 to 9 percent range for future development, they are on the lower end of that range. We believe that the CPUC's RPS calculator may be a useful tool for AECOM to use in the upcoming years as a way to anticipate the direction of the LSSE permitting market.

Based on the research and analysis conducted over the last 12 months, our final recommendations for AECOM include the following:

- AECOM should develop capacity within their firm to use this Group Project's calculations and the CPUC's 33 percent RPS Calculator so that they can better understand the utility and limitations of each method with regard to predicting future business opportunities. There is a strong advantage to understanding how the regulators and IOUs are making their renewable energy purchasing decisions, and that will help AECOM move strategically in the renewable energy development field during the upcoming years.
- AECOM should anticipate a decrease in the rate of solar thermal permitting activity in 2012. This is due to a decrease in demand for new renewable energy from IOU contracts and the expiration of the ARRA cash grants at the end of 2011.
- AECOM should be prepared to shift their focus to other types of renewable energy permitting. As opportunities to permit solar thermal decrease, the demand for

permitting large scale solar PV may increase, especially if PV prices decrease as a result of the DOE's Sunshot Initiative or technology developments in China (Section 4). The CPUC is anticipating a large increase in the amount of energy that large scale PV will contribute to the RPS (CPUC, 2011b).

- AECOM should follow the energy policy of Governor Jerry Brown closely in the upcoming months. If his administration introduces a European style feed-in tariff for small solar PV – one of his campaign promises – AECOM may see an opportunity in this emerging market.
- AECOM should use the LSSE suitability maps produced in this report as a guideline when working with developers in the upcoming year to identify potential LSSE sites. This will hopefully reduce the number of complications for LSSE during the permitting process.

10. Conclusions

Our projection for LSSE's contribution to California's electricity supply in 2020 is based on the results of our scenario and portfolio calculations. Although it is impossible to pinpoint exactly how much LSSE will contribute, we identified the boundaries within which development will occur. Based on the energy policy and solar technology trends discussed previously, we conclude that LSSE will contribute between 3.3 percent and 9 percent of the electricity needed to fulfill California's electricity demand in 2020. This electricity will be provided using a LSSE technology mix that is dominated by dry-cooled technologies similar to the mix presented in Portfolio B.

We believe that the amount of development will be above 3.3 percent because the extension of the ARRA cash grant until the end of 2011 will incentivize developers to continue to pursue the available funding for LSSE construction. We believe that the amount of development will remain below 9 percent because of competition for power purchase agreements with IOUs between LSSE projects and other in-state and out-of-state renewable energy developments.

The estimated land use from this range of LSSE construction will require development of 38,000 to 103,000 acres. Of the 3.9 million acres of available land for LSSE development in the CDCA, this is 0.97 to 2.66 percent. When the most stringent constraints are applied to limit the available land, there is still enough land available in the CDCA to accommodate the range of development predicted by our scenarios.

The range of estimated water use from construction and operation from this amount of development will be between 53,500 and 121,000 cumulative acre-feet of water by 2020. However, there are significant gaps in data on the availability of water in the CDCA, so it is unknown if there is enough water to meet these demands. Although many groundwater basins have high storage capacities, the data on the rate of recharge and their current water levels have not been uniformly reported or investigated. Ultimately, more information on the status of water supplies in the CDCA is required before specific conclusions can be made about how available water supplies will impact the projected range of LSSE development.

Looking closely at the land-use and water-use graphs (Section 7.3 and Section 7.4), it is important to note that in terms of land use, the land required for LSSE is determined by how much solar electricity is demanded. The technology portfolio used does have an effect, but it is small relative to the solar electricity demand. When we examine our final results for water, the effect is the opposite. The technology portfolio, rather than the solar electricity demand, affects the amount of cumulative water required. Thus, the tradeoffs between LSSE development and resource impacts are different for land and water.

The influence of technology portfolio on water use is significant. Because of this influence, Portfolio C becomes a greater possibility in the future of LSSE development if a water-constrained or a water-uncertain future is combined with a large decrease in PV costs. Because the water supply in the CDCA is uncertain, a future technology mix similar to the one represented in Portfolio C is a real possibility.

Taking our best estimate of how much LSSE generation is expected in 2020, we conducted a spatial analysis to answer AECOM's questions regarding where development in the CDCA would minimize resource-use impacts. We identified 346,000 to 1.3 million available acres that our analysis classified as having the highest suitability for LSSE development,

representing anywhere from nine to 27 percent of the potentially available area remaining after exclusion of all constraints. These identified areas are where solar development would be less likely have critical impacts to species and water resources and may therefore encounter fewer permitting challenges. The remaining areas are classified as medium or low suitability for LSSE development, though this classification is relative and does not necessarily preclude successful LSSE development. Rather, we anticipate developers encountering more challenges in the permitting process and more likelihood of litigation at a later stage in development because these areas are more likely to have greater resource impacts from LSSE developments.

Just because the land area is both available and suitable does not mean that development will necessarily happen or that it will be easy from a permitting and regulatory standpoint. Proximity to roads and transmission, while an important constraint and criteria for siting, are not as critical to the permitting process as water availability and species impacts. The current dearth of detailed information on water resources makes projecting suitable development areas even more challenging. Therefore, these projections and maps should be used, along with other available resources, as a guide rather than a prescription on where and how solar development will be most easily developed.

LSSE has the opportunity to significantly decrease the amount of GHG emissions that result from the generation of electricity by displacing the need for new fossil-fuel powered facilities. As California's population and energy demand grows during the next decade, LSSE will play an important role in helping the state reach its mandated GHG reductions. This report shows that there is enough land available in the CDCA to accommodate the development of LSSE in the amounts we project to be most likely. Whether there is enough water available for the projected development remains unknown. Water availability is likely to be an increasingly important constraint on LSSE development. With careful planning, it is possible to site LSSE plants in areas that are more suitable for development. However, development in these "most suitable" places still comes with significant resource impacts and tradeoffs that are likely to be contentious. Hopefully, the results of this Group Project will help those invested in the future of renewable energy development in California to evaluate the tradeoffs and move forward along the path to a sustainable energy future in the best way they see fit.

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Appendices

Appendix A: Suitability Analysis Additional Maps

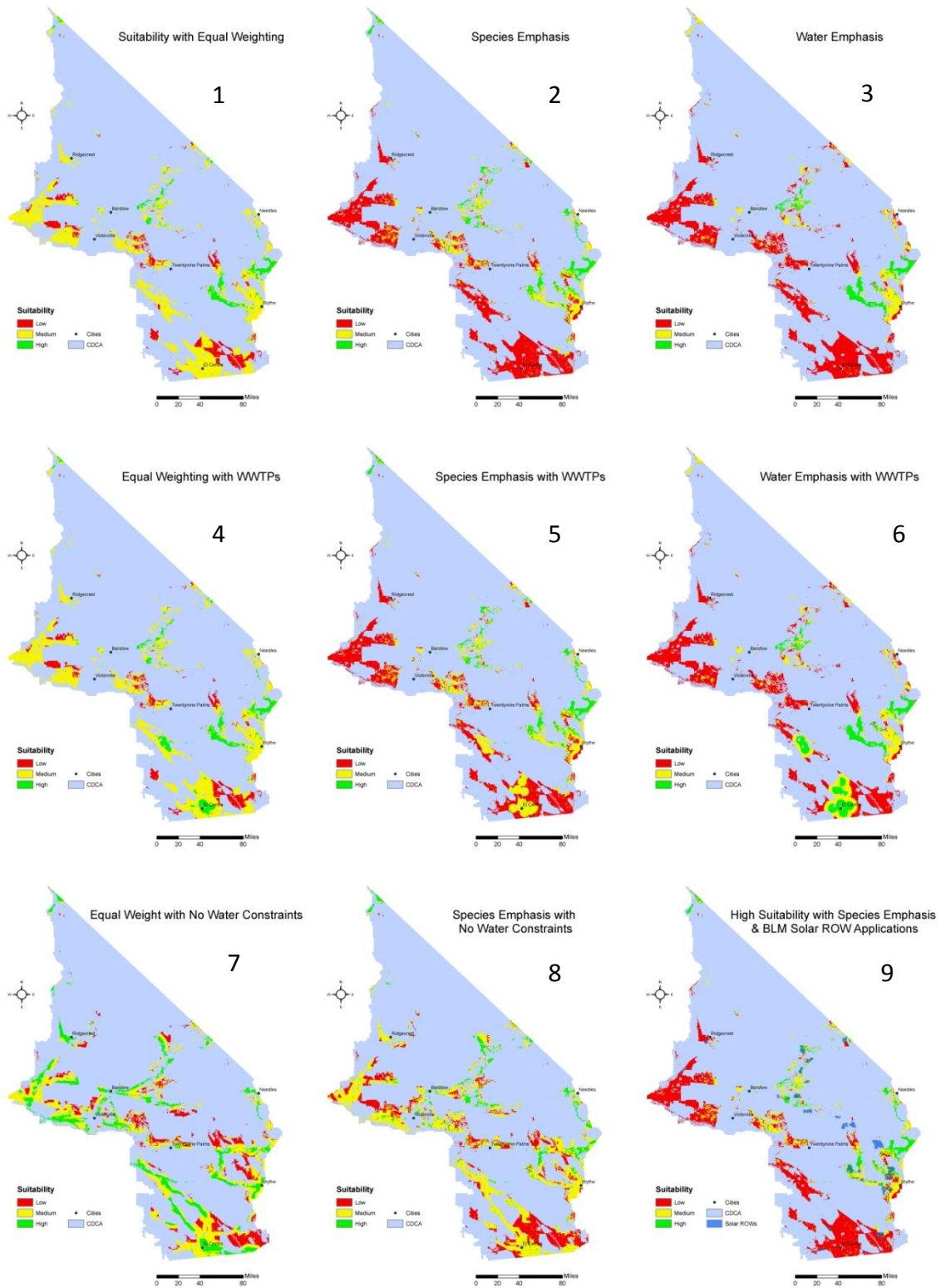


Figure 1. Solar development suitability ranking with equal weight (0.25) given to each criterion: distance to roads, distance to transmission, groundwater availability, and sensitive habitat avoidance.

Figure 2. Solar development suitability ranking with sensitive habitat weighted at 0.50. Groundwater availability is weighted at 0.25, transmission at 0.15, and roads at 0.1.

Figure 3. Solar development suitability ranking with groundwater availability weighted at 0.50. Sensitive habitat avoidance is weighted at 0.25, transmission at 0.15, and roads at 0.1.

Figure 4. Solar development suitability ranking with equal weight (0.25) given to each criterion: distance to roads, distance to transmission, groundwater availability (including distance to wastewater treatment plants, and sensitive habitat avoidance.

Figure 5. Solar development suitability ranking with sensitive habitat weighted at 0.50. Groundwater availability and distance to wastewater treatment plants together are weighted at 0.25, transmission is weighted at 0.15, and roads at 0.1.

Figure 6. Solar development suitability ranking with groundwater availability and distance to wastewater treatment plants weighted at 0.50. Sensitive habitat is weighted at 0.25, transmission at 0.15, and roads at 0.1.

Figure 7. Solar development suitability ranking with equal weight (0.33) given to each criterion: distance to roads, distance to transmission, and sensitive habitat avoidance.

Figure 8. Solar development suitability ranking with sensitive habitat weighted at 0.50. Transmission is weighted at 0.3 and roads at 0.2.

Figure 9. Solar ROW applications in relation to solar development suitability rankings. Sensitive habitat avoidance is weighted at 0.50, groundwater availability at 0.25, transmission at 0.15, and roads at 0.1.

Appendix B: Spatial Analysis GIS Processing Steps

B.1 Preliminary Data Processing and Parameters

In ArcGIS, the tools and Model Builder models can only access data layers that are already in a map's activated data frame. Therefore, it is necessary to import the necessary files into the activated data frame before using a model or tool.

B.1.1 Toolbox Path to Commonly Used Tools

Analysis tools > Extract > **Clip**

Conversion Tools > To Raster > **Polygon to Raster**

Data Management Tools > Projections and Transformations > Feature > **Project**

Spatial Analyst Tools > Reclass > **Reclassify**

Spatial Analyst > Math > Bitwise > **Bitwise Or**

Spatial Analyst Tools > Extraction > **Extract By Mask**

Spatial Analyst Tools > Distance > **Euclidean Distance**

B.1.2 Clipping

In order to limit file size and improve data management, most vector data (shapefiles) used in this analysis were clipped to the CDCA. Most of the original data were obtained in vector form. An analogous tool is available for clipping rasters; however, in this analysis all rasters were clipped to the ROI by setting the extent in Model Builder (see Section B.1.6).

Clipping Vector Data

1. Open a new Clip Tool.
2. Under "Input Features," select the shapefile to clip from the dropdown menu.
3. Under "Clip Features," select the layer that the input feature will be clipped to.
4. Under "Output Feature Class," choose a location to save the layer and rename it if necessary.
5. Leave the "XY Tolerance" field blank.
6. Click "OK."

7. The new clipped shapefile will be added to the map.

B.1.3 Projection

Each data layer used in the spatial analysis was, when necessary, re-projected into the North American Datum 1983 (NAD83) and Universal Transverse Mercator (UTM) 11N projection.

1. Open a new project tool.
2. Under “Input Dataset or Feature Class” select the shapefile to be re-projected from the dropdown menu.
3. Next to the “Output Coordinate System” dropdown bar, select the Spatial Reference Properties box.
 - a. Click “Select” to select a predefined coordinate system.
 - b. Select Projected Coordinate System > UTM > NAD 1983 > NAD 1983 UTM Zone 11N.
 - c. Click “Add.”
4. Leave the remaining optional boxes blank and select “OK.”
5. The re-projected shapefile will appear on the map.

B.1.4 Cell Size

A 100 meter cell size, equivalent to one hectare, was used for all analyses involving raster data. Of the 15 total raster layers supporting the analysis, one was obtained in original raster form with a cell size of 200 meters; this was resampled. Additionally, 14 vector layers were converted to raster layers for map algebraic analyses and surface modeling. Our core elevation raster data were provided at 200m native resolution. The remainder of the raster data for the project was derived from vector data of varying spatial accuracy.

Based on information provided in the attendant metadata, the vector data ranged in spatial accuracy from approximately 30 meters to 130 meters. Where no supportive metadata existed, the project vector data were compared with feature locations on aerial imagery with an accuracy of +/- 5 meters. As a result of these spatial quality indicators, a project raster cell size of 100 meters was selected. Any smaller cell size would imply an unrealistic degree of

spatial accuracy and precision. This decision was based on the following details: raster cell size consistency, data storage and manageability, processing speed in analyses, and large ROI.

B.1.5 Create Region of Interest (ROI) Mask

The initial step for this spatial analysis was to create a raster mask of the ROI. To view the following steps in Model Builder, open tool entitled 'ROI' – the output of this tool has been added to the mask, entitled CDCA_mask.

1. Using the **Polygon to Raster** tool, convert CDCA shapefile to raster, set cell size at 100, and name new file CDCA.
2. Reclassify the new raster so that every cell has the value '1.' There should be no '0's or 'No Data' values in the mask. Name output raster 'CDCA_mask.' This raster layer should encompass the entire ROI.
3. This mask layer can be used to set model parameters in subsequent steps. Setting model parameters appropriately will ensure uniformity in cell size and will automatically clip additional layers to the mask's extent.

B.1.6 Model Builder Logistics and Model Environments

Most analyses for this project were performed in Model Builder, which allows the user to easily document and adjust tool settings. Additionally, Model Builder keeps a record of the sequence of operations performed on the original data. In order to maintain consistency, the following steps are taken for each new Model used in the analysis.

1. **Create a New Toolbox:** Right-click on "ArcToolbox" in the toolbox window and select "New Toolbox." Make sure to save the toolbox in the appropriate folder on the drive.
2. **Create a New Model:** Click the "Start Model Builder" icon and save to the newly created toolbox. Saving a model to the appropriate toolbox can help significantly with organization.
3. **Set Model Environments:**
 - a. Select "Model" and choose "Model Properties" from the drop-down menu.
 - b. In the "Environments" tab, expand "General Settings" and "Raster Analysis Settings," then click the Values button below.

- c. Under “General settings,” select the desired “Scratch Workplace,” set the “Extent” to the appropriate mask layer (usually the ROI mask), and set the “Snap Raster” to the same.
- d. Under Raster Analysis Settings: set the “Cell Size” equal to the mask (or 100 meters) and select the ROI Mask for “Mask.”

B.2 Create “Hard Constraints” Layer in Model Builder

Each data layer incorporated into the hard constraints layer is first re-projected into the correct datum, then converted from polygon to raster format and reclassified as follows: all cells with data values are reclassified as “1,” while “NoData” cells are reclassified as “0.” This step assigns land that cannot be developed a value of “1,” while the area remaining available in the ROI is given a “0.” This reclassification sets up the format for excluding all cells determined to be unavailable for solar development. For instance, a layer representing National Parks and Monuments will be reclassified so that all areas inside park boundaries – and therefore legally incompatible with solar development – are classified as “1,” while all areas outside park boundaries are classified as “0.” Using the “Bitwise Or” tool, each input layer is combined sequentially to form a final constrains layer representing all land in the ROI unavailable for solar development. In following this process, each layer added will sequentially reduce the number of cells designated as “0,” so that the available land becomes increasingly smaller.

The next step is to extract the potentially available land using the “Extract By Mask” tool, which removes the constraints layer – or the excluded area – from the ROI. The cells assigned a value of “0,” which are available for solar development, will remain after the “Extract By Mask” tool is applied. Finally, the remaining available land area can be calculated.

B.2.1 Link the “Hard Constraints”

In total, 14 polygons and 1 raster were incorporated into the hard constraints layer. However, this process may be recreated with any number of data layers using the above model parameters and the following steps:

1. Open a new model entitled “Create Mask.”

2. Drag or insert the polygons and rasters to be included in the exclusion layer into the model. Note: follow steps 3 through 5 for each of the polygon files individually, and skip to step 5 for the raster file. The outputs from the individual files, created in Step 5, will be combined into a single layer using the “Bitwise Or” tool.
3. **Re-project the shapefile:** Drag the “Project” tool into the model and link the shapefile and tool. See the re-projection steps in B.1.3. If the shapefile is already in the NAD 1983 UTM Zone 11 coordinate system, skip this step.
4. **Convert Feature to Raster:** Add the “Feature to Raster” tool to the model and link it to the output from the previous step. Double-click on the tool to check that “Output Cell Size” is set to 100 (it should automatically be 100 if the model environments are set properly). If the cell size is not 100, navigate to the ROI mask and select it. For “Field,” select “Object ID” or the next most basic available field (e.g., FID).
5. **Reclassify:** This step takes the raster output from the previous step and reassigns all values as “1,” and all “NoData” values as “0.”
 - a. Under Reclassification, re-set the values under “old data” in the first row so that they incorporate the entire range of possible values. For example, if the first row includes values of “2 – 3,” and the last row includes “498 – 499,” then re-set the first row as “2 – 499” under the “old data” column. This should automatically delete all subsequent rows (if it does not, select and click on “Delete Entries” to the right).
 - b. Under “New Data” next to the cell containing the entire range of old values, set the value as “1.” This should leave one additional row with “NoData” in both columns. Re-set the “New Data” value as “0.” Now, there should be two rows: the first reclassifying all existing values in the dataset as “1,” and the second row reclassifying all “NoData” cells as “0.”
6. Link a new “Bitwise Or” tool to the output from the reclassification step for the first two exclusion layers. The second “Bitwise Or” step brought into the model is then linked to the previous “Bitwise Or” output and the reclassification output of an additional

exclusion layer. Thus, each “Bitwise Or” step will increase the size of the exclusion layer, until all exclusion layers are incorporated into the final constraints map.

Note: it is useful to add each sequential layer to display by right-clicking on the output in Model Builder and checking “Add to Display.” This allows the user to check that the correct data is included at each step. Also, for each intermediate step (green ovals in Model Builder) right-click on the oval shape and select “Managed,” this will allow Model Builder to overwrite the previously created files, should the model need to be re-run.

B.2.2 Extract By Mask Steps and Produce Initial Available Land Layer

Once the land area that is unavailable for solar development is compiled in the final “Bitwise Or” step, reclassify these cells as “NoData” and the remaining cell (potentially developable land) as “1.” Apply the “Extract by Mask” tool to extract the raster cells that correspond to developable land from the ROI mask. The resulting raster layer will include only the land that is *not* illegal or physically unavailable for solar development.

1. **Reclassify:** In Model Builder, connect the final “Bitwise Or” output from the exclusion layer to a new reclassify tool. Open the reclassify tool (All data for excluded land should have a value of “1” and the remaining data should have a value of “0”) and reclassify the data that has an old value of “1” as “NoData” and the data that has an old value of “0” as “1.” Then, add the CDCA mask to the model and link a new reclassify tool to the CDCA mask. Open the reclassify tool; all of the data in this mask should either be assigned a value of 1 or NoData. Reassign the old “1” value to a new “1” value and the old “NoData” value to a new “NoData” value.
2. **Extract By Mask:** Add the “Extract by Mask” tool to the model and link the Reclassify Output from both the Final Bitwise Or layer and the CDCA mask to the “Extract by Mask” tool. Open the tool to ensure that the final “Bitwise Or” reclassification is assigned as the ‘Input Raster’ and the CDCA mask reclassification is assigned as the “Input Raster or Feature Mask Data.”

3. **Run the Model:** Click the “Model” dropdown menu and select “Run.” Once the “Extract by Mask” output layer is displayed in the map this layer should be an absolute complement to the land exclusion layer, therefore representing the land area that is available for development. This layer will be called the “Hard Constraints Layer.”

B.3 Create Soft Constraints Layers in Model Builder

The suitability criteria layers – distance to transmission, distance to roads, groundwater availability, and sensitive species habitat – have additional characteristics that make them unfavorable for development. These “Soft Constraints” should also be eliminated before site suitability is assessed. The areas affected by the soft constraints may not be strictly unavailable to solar development, but are eliminated primarily due to the costs, environmental impacts, and permitting challenges they would likely impose upon a project. The following steps describe how we eliminated the criteria-specific soft constraints from each criteria layer, and then from the overall Hard Constraints layer. The area of the resulting map, after both hard and the soft constraints are eliminated, is 3,881,059 acres.

B.3.1 Transmission and Roads

Identical processes were used to build the transmission and the road site suitability models; the following steps apply to both the transmission and road layers. Both transmission and roads were treated as a rough proxy for project cost, given that the further a solar project is constructed from this infrastructure, the more expensive it will generally be.

We began building the transmission suitability layer in GIS by assigning each cell in the CDCA mask with its straight-line distance to the nearest transmission line. We then excluded the areas identified by the initial Hard Constraints layer in order to focus our analysis only on land potentially available for LSSE development. We then reclassified the map so that cells within 20 miles of existing transmission were given a value of 1 through 20, corresponding to their distance in miles from transmission. All of the cells beyond the 20miles cutoff were reclassified as “NoData,” eliminating them altogether. We assumed a linear relationship between distance to transmission lines and cost, so the cell assignment values remained linear from 1 to 20 for the purpose of our suitability analysis.

The transmission line data downloaded from the BLM's GIS webpage were available as a line shapefile entitled ptllca (short for pipelines and transmission lines), which contained data on transmission lines, pipelines and other linear features. The transmission features were selected and exported as a new shapefile. To assess the approximate accuracy of transmission data, they were added to a map and checked against NAIP orthophotos; the BLM transmission data fell consistently within 10 meters of where transmission lines appeared to be located in these orthophotos.

Distance to transmission and roads: model procedures

1. Create a new model entitled "transmission." In Model Environments, set the Extent, Snap Raster, and Mask to California mask shapefile. See Section B.1.6 titled "Model Builder Logistics and Model Environments," for more detail on setting model environments.

Note: we are including all transmission data within the CDCA and any lines that lie 20 miles beyond the CDCA in California in our distance to transmission analysis.

Transmission lines that lie just beyond the boarder of the CDCA can potentially be used to transmit energy from a solar facility. Therefore, use California as the mask layer to include all transmission lines within and surrounding our ROI.

2. Add the BLM's transmission line data to the model
3. **Re-Project:** Add the "Project" tool to the model and link it to transmission data. See Section B.1.3 for re-projection steps.
4. **Euclidean Distance:** Link the Euclidean Distance tool to the output from the "Project" tool in the previous step. Open the tool to ensure the cell size is set to 100.
5. **Run The Model:** Click the "Model" dropdown menu and select "Run" to generate the "Euclidean Distance Output" layer.
6. Create a new model and in "Model Environments" set the "Extent," "Snap Raster," and "Mask" to the CDCA mask. The Mask setting will clip the output from the Euclidean Distance layer to the CDCA mask, since we only want to know how far each cell in the CDCA mask is from transmission.
7. **Extract By Mask:** Add the Euclidean Distance Output (Step 5), the Hard Constraints Layer (created in Section B.2.2), and the "Extract By Mask" tool to the new model.

- a. Link both the Euclidean Distance Output and the Hard Constraints Layer to the Extract By Mask tool.
 - b. Open the tool to check that the Euclidean Distance Output is assigned as the “Input Raster” and the Hard Constraints layer is the “Input Mask Data.”
 - c. **Run The Tool:** Right-click on the Extract By Mask tool (yellow rectangle) and select “Run.” The output will be the Euclidean Distance Output layer clipped to the Hard Constraints layer boundaries. This will give us the distance to transmission from every cell of available land that remained after extracting our Hard Constraints from the CDCA.
8. **Reclassify:** Bring a Reclassify tool into the model and link the output from the previous step to the Reclassify tool.
- a. Open the Reclassify tool and reclassify the old data from meters to miles.
 - b. Give each mile, up to 20 miles, a row in the “Reclassification” window. Therefore, the “Old Values” will be the meter values that correspond to the mile values given in the “New Values” column (see the table below).
 - c. Add an additional line after the 20th mile row to reclassify the land beyond 32186.88 meters (20 miles) to “NoData.”

Old Values (meters)	New Values (miles)
0-1609.344	1
1609.344 – 3218.688	2
Continue entering meter ranges that corresponding to each additional mile value	Continue to 20 miles
32186.88 – Furthest distance	NoData

9. **Run The Model:** The raster output layer is the same land area as the Hard Constraints layer but with all land beyond 20 miles of the nearest transmission line excluded. The raster cells in the remaining land area are classified based on their distance to the nearest transmission line.

B.3.2 Groundwater

B.3.2.1 Groundwater Basin Data Source and Processing

A shapefile containing groundwater basins and associated attribute data was downloaded from the DWR website (http://www.water.ca.gov/groundwater/bulletin118/gwbasin_maps_descriptions.cfm) and clipped to the CDCA. The attribute field for this shapefile contained limited data on groundwater basin status. Additional data on groundwater basin storage capacity, volume in storage, minimum, maximum and average well yield, TDS content and adjudicated status were obtained for 142 basins underlying the CDCA from the Groundwater Basin reports available on the DWR Bulletin 118 website (DWR, 2011). This data was compiled in an Excel spreadsheet and linked to the groundwater basin shapefile's attribute field for further analysis via the "Join" function in ArcGIS and exported as a new shapefile in order to provide GIS data with more comprehensive groundwater data for analysis. Information on groundwater basin suitability for power plant siting was obtained from a 1979 DWR reconnaissance study entitled 'Sources of Power Plant Cooling Water in the Desert Area of Southern California.' This report classified the groundwater basins in the CDCA as "Suitable," "Potentially Suitable," "Unsuitable" or as having inadequate data to make a determination of suitability. Additionally, several basins in the CDCA were not assessed. The DWR classification scheme was adopted for the suitability analysis performed in this project as follows.

1. Create a new attribute field for basin suitability in the groundwater basin shapefile attribute table.
2. Using the Edit function, assign the "Suitable" basins a value of 3, "Potentially Suitable" basins a value of 2, and "Unsuitable" basins, data inadequate basins, and non-listed basins a value of 1.
3. Using the **Polygon to Raster** tool, convert groundwater basin shapefile to raster. For value field, choose the basin suitability field, and set cell size at 100. Click OK.

B.3.3 Species

1. Identify the species of interest. This methodology for this is outlined in the text. We chose 35 species.
2. Download presence/absence data from the Global Biodiversity Information Facility: <http://data.gbif.org/welcome.htm>.
3. Download environmental layers from USGS report: <http://pubs.usgs.gov/of/2009/1102/>.
4. Prepare files for Maximum Entropy. Create species files in *.csv format for each of the species.
5. Run Maximum Entropy species distribution model programming for each of the species.
6. The output from Maximum Entropy will be two *.ascii files for each species – one of them contains continuous spatial data and the other binary spatial data. The one with the binary data will be called *_thresholded.ascii.
7. Reclassify the thresholded species distribution model data by the weighting scheme. (we used R programming for this step)
8. Sum all of the weighted thresholded spatial data into one *.ascii file. (We used R programming for this step)
9. In ArcGIS, convert summed & weighted *.ascii file to raster.
10. In ArGIS, clip the *.ascii file to the study area – the CDCA. (Extract by Mask tool) This will show summed & weighted predicted habitat suitability for 35 species. The higher the value of a raster, the higher the value of the land in terms of habitat suitability for ranked species.
11. Additionally, clip the *.ascii file to the “All Constraints” map. (Extract by Mask tool)

B.3.4 Soft Constraints Exclusion Layer

B.3.4.1 Soft Constraints Layer With Water Constraints

The land area included under Soft Constraints is not ideal for solar development due to cost factors, environmental impact, and resource availability. Unlike the Hard Constraints, the Soft Constraints are not extracted due to legality issues or physical obstacles.

The steps above describe how each criterion's Soft Constraints were removed from the available land area individually; however, all the Soft Constraints removed from the available land are in addition to the Hard Constraints. Below are the steps to combining the Soft Constraints and extracting them from the available land in order to produce a new layer representing the remaining land area suitable for solar development. Each Soft Constraint will first be reclassified separately, then added to the others in one exclusion layer using the "Bitwise Or" tool.

1. **Reclassify:** Open a "Reclassify" tool and select the distance to transmission in the entire CDCA layer (created in Section B.3.1 - Step 7) from the "Input Raster" dropdown menu.
 - a. Open the tool and reclassify the "Old Values" from "0-32186.88" meters (20 miles) to "0" in the "New Values" column.
 - b. In the next row, reclassify the remaining "Old Values" from 32,186.88 meters to the furthest distance from transmission as "1" in the corresponding "New Values" cell.
 - c. **Run the Tool:** The output layer will be referred to as the "distance to transmission cutoff layer" and will isolate the area beyond 20 miles from transmission which we want to extract from our analysis.

Note: The same steps are used for the distance to roads in the CDCA layer.

2. **Reclassify:** Open a new "Reclassify" tool and select the groundwater basin layer from the "Input Raster" dropdown menu. Reclassify the groundwater basin layer, so that the basins that are characterized as having a TDS content greater than 5000 mg/l or are classified as an adjudicated basin are given a "New Value" of "1," while the remaining basins and "NoData" classifications are reassigned a new value of "0."
3. Isolate the Critical Habitat Soft Constraints.
 - a. To create the Critical Habitat Soft Constraints layer, create a new model with the Extent, Snap Raster, and Mask set as the CDCA mask in the Model Environments. Bring the following 4 layers into the model:
 - i. Critical Habitat layer that includes the 17 federally-listed endangered or threatened plant and animal species occurring in the CDCA

- ii. Flat-tailed Horned Lizard Management Area layer
 - iii. Mohave Ground Squirrel Conservation Area layer
 - iv. Mojave Fringe Toed Lizard Habitat layer
 - b. **Bitwise Or:** Link the Critical Habitat layer that includes the 17 federally-listed endangered or threatened plant and animal species occurring in the CDCA and the Flat-tailed Horned Lizard Management Area to a new “Bitwise Or” tool.
 - c. **Bitwise Or:** Link the Bitwise Or Output and the Mohave Ground Squirrel Conservation Area to a new Bitwise Or tool.
 - d. **Bitwise Or:** Bring in one last Bitwise Or tool and link the output from the previous Bitwise Or tool and the Mojave Fringe Toed Lizard Habitat to the new tool.
 - e. **Reclassify:** Bring a new “Reclassify” tool into the model and link it to the output from the previous step (d). Open the reclassify tool and reclassify the data so that the Critical Habitat land area is given a “New Value” of “1,” while the remaining area is given a “New Value” of “0.”
4. Create a new “Soft Constraints” model with the “Extent,” “Snap Raster,” and “Mask” set as the Hard Constraints Layer in the “Model Environments.”
- a. Bring the Final Bitwise Or layer from the Hard Constraints model into the Soft Constraints model. Also bring the output from Steps 1-3 above into the model.
 - b. **Bitwise Or:** Link the final Bitwise Or Hard Constraints layer and the distance to transmission cutoff layer to a new “Bitwise Or” tool in the model.
 - c. **Bitwise Or:** Link the output from the “Bitwise Or” tool in the previous step and the distance to roads cutoff layer to a new “Bitwise Or” tool.
 - d. **Bitwise Or:** Repeat the previous step twice more, but in place of the distance to roads cutoff layer use the critical habitat soft constraints layer and the groundwater soft constraints layer.
 - e. **Reclassify:** Link a new “Reclassify” tool to the last “Bitwise Or” output in this model. Open the Reclassify tool and reclassify the data so that the old “0” values

are assigned the new value of “1” and the old “NoData” and “0” values are given the “New Value” of “NoData.”

- f. **Extract By Mask:** Link the output from the reclassify tool and the CDCA mask layer to an “Extract By Mask” tool. Open the tool to ensure that the reclassified output is set as the “Input Raster” and the CDCA mask is set as the “Input Raster or Feature Mask Data.”

The output from this model will be the suitable land area available for solar development in the CDCA after the hard and soft constraints are removed from the CDCA mask. This layer will be referred to as the “All Constraints” layer throughout the remainder of this Appendix.

B.3.4.2 Soft Constraints Layer Without Water Constraints

Because the water requirements for some solar technologies are quite minimal (e.g., PV), we performed an additional suitability analysis that did not exclude soft constraints related to water availability and that did not incorporate water criteria in the overall suitability analysis. To make this distinction, we created an additional layer that excluded the hard and soft constraints described above from the CDCA mask, but kept the high TDS content and adjudicated basins formerly excluded from the analysis.

The same steps described above are used, but with one fewer layer in the Bitwise Or step in Step 4.d; instead link the Critical Habitat Bitwise Or output to the reclassify tool in Step 4.e.

B.4 Suitability Analysis

We begin our suitability analysis by reclassifying each criteria raster layer to a common suitability scale, where 1 = low, 2 = medium, and 3= high suitability. The four individual criteria’s unique scales were re-ranked on the same scale so that they can be entered as inputs into the weighted sum tool and produce output values from 1 to 3.

Once each criteria layer was ranked according to the common low=1, medium= 2, high=3 suitability scale, we used the Weighted Sum tool to multiply each raster cell ranking by the percentage weight that we assigned to each criteria layer. Once the weighted criteria ranking was calculated for each individual criteria layer, the tool summed the weighted rankings

for each raster cell of available land. Therefore each cell was assigned a single ranking value based on several weighted input criteria. However, the output rankings generated by the Weighted Sum tool were on a continuous scale of values from 1 to 3, but we wanted to perform our analysis using three distinct ranking values. So following the weighted sum tool we reclassified the range of continuous values from 1 to 3 into three equal intervals, meaning that the decimal values were rounded to be an integer value of 1, 2, or 3. The discrete 1, 2, 3, values allowed us to identify greater areas of land that have the same suitability rank and to see more distinct spatial patterns.

B.4.1 Suitability Analysis using Weighted Sum Tool

The following steps describe the suitability analysis using the four standard criteria layers (distance to transmission, distance to roads, groundwater basin suitability, and critical habitat score). The same procedure is used for the site suitability map which includes wastewater treatment plants as a possible water source and the site suitability map which excludes water as a criteria altogether.

1. Create a new model, and depending on the suitability analysis (with water constraints vs. without water constraints), set the “Extent,” “Snap Raster,” and “Mask” to the All Constraints layer (or the No Water Constraints layer from Sections B.3.4.2).
2. **Reclassify:** In the model, reclassify the unique suitability scales for each of the final four criteria layers whose individual soft constraints have been extracted (Section B.3) – distance to transmission, distance to roads, groundwater suitability, and critical habitat score – into the common 1, 2, 3 ranking scale where 3= high suitability, 2=medium suitability, and 1=low suitability.
 - a. Bring four “Reclassify” tools into the model and link each criteria layer with its own Reclassify tool.
 - b. Open the tool and select the Classify button. In the “Classification” box, select “Equal Intervals” and select “3” intervals.
 - c. Close the classify box and check that the highest suitability areas are assigned a “New Value” of “3,” the medium suitability areas are assigned a “New Value” of

“2,” and the lowest suitability areas are assigned a “New value” of “1.” For example: for distance to transmission and roads, the old values from “0-20” miles from transmission will be assigned a new value of “3” or high suitability.

3. Once each layer is reclassified, link the four layers to a new “Weighted Sum” tool. Open the tool and assign weights to each layer.

Note: The individual weights must be values from 0 to 1 and must all sum up to 1.

4. The Weighted Sum tool will output continuous values from 1 to 3 for each raster cell in the available land area. To achieve the same discrete 1, 2, 3 scale for ranking cell suitability, link the Weighted Sum output to a “Reclassify” the tool.
 - a. Open the reclassify, select the “Classify” box and, and choose “3 Equal Intervals.” The decimal values will be rounded up or down to one of the three suitability integer values.
5. **Run the Model:** The output of this model will be a map of the available land area ranked on overall site suitability.

B.4.1.1 Create the Map That Includes WWTPs: Replace the groundwater only criteria layer with the groundwater & Wastewater treatment plant layer. The steps to build this layer are described in Section B.5.

B.4.1.2 Create the Map That Does Not Include Water Constraints Or Criteria: Change the “Extent,” “Snap Raster,” and “Mask” to be the All Constraints Minus Water Constraints layer (See Section B.3.4.2), and do not include the water criteria layer in the analysis (step 2).

B.5 Wastewater Treatment Plant Layers

B.5.1 Distance to Wastewater Treatment Plants Suitability

Currently, California’s solar facilities primarily source their water from groundwater wells, but the state-preferred water sources for these plants are tertiary-treated water from wastewater treatment plants. Therefore, we built a layer that comprises both groundwater and WWTP suitability values to include in our suitability analysis.

Once we identified 12 public NPDES wastewater treatment plants that fall within the CDCA, we used Google Earth to identify the Universal Transverse Mercator coordinate points for each plant. We then entered the points into an Excel spreadsheet, which was imported into GIS as described below. The wastewater treatment plants appeared in GIS as point data, which provided a visual reference for the areas in our constraints layer that can potentially source water for solar facilities from these plants. We created a 20-mile buffer around each point, to provide an exact representation of the land area that may be able to source its water from a WWTP at a reasonable cost.

1. Select the source tab below the data frame and click “add data,” then select the Excel sheet that contains the UTM coordinates for each plant.
2. Right-click on the table in the data frame and select “Display XY Data.”
 - c. Select the longitude column in the imported table as the “X Field” and the latitude column in the imported table as the “Y Field.”
 - d. Edit the Description and select the NAD 1983 UTM Zone 11 coordinate system.
3. A new data layer will appear in the source tab depicting the wastewater treatment plant points.
 - c. Right-click on the new layer and select “Export Data.”
 - d. Keep all default settings and export.
 - e. A new permanent layer will appear in the display tab, representing the 12 NPDES wastewater treatment plants.
4. Create a new model and add the WWTP data points file. Right-click on the model and select “Model Properties” then “Model Environments.” Set “Extent,” “Snap Raster,” and “Mask” values as the CDCA mask.
5. **Euclidean Distance:** Add the “Euclidean Distance” tool and the WWTP layer to the model and link the WWTP layer to the tool.
6. **Reclassify:** Link the output from the Euclidean Distance tool to a new “Reclassify” tool to reclassify the distance to WWTPs up to 20 miles (32816.88 meters) on the same high=3, medium=2, low=1 suitability scale as the other four

criteria layers. Open the reclassify tool and enter the following old values (in meters) and their corresponding new values into the reclassification rows:

Old Values	New Values
0-10718	3
10718-21436	2
21436-32187	1
32187-349194	NoData

B.5.2. WWTP and Groundwater Join Layer

To create the layer that merges the wastewater treatment plant distance layer and the groundwater layer, we removed the area within 20 miles of any of the 12 NPDES WWTPs from the groundwater layer, then merged it to the WWTP layer using the Spatial Analyst Raster Calculator. The resulting output layer covers the same land area as the all constraints map although the areas within 20 miles of a wastewater treatment plant are assigned a suitability value based on its proximity to the nearest WWTP up to 20 miles. The raster cells for the available land area beyond the WWTP plant buffer are classified based solely on groundwater suitability.

1. Create a new model to extract the area within 20 miles of a WWTP from the groundwater layer. Set the “Extent,” “Snap Raster,” and “Mask” to the “All Constraints” layer in “Model Environments.” Bring the distance to WWTPs suitability layer (created in Step B.5.1) into the model.
2. **Reclassify:** Link the distance to WWTPs suitability layer to a new “Reclassify” tool. Reclassify the data so that the old WWTP suitability values of “1-3” are given a “New value” of “NoData” and the old “NoData” value is given a “New Value” of “1.” The output of this layer will be a layer that covers the same land area as the All Constraints layer, but excludes the distance to WWTPs layer.
3. **Extract By Mask:** Link the output of the reclassify tool and the groundwater basin suitability layer to an “Extract By Mask” Tool. Open the tool to ensure that the

output from the reclassify tool is set as the “Input Raster” and the groundwater suitability layer is set as the “Input Raster or Feature Mask.”

4. **Run the Model:** Click “Model” in the toolbar and select “Run.” The output layer will include the groundwater suitability values, which will be necessary in the suitability analysis.
5. Now we have two complementary layers, which together, make up the All Constraints layer. To combine these layers we used the “Spatial Analyst Raster Calculator.”
 - a. In the GIS map containing the distance to WWTPs suitability layer and the groundwater suitability layer, select “Options” in the “Spatial Analyst” dropdown menu.
 - b. Select the “Extent” tab. In the dropdown list select “Union of Inputs” and click “OK.”
 - c. Select the “Raster Calculator” from the “Spatial Analyst” dropdown list.
 - d. Type ‘MERGE(’ in the expression box, then double click on the distance to WWTPs suitability layer in the list of layers available. Add a comma after the WWTP layer and double click on the Groundwater suitability layer then close the parenthesis. Click “Evaluate.”

The output raster from this operation will show up as “Calculation” in the map’s data frame. To make this layer permanent, right-click “Calculation” and select “Make Permanent.” This layer can now be used in the suitability analysis map that evaluates overall suitability when both groundwater and WWTPs are available as water sources.

Appendix C: Species Included in Spatial Analysis

Class	Scientific Name	Common	CESA	ESA	CA	BLM
					SSC	SS
Aves	<i>Aquila chrysaetos</i>	Golden eagle				X
Aves	<i>Asio otus</i>	Long-eared owl			X	
Aves	<i>Athene cunicularia</i>	Burrowing owl			X	X
Aves	<i>Buteo regalis</i>	Ferruginous hawk				X
Aves	<i>Buteo swainsoni</i>	Swainson's hawk	T			
Aves	<i>Charadrius alexandrinus</i>	Snowy plover			X	
Aves	<i>Charadrius montanus</i>	Mountain plover			X	
Aves	<i>Colaptes chrysoides</i>	Gilded flicker	E			
Aves	<i>Dendroica petechia</i>	Yellow warbler			X	
Mammalia	<i>Dipodomys merriami</i>	Merriam's kangaroo rat			X	
Aves	<i>Empidonax traillii</i>	Willow flycatcher	E			
Reptilia	<i>Gopherus agassizii</i>	Desert tortoise	T	T		
Aves	<i>Haliaeetus leucocephalus</i>	Bald eagle	E	D		
Aves	<i>Icteria virens</i>	Yellow-breasted chat			X	
Aves	<i>Lanius ludovicianus</i>	Loggerhead shrike			X	
Mammalia	<i>Macrotus californicus</i>	California leaf-nosed bat			X	X
Reptilia	<i>Masticophis flagellum</i>	Coachwhip			X	
Aves	<i>Melanerpes uropygialis</i>	Gila woodpecker	E			
Mammalia	<i>Myotis velifer</i>	Cave myotis			X	X
Mammalia	<i>Ovis canadensis nelsoni</i>	Bighorn sheep	T	E		

Mammalia	<i>Perognathus longimembris</i>	Little pocket mouse			X	X
Reptilia	<i>Phrynosoma mcallii</i>	Flat-tail horned lizard			X	X
Aves	<i>Pyrocephalus rubinus</i>	Vermilion flycatcher			X	
Reptilia	<i>Salvadora hexalepis</i>	Western patchnose snake			X	
Magnoliopsida	<i>Sidalcea pedata</i>	Bird-foot checkerbloom	E	E		
Mammalia	<i>Spermophilus tereticaudus chlorus</i>	Palm Springs round-tailed ground squirrel		C		
Aves	<i>Toxostoma bendirei</i>	Bendire's thrasher			X	X
Aves	<i>Toxostoma crissale</i>	Crissal thrasher			X	
Reptilia	<i>Uma inornata</i>	Coachella Valley fringe-toed lizard	E	T		
Reptilia	<i>Uma notata</i>	Colorado desert fringe-toed lizard			X	X
Reptilia	<i>Uma scoparia</i>	Mojave fringe-toed lizard			X	X
Aves	<i>Vermivora luciae</i>	Lucy's warbler			X	
Aves	<i>Vireo bellii pusillus</i>	Least Bell's vireo	E	E		
Aves	<i>Vireo vicinior</i>	Gray vireo			X	X
Reptilia	<i>Xantusia vigilis</i>	Desert night lizard			X	

Appendix D: Mitigation Requirements

Mitigation requirements for project impacts range from simple and inexpensive to complex and highly expensive. Despite efforts to minimize environmental impacts and avoid sensitive areas, some degree of mitigation is nearly always required. CEQA, and to a somewhat lesser extent, NEPA documents describe in detail the impacts caused by projects and the requirements imposed by agencies to mitigate those impacts. Impact mitigation may take many forms, including dust control during construction, water conservation measures to offset project groundwater use, plant redesign to minimize impact on sensitive hydrogeological functions, erosion control, species relocation, implementation of monitoring plans, and the purchase of off-site habitat for sensitive species. The goal of such mitigation measures is to reduce project impacts to below a threshold of significance. Regulatory agencies generally require or recommend measures to ensure that a project has no 'significant effect' (California, 1970) or no 'significant adverse impact' (NEPA, 2000) on the environment. The project developer must agree to meet these conditions in order to be licensed. Mitigation measures are required for a range of projects requiring state or federal approval; however, the large areas required for solar plants and the often pristine nature of the desert ecosystem involve special challenges.

Compensatory mitigation measures for biological resource impacts are often among the most significant required by regulatory agencies. The Final Decision issued by the CEC for solar thermal plants lists and describes the anticipated impacts of a project on native habitats and their associated plant and wildlife species. Particular attention is given to sensitive or special-status species, as well as to areas defined as waters of the state (defined as "any surface water or groundwater, including saline waters, within the boundaries of the state" (BLM, 2010). Project impacts are generally divided into direct impacts, which are caused directly by project activities such as excavation or grading in the same area and at the same time, and indirect impacts, which may occur in the future or at some distance from the project area. There is also a distinction made between temporary and permanent impacts; because of the slow recovery rates of desert ecosystem plants, impacts are defined as temporary only if pre-disturbance conditions can be recovered within five years (CEC, 2010). Biological mitigation usually takes

the form of avoidance and minimization measures, including redesigning part of a plant to avoid a sensitive area, and off-site habitat acquisition and enhancement measures. Off-site species mitigation may involve the purchase of a specified acreage of comparable habitat elsewhere, at a ratio reflecting the quality of the habitat to be disturbed by the project and the sensitivity of the species in question. Ratios may range from 1:2 (two acres purchased for each acre permanently lost) up to 1:5, or payment into a mitigation fund. A significant challenge for project developers may be finding enough suitable mitigation habitat at a manageable price (mitigation costs can go up to \$3,000 per acre).

The list of mitigation requirements for any given project are too numerous to cover here in detail. However, a few examples from the BSPP are:

- Acquisition and enhancement of 1,384 acres of ephemeral desert washes.
- Implementation of a weed control plan to mitigate impacts to 593 acres of state Waters, including desert dry wash woodland, ephemeral streams and ephemeral dry wash (CEC, 2010).
- The creation of a water source in nearby mountains for bighorn sheep to mitigate the loss of spring forage habitat.
- Implementation of sand dune mitigation plan.